NATIONAL BUREAU OF STANDARDS REPORT

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Preliminary Report on the Thermodynamic Properties of Selected Light-Element and Some Related Compounds

(Supplement to NBS Reports 6297, 6484, 6645, 6928, 7093, 7192, 7437, 7587, 7796, 8033, 8186, 8504, and 8628)

1 July 1965

NBS

U.S. DEPARTMENT OF COMMERCE

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Fourteenth Technical Summary Report
on the Thermodynamic Properties
of Light-Element Compounds

Reference: ARPA Order No. 20

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ABSTRACT

This is the fourteenth semiannual report on the current experimental, theoretical, and evaluative program, at the National Bureau of Standards, on the thermodynamic properties of selected light-element and some related compounds of primary interest in high-temperature research. The content of the report falls logically into the following three categories.

Summary of Past Accomplishments in this Program. Accomplishments since the program began in 1958 are summarized in some detail for each of the approximately twelve lines of activity, and research plans for the immediate future are indicated (Part A). The 135 actual and projected publications in the subject area by the staff in that period of time are listed (Appendix III).

Reporting of New Experimental Results. Although some thermochemical ambiguities remain to be resolved, the heat of formation of solid BeF_2 has been determined by two independent methods (rotating-solution and fluorine-combustion calorimetry); the techniques and results are described in extensive detail (Chapters B9 and B10). In arc-image research on the rates of evaporation of liquid Al_2O_3, refined attention to ambient gas pressures and the reliability of temperature measurement has led to calculated equilibrium constants and the heat of evaporation to atoms (Chapter B8). An intensive matrix-spectroscopic investigation of metal-difluoride molecules has provided preliminary new values for the molecular constants of MgF_2 (Chapter B5). Time-resolved electrical measurements in high-current electrical discharges are described, with application to exploding-wire samples and the use of calorimetric calibration (Chapter B6).

Literature Reviews and Bibliographies. Included are a comprehensive bibliography (1600 references) and index (with properties identified), covering the 13 months preceding 1965, of published and abstracted papers on thermochemistry and chemical thermodynamics of all the chemical elements and their compounds (Appendix IV). The existing thermodynamic-data status for light-element compounds of several important "heavy" elements has been surveyed and partially assessed: standard entropies and heats and free energies of formation at room temperature (6 heavy elements; Chapter B3); and high-temperature enthalpies and vaporization equilibria (12 heavy elements; Chapters B1, B2, and B4). A critical analysis of the available heat-capacity and enthalpy data for 17 various substances has led to new tables of their condensed-state thermodynamic functions (Chapter B7 and Appendix II). Detailed formula-property and property-formula indices of the 13 reports preceding this one are given also (Appendix I).

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B-140	$CsClO_4$	s	0-300	265
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PART A. SUMMARY OF RESEARCH ACCOMPLISHMENTS SINCE 1958, AND FUTURE PLANS

Beginning over ten years ago the National Bureau of Standards has engaged in experimental and theoretical research on the thermodynamic properties of boron compounds, as well as issuing definitive thermochemical tables (NBS Circular 500) and numerous tables of ideal-gas thermodynamic properties of the more common gases. The present NBS research program on propulsion thermodynamics has been in continuous existence since September 1958, being under the sponsorship of first the Advanced Research Projects Agency and later the Air Force Office of Scientific Research.

The objective of the present NBS research program has been to supply new or better values for the thermodynamic properties of all substances which are important as products of combustion in chemical propulsion, at temperatures and pressures up to the order of 6000°K and 100 atm., respectively. The principal area of chemical composition has comprised 2-element and 3-element compounds and species of Be, Aℓ, Li, B, Ti, Zr, F, O, H, Cℓ, N, and C. These materials include combustion products, certain important fuels and oxidizers, and other substances important in high-temperature research. Emphasis is placed on the accurate determination of these properties, their thermodynamic consistency, and their concise presentation as tables and equations adapted to needs in both pure and applied research. The principal activity has been experimental: developing new apparatus, and measuring thermodynamic properties (heats of formation by calorimetry; heat capacities; equilibria involving gases; fast-measurement techniques at very high temperatures; infrared, microwave, matrix, and mass spectrometry; chemical synthesis; phase-diagram analysis; etc.). Also included has been the experimental investigation of a few highly important fuel and oxidizer materials. Some kinetic work has been carried out on decomposition and phase transformation. Simultaneous with the experimental activities are constant surveys of the subject-area literature, the critical evaluation of the available thermodynamic properties, and the issuance of computer-programmed tables of thermodynamic properties from 0 to 6000°K or higher temperatures where needed in propulsion research.

To achieve the objective of the program, there is being effected a broad synthesis of experimental and theoretical methods needed to complement one another and to check the accuracy of alternative

approaches. Generally speaking, the experimental methods used may be classified as of two types. First are those that accurately measure gross properties of the material system under study, especially the energy changes accompanying chemical and physical changes of the material or system up to high temperatures. Second are the several types of analysis of data from spectroscopy, which single out specific components of the system and identify them, estimate their amounts, and accurately determine many of their molecular properties. The theoretical methods utilize molecular and basic thermodynamic principles that greatly help to interpret the data for practical operating as well as for laboratory conditions, and elucidate by theory and analogy intramolecular and especially intermolecular forces that play an important role in the bulk properties. Theories of non-equilibrium behavior (radiation, heat-flow, diffusion, etc.) also are used as important guides to achieving experimental accuracy, such as in measuring high temperatures. Insofar as possible, experiment and theory applied to new types of materials are first always tested and refined by application to materials whose properties are already known.

The tasks undertaken may be described broadly as several concurrent and sequential phases. (1) It is ascertained what substances and in what states may be important components of the high-temperature systems. (2) Already published and reported properties of these materials are collected and critically evaluated, to find which are missing or inadequately known. (3) New apparatus, especially for unusually high temperatures, is developed. (4) Previously existing and new apparatus are used to fill the significant data gaps in the field. (5) Thermodynamic, molecular-structure, and other theory are used to supplement and test the experimental values. (6) From the ensemble of properties thus arrived at, definitive tables of the basic thermodynamic properties from low to high temperatures are computed in standard form for ready application to specific problems.

As planned from the first, the major phase of the program has been experimental, mainly to fill seriously deficient data gaps on the thermodynamic properties of the simpler compounds and high-temperature species of the most energetic light chemical elements. Some precise apparatus, such as calorimetric, was in existence at the start of the program, and its use for measurements began promptly. Other apparatus, such as a high-temperature mass spectrometer, was later procured, and has since been applied steadily in the present program in yielding new data. Still other apparatus had to be designed, built, and tested, but is now yielding data for the program or nearing the point of doing so.

An important phase of the program concurrent with the experimental work has been the continual survey of the journal and report literature on thermodynamic and related properties of light-element compounds (in addition to private communication with contemporary workers in other institutions). The result has been the compilation of extensive up-to-date bibliographies and reported thermodynamic values, their examination for accuracy and thermodynamic consistency, and the generation of tables of heats of formation and thermodynamic functions in the subject area.

The present organization of the NBS program according to specific properties and techniques is summarized below.

A. Experimental

1. Heats of Formation, Reaction, and Solution by Calorimetry (Reaction calorimetry of various types: fluorine-bomb, oxygen-bomb, fluorine-flame, etc.; solution calorimetry)

2. Heat Capacities of Solids and Liquids; Heats of Fusion and Vaporization by Calorimetry (Adiabatic calorimetry at low temperatures, dropping-type calorimetry at high temperatures attained by resistive and inductive heating)

3. Equilibria Involving Gases (Mass spectrometry, arc-image heating, transpiration studies; heats of reaction and formation from changes of equilibria with temperature)

4. Absorption and Emission Spectroscopy (Infrared, microwave, matrix-isolation techniques, fast measurement at high temperatures and pressures)

B. Evaluative

1. Production of critical tables of thermodynamic properties

2. Up-to-date literature coverage, and compilation of bibliographies

3. Critical analysis of published data

4. Computation of new and revised thermodynamic tables

On the following pages are given in more detail the research accomplishments and future plans of individual research groups in the NBS program.

1. COMBUSTION AND REACTION CALORIMETRY OF FLUORINE AND ITS COMPOUNDS

Bomb Calorimetry of Metals

At the outset of the work, preliminary literature survey revealed serious gaps in the thermochemistry of the fluorine compounds of the light metals, Li, Be, Mg, Aℓ. In particular it was learned that no complete determination of the heat of formation of BeF_2 (crystal or amorphous solid) had been made, and that the only completed study of $A\ell F_3(c)$ was based upon a novel procedure which led to results greatly at variance with previous estimates. The determination or verification of the heats of formation of these two substances was undertaken as an urgent task, with first priority being assigned to $A\ell F_3$. This task has been carried out and the results have been published in the case of $A\ell F_3$ and appear elsewhere in this report in the case of BeF_2. For BeF_2 some finishing touches are needed to establish definitely the relation between crystalline and amorphous forms, which await the preparation of good quality crystalline BeF_2.

In the process of carrying out the studies on $A\ell F_3$ and BeF_2, two significant developments of technique in calorimetry were made; in addition innovations in analysis of starting materials and products of combustion were made, which provide a firm understanding of the processes that occurred and cause the results to be superior, in our opinion, to any previously reported studies on these two compounds.

Both fluorides were studied by direct combustion of the respective metals in elemental fluorine. Dependence upon auxiliary data for heats of formation were thus reduced to a minimum, and were needed only for corrections applied for reactions of impurities. The metals were found to be refractory to fluorine combustion, and a substantial amount of time was spent developing a suitable technique and reaction conditions for achieving complete combustion. The technique that was used increases the range of applicability of fluorine bomb calorimetry and is a significant advance in this respect. It consists of pelleting the metal in the form of a powder with powdered Teflon. The Teflon makes the pellet easy to ignite, and causes it and the incorporated metal to burn smoothly and nearly completely. With aluminum, greater than 99 percent combustion was obtained. With beryllium, 80 percent to greater than 99 percent combustion was achieved. A significant improvement over previously reported combustions.

In the analysis of the starting metals, neutron activation analysis was used, for the first time in reaction calorimetry, so far as we are aware, for determining oxygen. The amount of oxygen found in the aluminum was much larger than had been expected.

The observed heat of formation of aluminum fluoride was more negative than any previously reported value. The difference between the observed results and those reported by tohers, based on reaction calorimetry involving other fluorides, are brought into better agreement by application in a systematic way of a revised, more negative, heat of formation of HF(g). The results therefore provide a significant additional piece of data favoring the more negative heat of formation of HF(g), for which evidence has also been accumulating from other sources.

In the combustion experiments with Teflon, which was burned separately in order to establish the amount of heat involved in the combustion of Teflon in the pellet, the results obtained lead to new values for the heat of formation of Teflon and added information about the heat of formation of CF_4.

The heat of formation of beryllium fluoride was also verified by dissolving the metal in aqueous hydrofluoric acid, and combining the result with a previously reported heat of solution of beryllium fluoride (crystal) in aqueous HF. This experiment also involved a new technique. The reaction was carried out in a rotating bomb, and is, so far as we are aware, the first time that the feasibility of using the rotating bomb calorimeter for dissolving a metal in acid has been demonstrated. The technique is suitable for powdered metals, which dissolve rapidly in HF(aq), and the resulting solution is made homogeneous by rotation of the bomb. Hydrogen evolved in the reaction is readily converted to H_2O and measured as a quantitative measurement of the amount of reaction, in verification of the amount calculated from the mass of metal dissolved, and its analysis. The method may have a wide applicability. The procedure is very simple and experiments are readily carried to completion.

Bomb Calorimetry of Compounds

The heat of formation of aluminum carbide was determined by combustion in oxygen in a bomb calorimeter. The observed heat of combustion was combined with existing data for heats of formation of aluminum oxide and carbon dioxide to calculate the heat of formation of Al_4C_3. Analysis of the starting material was an important feature of the experiments and several analyses were made. The material used was the same as that used in low and high temperature heat capacity studies in this light element program. The carbon dioxide formed was measured, in confirmation of the completeness of reaction (~ 100%) and composition of the combustion sample.

An interesting result of the study from the point of view of applications of aluminum in organic rocket propellants was the finding that in addition to the commonly known alpha aluminum oxide a significant fraction of the product was the lesser known delta aluminum oxide. The formation of this oxide is apparently promoted by the presence of carbon (and perhaps of nitrogen) in the combustion mixture. The energy difference between the phases was determined for us in another laboratory in a high temperature solution calorimeter.

Flame Calorimetry of Inorganic Fluorides

The heats of formation of oxygen difluoride and chlorine trifluoride are objectives in a study of reactions of fluorine compounds by flame calorimetry. A flow system and calorimeter have been set up for measuring heats of reaction involving highly reactive gaseous fluorides. The apparatus consists principally of four parts: (1) the burner, (2) the flow control system, (3) the analysis train, and (4) the calorimeter and its accessory apparatus for measuring the heat of the reaction. Experimental flames have been studied in order to establish ignition conditions and burning characteristics of F_2O in hydrogen. The possibility that the reaction may be carried out in such a way as to lead to $H_2O(g)$ and $HF(g)$ collected separately outside the calorimeter, or $HF(aq)$ collected in the calorimeter, is still under consideration. The former process has the disadvantage that at low temperatures a large fraction of the water and some HF are left in the burner at the close of an experiment, and determination of the amount and thermodynamic state of this solution is not easy. It also has the disadvantage that even less is known about the P-V-T properties of $HF-H_2O$ gas mixtures than those of $HF(g)$ alone.

Solution Calorimetry of Simple and Complex Fluorides

No information exists on the heats of formation of $Li_2BeF_4(c)$ and $Li_3A\ell F_6(c)$, in contradistinction to that of $Na_3A\ell F_6(c)$, which is well known. The determination of the heats of formation of the double salts by solution of LiF, $A\ell F_3$, and $Li_3A\ell F_6$, and of LiF, BeF_2, and Li_2BeF_4 in aqueous acid solution has been studied briefly but not heat measurements have been made. The work was carried to the point of finding a suitable solvent for the Be system, but the major part of this task remains to be done.

Rotating Bomb Calorimeter Development

For use in reactions of metals with acids (as in the case of Be and $HF(aq)$) or for other reactions leading to aqueous solutions, the final solution will not be homogeneous unless stirred. The heats of

formation of most substances in aqueous solution do not vary linearly with concentration and hence a non-homogeneous solution potentially liberate additional heat on mixing. To achieve a thermodynamically well defined standard state among the products of a bomb reaction, the bomb may be rotated. A rotating bomb calorimeter was built in the laboratory following the general pattern of that at the Argonne National Laboratory. This calorimeter was used for the solution calorimetry of beryllium. It is a highly accurate calorimeter as shown by the low standard deviation of a measurement, which is less than 0.02 percent.

The NBS calorimeter has a motor driven gear arrangement for rotating the bomb. This includes a solenoid switch which is thrown to begin rotation, and shafts into the calorimeter connecting the motor on the jacket to the circular gear around the bomb. Attached to the motor shaft is a cam which trips an electric counter and thus causes it to count the number of shaft revolutions. The counter may also be set to terminate the rotation automatically after a pre-set number of revolutions.

The motion imported to the bomb is two-fold. The most rapid is an end-over-end turning of the bomb. Superimposed on this mode is the slow axial spinning of the bomb. Speed of the end-over-end rotation is 10 rpm.

Another important feature is that the assembled calorimeter is designed to be air tight. The main opening of the calorimeter can, through which the bomb is introduced, is closed by a lid which has a rubber gasket covering the entire sealing surface. Good sealing contact is insured by tightening down the four corners of the lid with screws. The drives for the calorimeter stirrer and bomb rotation pass through oil seals. The platinum resistance thermometer is inserted through a Nylon bushing tightly fitted to the calorimeter can thermometer port.

The bomb is made of stainless steel. Platinum liners protect the inner bomb body and bomb head. All internal fittings are fabricated from platinum. The head is fitted with two valves for introducing oxygen and releasing the gaseous combustion products. The sample to be burned is placed in a crucible which in turn is supported in the center of the bomb by a gimble. The gimble support drops with the crucible from a hangar when the bomb begins to rotate and so permits rinsing of the crucible in the bomb liquid. The bomb, inverted, is inserted into the calorimeter and two spring clips are attached to make the fuse firing connections. The inverted position directs the flame of the burning sample away from the gaskets around the several ports in the bomb head. When the bomb first begins to rotate, the spring electrodes snap away.

Heat exchange by conduction between the calorimeter and the jacket is minimized. Connections to the bomb drive and calorimeter stirrer are made through nylon chucks. The calorimeter can is suspended in the isothermal cavity from three lucite V-supports.

The nickel-plated brass isothermal jacket (or bath) is cylindrical in appearance and measures approximately 15" high and 18 1/2" along the diameter. It sits on three leveling legs. The calorimeter cavity in the jacket parallels the geometry of the oddly-shaped calorimeter can so that the can is surrounded everywhere by an isothermal surface about 1 cm away. The cavity is sealed from the top, through which the can is introduced, by two hollow hinged lids. Bath water is circulated through the lids; each lid has a glass port to provide confirmation that the lid is filled with water. Mounted on the jacket are two 1/15 h.p. motors that drive the two jacket stirrers fixed opposite one another in the jacket. The jacket is provided with ports to accept the bath thermostat, platinum resistance thermometer, two tubular heaters, and a cooling coil. The jacket also is provided with a drain on an overflow.

The calorimeter can is made of nickel-plated copper sheet. Its unusual shape results from the desire to minimize its volume while still allowing space for the rotation of the bomb. Four small screw connections accommodate the four electrical leads -- two to the ignition system and two to the cartridge heater used to bring the calorimeter to starting temperature. The calorimeter can filled with water weighs almost 5 kg.

Literature Search and Critical Evaluation of Heats of Formation of Fluorine Compounds

An important part of the task on fluorine reaction calorimetry particularly in the beginning of the program, was the systematic search of the literature and compilation of a bibliography and literature file on the thermochemistry of fluorine compounds and some related compounds of the light elements and other elements added from time to time. Portions of this task were carried out in collaboration with members of the Thermochemistry Section (NBS) and some contributions were made by a number of others in the NBS laboratories, with respect to certain compounds. To a limited extent the materials found have been correlated, critically evaluated and presented in the form of tables of selected best values of heats of formation and dissociation.

A far greater part of the work remains in an unfinished state, of potentially great value for the preparation of a catalog of thermodynamic determinations and of selected best values of thermodynamic constants.

The portion of the work described here was limited in scope to isothermal processes involving the compounds of interest. By this limitation, heat capacity studies were excluded, but many peripheral data were included, such as heats of fusion, evaporation, and other phase changes, as well as the directly applicable equilibrium constants of isothermal physical and chemical processes.

At one stage, the compilation of data was supplemented by an exhaustive search for the literature on fluorine compounds of all types, carried out with aid from other sources. This search resulted in an extensive compilation which was published as a review of thermodynamic data of fluorine compounds covering the interval from 1952 to 1961.

The searches that have been carried out on this program have resulted in the accumulation of a file of reprints, copies of reports, and original documents of various kinds numbering close to two thousand. The source references have been prepared on tape for ready typewriter duplication. A master card for each reference lists the compounds described in it, and shows the abstract if that was found, as well as other relevant information. A file by compound has for each fluorine compound and phase a reference to the source of data and an indication of the type of data. Many reviews are also referenced in these cards.

2. HEATS OF FORMATION OF CHLORINE-CONTAINING COMPOUNDS

The Thermochemistry Section has developed modifications of bomb combustion techniques to measure the heats of decomposition of potassium perchlorate and sodium and potassium chlorate. The results on $KClO_4$ were reported in Report 6645 (January 1960); the data on the chlorates have recently been published in J. Research NBS 69A, 1 (1965). The value obtained for $KClO_4$ was then combined with calorimetry on the heats of solution and mixing of other perchlorates to obtain values for the heats of formation of lithium, sodium and ammonium perchlorates. These results are reported in Report 6928 (July 1960). A similar technique was used for the heat of formation of nitronium perchlorate as given in Report 7437 (January 1962).

The heat of formation of $BeCl_2(c)$ was measured by the direct chlorination of beryllium metal. The results are given in Report 6928 (July 1960). Unfortunately the crystal phase of the $BeCl_2$ produced in the reaction was not identified. Calorimetric measurements were also made on the heats of solution in HCl(aq) of Be(c) and a sample of beryllium hydride. Because of impurities present, unambiguous results were not obtained.

In Report 8628 (January 1965) the results of recent measurements on the heat of chlorination and formation of $Al(BH_4)_3(liq)$ were given. These measurements were made using a flame technique with $Cl_2(g)$ as oxidizer.

Current research on this program has been directed towards measurement of the heat of formation of hydrazine diperchlorate. A double decomposition reaction will be used involving $AgClO_4$, the heat of decomposition of which is presently being measured.

3. CRITICAL EVALUATION OF CHEMICAL THERMODYNAMIC DATA

The Chemical Thermodynamic Data Group of the Thermochemistry Section has been involved principally in reviewing the status of available data on various groups of compounds of interest to the program and in the preparation of tables of thermodynamic functions of a large number of gases, solids and liquids. The results of these calculations and evaluations have been reported in the Semi-Annual Reports of the Project.

In January 1959 (Report 6297) thermodynamic functions [$(F°-H_0^\circ)/T$, $(H°-H_0^\circ)/T$, $S°$, $(H°-H_0^\circ)$, $C_p°$] for 16 diatomic species were calculated from 50°K to 7000°K; in July 1959 (Report 6484), thermodynamic functions for 65 gaseous species were computed and tabulated.

In January 1960 (Report 6645) W. H. Evans prepared a table summarizing the thermodynamic functions of C(graphite) up to 4000°K. A review by D. D. Wagman of thermochemical data on metal hydrides (42 compounds) and inorganic oxidizers (42 compounds) was presented in Report 7437 (January 1962).

A review of the available thermochemical and related data on boron oxides, hydrides and halides was presented in the January 1961 report (No. 7093). Included with this review were 52 tables of thermal functions for boron compounds. This was followed by a review of data on metal borates in the July 1961 report (No. 7192). The latter report also includes tables of data on a number of gaseous ions and on NF_2 and N_2F_4.

In July 1964 (Report 8504) and January 1965 (Report 8628) two sets of tables of selected values of heats and free energies of formation of inorganic compounds as prepared for a general revision and updating of the material in NBS Circular 500 were presented.

A Substance-Property Index for 1962, summarizing in tabular form the content of chemical thermodynamic data on inorganic substances that was published during that year, was included in NBS Report 7796. This index was a portion of a more complete index prepared for the Annual Bulletin of Thermodynamics and Thermochemistry of the International Union of Pure and Applied Chemistry.

4. LOW TEMPERATURE CALORIMETRY

A. Objectives and Scope of Work

Values of heat capacity from 0°K are needed in the calculation of thermal functions. Experimental measurements and literature reviews of heat-capacity data from 10°K and lower to about 400°K are conducted on substances of interest to the program and the thermal functions calculated from the data. Wherever data are lacking, pure samples are procured and, if necessary, special calorimeter vessels are designed for the experimental investigations. Computer codes are developed for processing the experimental and literature data.

B. Summary of Accomplishments

1. Experimental Activities

a. Heat Measurements

Measurements of the heat capacity have been made in the range of about 15° to 380°K on the following substances: LiH, $LiA\ell H_4$, BeO, $A\ell_2O_3 \cdot BeO$, and $A\ell_4C_3$. Measurements on $3A\ell_2O_3 \cdot BeO$ and Be_3N_2 are in progress.

Although the samples of LiH and $LiA\ell H_4$ used were not of the desired purity, measurements were obtained with the expectation of making corrections for the impurities. Heat effects were detected within the calorimeter vessel in both samples during the heat-capacity measurements, indicating that a chemical reaction was taking place within the sample or the sample was reacting with the calorimeter vessel. Following the completion of the heat measurements, the samples were removed and sealed in glass ampoules for future chemical analysis. Before the analysis could be made sufficient hydrogen gas was apparently formed in the $LiA\ell H_4$ ampoules to explode and rupture all the nearby ampoules. LiH is expected to be stable under the condition of storage. The chemical composition of the LiH and $LiA\ell H_4$ samples used in the measurements is too uncertain to report any results. New measurements are being considered on purer samples using a platinum calorimeter vessel since it is possible that our standard copper calorimeter vessel initiated the decomposition reaction in $LiA\ell H_4$.

BeO powder, prepared by igniting $Be(OH)_2$ precipitated from soluble salts, is sub-micron in size. To minimize size-effect contribution to the heat capacity, pure BeO powder was pelleted by high compression and sintered at about 1800°C to obtain as large crystals as possible. The average crystal size of the sample was about 10 microns. The heat capacity obtained is significantly lower than the previously published values. For example, the entropy calculated at 298°K is about 3 percent lower and the heat capacity at 50°K is about 50 percent lower. The earlier published measurements possibly contained some contribution to the heat capacity from the size effect. It is, however, doubtful that the size effect is as large as 50 percent at 50°K. As a check on the new results, additional measurements are planned on another BeO sample prepared by arc melting the powder. The crystal size of this sample is in general larger than 50 microns.

The additivity of heat capacity of $Al_2O_3 \cdot BeO$ was compared using the results obtained. From 200 to 380°K the agreement is within +1 percent

$$(100 \times [C_p(Al_2O_3 \cdot BeO) - C_p(Al_2O_3 + BeO)]/C_p(Al_2O_3 \cdot BeO)) \quad ,$$

at 100°K about +5 percent, and below this temperature deviation increases positively quite rapidly to 28 percent at 10°K. This behavior seems to be typical of many mixed-metal oxides.

Thermal functions up to 2000°K were calculated for Al_4C_3 using results of low-temperature measurements in conjunction with those obtained at the high temperatures by another group in the program. Comparison of the calorimetric data with the high-temperature vapor-equilibrium data shows a systematic deviation. This is attributed to possible deviation from unity of the activity coefficients of the components of vapor-equilibrium reactions that were investigated.

b. Sample Preparation

An attempt was made to prepare pure $AlCl_3$ for the heat measurements by vacuum sublimation. Since there is a considerable increase in specific volume in the transformation from solid to liquid, effort was made to collect the material in the powder form. Although the material condensed initially as powder, the subsequent condensate was a solid mass because of poor thermal conductivity under the high vacuum condition. When the collected solid material was heated for the second stage of sublimation, the thermal expansion was so large that the flask was ruptured.

Consideration was then given to the use of a carrier gas such as helium to provide the necessary thermal conduction to condense $AlCl_3$ as powder. Since another laboratory (outside of NBS) reported new heat-capacity measurements on $AlCl_3$, the preparation and the heat measurements on $AlCl_3$ were temporarily abandoned.

c. Development of Apparatus and Methods

The heat-capacity measurements with LiH and $LiAlH_4$, which were considered to be inert when sealed in our standard copper calorimeter vessel, indicated that possibly these substances or the impurities they contained reacted with the vessel or their decomposition was catalyzed by the vessel. A platinum calorimeter vessel, therefore, was designed for use in measurements on corrosive and highly reactive substances. The results of design tests show that platinum calorimeter vessels of the new design could be used in measurements on most substances, corrosive or non-corrosive.

The design of the vessel includes efforts to obtain measurements of improved accuracy. By sealing the thermometer and heater assemblies along with helium gas in the re-entrant well of the vessel, the lag in temperature measurement and heat dissipation is expected to be decreased. The thermometer resistance is designed to be 125 ohms in contrast to 25 ohms of a standard thermometer so that the temperature change associated with the heat input can be determined more precisely at the lower temperatures. A recently discovered heater wire of smaller temperature coefficient will be incorporated in the vessel. Above 250°K the new wire has comparable temperature coefficient as the previously used wires. However, below this temperature down to 10°K, only 0.9 percent change in resistance occurs in the new wire as compared to about 10 percent in the previously used wires. More precise energy measurements have been possible with the new wire in applications with calorimeter vessels of other designs. A thin copper shell encloses the vessel to provide a good isothermal surface to the "surroundings" and achieve better adiabaticity and reproducibility. The assembly of the new calorimeter vessel is now nearly complete. The plan is to use the vessel in measurements with Li_2BeF_4 and BeF_2.

In the course of work in the program the calorimeter in use developed an electrical leakage. A new calorimeter was designed as replacement with provisions for calibration of the thermometer sealed in the platinum calorimeter vessel described earlier. The adiabatic shield incorporates a standard, calibrated thermometer to which the thermometer in the calorimeter vessel is compared and thus calibrated. As a test our standard copper calorimeter vessels, containing thermometers that have been previously calibrated, have been used in the measurements on Be_3N_2 with the new calorimeter. The results show very satisfactory performance.

During the program a constant current power supply of long-term (24 hours or longer) stability of about 1 part in 200,000 or better, specially designed to meet our power capacity requirements, was procured in order to make energy measurements simpler and more precise. This application of a commercially available constant current supply in precision calorimeter has spread to other laboratories.

2. Literature Survey and Preparation of Tables of Thermal Functions

The literature survey was focussed initially on the elements Li, Be, Mg, and Aℓ and their compounds with H, O, N, F, and Cℓ. The work was expanded subsequently to include the elements: N, C, Si, Ti, Zr, Hf, Na, K, B, Hg, Pb, W, Br, I, Ca, Ba, Cr, Fe, and Ni, and the compounds among them and with the earlier nine elements. In addition to the binary compounds, the survey included the relatively more complex mixed metal oxides, halides, and hydrides of the above elements.

The survey was conducted step-wise so that the status of heat-capacity data was reported initially. This was followed by tables of thermal functions wherever data were available for analysis. Tables on about 130 substances have been issued.

Computer codes were developed for analyzing the laboratory and literature data to obtain smooth values of heat capacity at regularly spaced temperature intervals from 0°K on up and calculate the thermal functions. Since the shape of the heat-capacity curve varied greatly from substance to substance, no single code could be used for analyzing the data of all substances. A "master" least-square code was devised for fitting equations, containing up to twenty selectable terms, to the literature data. Each selected term could be a simple power function or a complicated function, e.g., Debye, Einstein, or a rational fraction. Successive linear and higher-power interpolated methods were found practical where the data points were abundant, suitably distributed, and precise. The method was extended to interpolation of the apparent Debye Θ's calculated from the observations after suitable scaling. The lowest temperature of much of the data was about 50°K. Semi-theoretical methods were developed for extrapolation to 0°K. Differencing codes for the test of smoothness of the values at regular intervals and smoothing codes, for application whenever required, have been developed and extensively used in the preparation of the tables of thermal functions. The preparation of a code for rounding the calculations of the thermal functions to the desired number of significant figures depending on temperature was also found necessary. Some of the computer codes that have been developed are in use by other laboratories.

As expected, wherever paucity of data was encountered the substance was difficult to obtain, highly reactive or toxic, of questionable existence, or relatively new. Methods of preparation and analysis of samples for the heat-capacity measurements were investigated and specifications for satisfactory preparation determined. For example, in the fusion preparation of refractory samples the use of containers of the same material was stressed to avoid chemical contamination. Procedures for the preparation of some of the nitrides and carbides were reported. A number of samples, for example Be_3N_2, Be_2C, Be_2B, $A\ell_2O_3 \cdot BeO$, $3A\ell_2O_3 \cdot BeO$, BeO, $Li_2O \cdot 5A\ell_2O_3$, etc. have been procured for experimental investigations.

C. Future Plans

1. Experimental Activities

Heat-capacity measurements in progress on Be_3N_2 and $3A\ell_2O_3 \cdot BeO$ will be completed. Future measurements are planned on the following substances: Li_2BeF_4, $Li_3A\ell F_6$, Be_2C, and BeO (second sample of larger crystal size). About three substances from the following list will be investigated: BeF_2, $BeBr_2$, BeI_2, Be_2B, Li_3N, Mg_3N_2, α-$A\ell B_{12}$, TiB_2, $Li_2O \cdot B_2O_3$, $Li_2O \cdot 2B_2O_3$, $A\ell_2O_3 \cdot B_2O_3$, $A\ell_2O_3 \cdot 2B_2O_3$, and $Li_2O \cdot 5A\ell_2O_3$. These substances are on hand but require chemical and phase analysis. The final selection will be based on priority and purity of the sample.

2. Literature Survey

The data that have been compiled on the Fe, Cr, and Ni compounds will be analyzed and tables of thermal functions prepared. New data or more detailed information have been obtained on some of the substances that were previously analyzed and reported. The data on these substances will be re-evaluated. In all about 30 new tables and 10 revisions will be made.

5. MEASUREMENTS AT MODERATELY HIGH TEMPERATURES OF ENTHALPY BY DROP CALORIMETRY AND OF VAPORIZATION EQUILIBRIA BY A TRANSPIRATION METHOD

A. Enthalpy

Relation to Other Thermodynamic Properties. Accurate enthalpy values of solids and liquids must be determined calorimetrically. The enthalpy-temperature function gives heats of fusion and transition as well, when they are involved in the measurement range. It is appropriate to summarize the principal applications of such enthalpy data above room temperature when the data are combined with other thermodynamic data for the same materials:

(1) In effect, high-temperature enthalpies correct heats of formation and reaction, which are most accurately determined at room temperature, to the high temperatures where they are often needed.

(2) In combination with the data of low-temperature calorimetry, absolute entropies are provided which permit evaluating important high-temperature equilibrium constants. (In addition, comparison of low-temperature and high-temperature results in the temperature region of overlap near room temperature, affords a valuable check on the accuracy of the calorimetry techniques.)

(3) The heat capacities of "complex" compounds are often estimated, in the absence of experimental data, as the additive sum for their chemical components. Accurate data on a few such complex compounds affords testing and possible refinement of such simplified estimation procedures.

Existing-Data Status Before the Program Began. From the standpoint of the aims of the program, the substances of greatest importance may be said to be Aℓ, Be, B, Li, and their compounds with H, F, Cℓ, O, N, and C which are stable up to, say, 1500°K. There has been a secondary interest in Zr and Mg and their similar compounds. The specific phase of the program discussed here is limited experimentally to the temperature range 300°-1800°K, for which fair to accurate published enthalpy data existed in 1958 for the majority of the two-element compounds. Among the most accurate were data measured in this laboratory in earlier programs over the temperature range 300°-1200°K on the light-element substances Be, Li, Zr, $Aℓ_2O_3$, BeO, MgO, LiF, LiCℓ, and solid zirconium hydride of several compositions. However, enthalpy data existed for but very few solid stoichiometric compounds and liquid solutions composed of three or more of the above chemical elements.

Apparatus. In this phase of the program the "drop" method alone has been used: A sample in a suitable container, at a known temperature in a furnace, is dropped into an ice calorimeter which measures the heat (enthalpy) removed from the sample in cooling to the ice-point. Two independent such apparatuses are available. In the first, the sample in the furnace is surrounded by thick silver to improve the accuracy and ease of temperature measurement, so that only the temperature range 273°-1200°K has been covered using it. A volume change of the calorimeter contents of one part in a million corresponds to approximately one calorie of heat, and at one stage in the current program many months were required to locate and repair small leaks that had led to inferior precision. The second apparatus, constructed primarily to cover the range 1200°-1800°K, contains no silver but must rely on platinum and close spacing for accurate sample-temperature measurement, a feature which has not yet been perfected to the point of allowing the taking of final data with this apparatus. Both apparatuses were designed and constructed in earlier programs, and are described in detail elsewhere [1,2].

The "drop" method for measuring high-temperature enthalpies is rapid and accurate, except that substances such as BeF_2 which do not crystallize to well-defined states on cooling must employ an additional technique such as solution calorimetry to overcome this deficiency.

Measurements Completed or in Progress. Enthalpy measurements have been completed in the present program on Be_3N_2 (273°-1173°K) [3], Al_4C_3 (273°-1173°K) [4], $BeO \cdot Al_2O_3$ (273°-1173°K) [5], $BeO \cdot 3Al_2O_3$ (273°-1173°K) [5], $2LiF \cdot BeF_2$ (273°-873°K) [6], and $3LiF \cdot AlF_3$ (273°-973°K) [7]. (The numbers in brackets reference detailed accounts of the results.) Some of the samples were unobtainable with high purity, but all were carefully analyzed chemically at the Bureau, and the thermal data were corrected for both the impurities and any premelting they caused. In the case of $3LiF \cdot AlF_3$ it was necessary to defer measurement of the heat of fusion and the liquid heat capacities because of leakage through the container walls, a difficulty commonly shown by liquid fluoroaluminates.

Future Plans. Precise measurements of the high-temperature heat capacity of AlF_3 are available in the literature, and earlier were considered adequate. However, owing to a 20-degree temperature uncertainty in some of those results it was decided to make repeat measurement on this substance in the near future, partly because AlF_3 is of major importance and partly because accurate enthalpy data are needed in treating other thermodynamic data obtained in the program. The deferred measurements on $3LiF \cdot AlF_3$ mentioned above will then be carried out. Subsequent enthalpy measurements during the following several months are planned on perhaps two additional substances chosen from Be_2C and several two-metal oxides of the metals Al, Li, and B samples of which are now on hand.

B. Vaporization Equilibria

Brief Description of the Transpiration Method; Thermodynamic Properties Determined; Comparison with Other Vapor-Pressure Methods. In the simplest application of the transpiration method, a non-reacting gas is flowed over another substance in a condensed state, which partially evaporates to saturate the gas with the vapor. These gases are usually assumed to obey the ideal-gas law to a sufficient approximation, so that measurement of the mass of vapor, the temperature, and the volume of gas flowed enables the product of the vapor pressure and the vapor molecular weight to be calculated. The method obviously can be, and often is, extended to measurement of gas-phase equilibrium constants for non-congruent evaporation and for reactions of the vapor with one or more components of the flowing gas. The partial pressure of any species does not change as long as the composition of the condensed phase from which it arises by simple evaporation does not change. And this partial pressure may already be known from other measurements involving this simple evaporation only.

The empirical volatility of the condensed substance in the presence of a reacting gas is often of practical value in itself. But it is of more general application when, with measurements at different temperatures and different activities of condensed and/or vapor components, the equilibrium constants, heats of reaction, and other thermodynamic quantities derivable from them may be calculated unambiguously for clearcut chemical reactions or vaporization processes.

With conventional techniques of measurement, the optimum pressure range of the transpiration method extends from approximately 0.1 to 10 mm Hg or higher, an intermediate range compared with those of the effusion and direct-pressure-measurement techniques. The transpiration method can be fairly precise; as used heretofore it has a precision of the order of one percent, but, unlike mass spectrometry, sometimes suffers from being unable to discriminate among and determine different possible molecular components of the vapor, such as monomer (p_1), dimer (p_2), and sometimes trimer (p_3). In principle, the combination with other methods affords some opportunity to resolve this indeterminacy, since the assumption of the monomer molecular weight leads to a calculated total pressure equal to ($p_1+2p_2+3p_3$) by the transpiration method, ($p_1+\sqrt{2}\,p_2+\sqrt{3}\,p_3$) by the effusion method, and ($p_1+p_2+p_3$) by the torsion-effusion or by a direct-pressure method.

Apparatus Development. The details of the transpiration apparatus designed, constructed, and tested early in the program are given elsewhere [8], but may be summarized here. A resistance-heated furnace was built to house the evaporation cell, which for temperature uniformity and inertia was first surrounded by thick copper that was soon replaced by nickel to allow higher operating temperatures. The temperature gradients in the evaporation cell were extensively studied, and minimized by redistribution of the heater inputs. In practice steady-state heating

was found to give temperature steadiness so good as to permit correction to the average temperature during a run by simple integration. Since the first systems planned for measurement are non-metallic, the flow train through the furnace was constructed of platinum-rhodium parts, with constrictions designed to prevent error-producing vapor diffusion and radiation losses. Thoroughly dried argon is used as the carrier gas, sufficient approach to evaporation equilibrium having been established by varying the flow rate. The mass of entrained vapor is determined by weighing it after its condensation downstream. The evaporation of high-purity benzoic acid was selected for preliminary trial runs.

Measurements on Aluminum Trifluoride. At the start of the program the existing vapor-pressure and vapor-association data for $A\ell$, Mg, $A\ell F_3$, MgF_2, $MgC\ell_2$, and LiF were analyzed for thermodynamic consistency. It was found that the vapor-pressure data on $A\ell F_3$ (then believed to be highly monomeric) gave highly discordant heats of vaporization (on which the evaluation of its standard heat of formation depends), and so a high-purity sample of this substance was chosen for the initial investigation. The results are described in detail elsewhere [8]. Seventeen runs were made over the temperature range 1233°-1288°K, and the calculated Third-Law heats of sublimation (at 0°K) showed no drift with temperature and a standard deviation of 0.08%. A recently published mass-spectrographic study [9], though subject to the limited precision of that technique, indicated that the vapor in the present study contained between 4 and 15 mole percent of dimer ($A\ell_2F_6$). The present data were analyzed, and were found to correlate closely with published data on aluminum trifluoride by other methods at about 1050° and 1425°K if in all these cases the saturated vapor were assumed to contain at least some dimer, but close to the lower limit indicated by the mass-spectrographic data.

Investigation of the $A\ell F_3$-$A\ell C\ell_3$ System. A single run at about 1250°K was made in which $A\ell F_3$ evaporated in the presence of finely-divided crystalline $A\ell_2O_3$. But there was no detectable enchancement of the apparent vapor pressure of the $A\ell F_3$, which should result if an appreciable amount of a gaseous aluminum oxyfluoride were formed.

In contrast, $A\ell F_3$ and $A\ell C\ell_3$, which as gases are largely monomeric near 1250°K, are expected to undergo extensive interaction according to the all-gas reactions

$$2A\ell F_3 + A\ell C\ell_3 = 3A\ell F_2C\ell$$

$$A\ell F_3 + 2A\ell C\ell_3 = 3A\ell FC\ell_2$$

Heretofore, in the absence of any data, the heats of these reactions have been estimated by others as zero or nearly so.

Calculations showed that the transpiration method should be well adapted to studying this system and evaluating the thermodynamic properties of both mixed halides, and the apparatus was modified to evaporate $A\ell C\ell_3$ in a boiling-liquid thermostat and pass it (with argon) through a heated path over solid $A\ell F_3$ at higher temperatures. Two preliminary runs indicated such extensive interaction between the two halides as to require a very accurate determination of the amount of unreacted $A\ell C\ell_3$ vapor. However, the latter is so reactive chemically that it was found necessary to modify the apparatus radically in order to eliminate contamination from traces of moisture. In addition, a section of gold-plated nickel in the flow path that had been corroding was replaced by stainless steel type 316, a material which had shown little or no such corrosion. Whatever mixed halides form are assumed to disproportionate to $A\ell F_3$ and $A\ell C\ell_3$ when cooled, and the latter is condensed and analyzed by weighing and titration, which agree within a few tenths of a percent. Chemical analysis at the Bureau of the unevaporated and condensed samples of $A\ell C\ell_3$ show within less than 0.1% the theoretical aluminum content.

Future Plans. Systematic runs on the $A\ell F_3$-$A\ell C\ell_3$ system will be carried out during the coming months. The next system planned for similar study is $A\ell F_3$-HF. If this study gives completely negative results, it is planned to proceed soon thereafter to another light-element halide system.

References

[1] G. T. Furukawa, T. B. Douglas, R. E. McCoskey, and D. C. Ginnings, J. Research NBS 57, 67-82 (1956).

[2] T. B. Douglas and W. H. Payne, "New Apparatus for the Precise Measurement of Heat Content and Heat Capacity from 0° to 1500°C," NBS Handbook 77, Volume II (1961), pp. 241|1-276|36.

[3] T. B. Douglas and W. H. Payne, NBS Report 7587, 1 July 1962, pp. 44-54, 134.

[4] G. T. Furukawa, T. B. Douglas, W. G. Saba, and A. C. Victor, J. Research NBS 69A, Sept.-Oct. issue (1965); W. G. Saba and G. T. Furukawa, NBS Report 7587, 1 July 1962, pp. 39-43, 135-136.

[5] D. A. Ditmars and T. B. Douglas, (in a later report).

[6] T. B. Douglas and W. H. Payne, NBS Report 8186, 1 January 1964, pp. 75-82, 163.

[7] T. B. Douglas and J. E. Neufer, NBS Report 8186, 1 January 1964, pp. 68-74, 162.

[8] R. F. Krause, Jr., A. C. Victor, and T. B. Douglas, NBS Report 7796, 1 January 1963, pp. 157-171.

[9] R. F. Porter and E. E. Zeller, J. Chem. Phys. 33, 858-863 (1960).

6. ENTHALPY MEASUREMENTS ABOVE 1200°K

The thermodynamic properties of materials at high temperatures are often estimated by extrapolation of measurements at lower temperatures. Extrapolation often is adequate to estimate properties of a solid at high temperatures from good lower temperature data, but, if properties of the liquid are desired, some other means of estimating the heat of fusion and liquid heat capacities are required. Such estimates may be considerably off the mark. For example, the heat of fusion of LiF was estimated from phase diagrams [1] to be about 1/3 the value observed later [2]. The heat of fusion of $A\ell_2O_3$ is another example of the need for data in the liquid range. Walker [3] estimated the heat of fusion from phase diagrams to be 26 kcal/mole. The measured value is about ten percent higher.

The work reported below was undertaken to measure the properties of high temperature liquid phases directly and eliminate some of the uncertainties.

Summary of Accomplishments since January 1965

Measurements of the enthalpy of $A\ell_2O_3$ relative to room temperature have been made by the method of mixtures from about 1200°K into the liquid range, including the heat of fusion. The apparatus used consists of an adiabatic calorimeter which is calibrated electrically with a precision of 0.005% (standard deviation), a new precise automatic optical pyrometer which gives a continuous reading of the furnace temperature and is also used to control it, and an rf induction furnace well-insulated to reduce the power requirements and the accompanying temperature gradients.

To obtain the enthalpy at a given furnace temperature, four experiments are made on the same day - - the first on the empty capsule, two more on the capsule + $A\ell_2O_3$, and the last on the empty. These data suffice to determine the enthalpy at that temperature and estimate the precision of the measurements. Subsequent changes in the sample or the capsule do not affect these results. The order of experiments serves to average small changes during the day in weights, emittance, temperature gradients in the furnace, etc. The capsule is removed from the apparatus twice daily and the weight can be checked at these times as well as before and after the day's work. No other high temperature enthalpy measurements provide these checks on changes in the sample and capsule.

The results obtained for $A\ell_2O_3$ with this apparatus and method are believed to be more accurate over this extended range than any other measurements above 1200°K.

References

[1] K. K. Kelley, U. S. Dept. of the Interior, Bureau of Mines Bulletin 393 (1936).

[2] T. B. Douglas and J. L. Dever, J. Am. Chem. Soc. 76, 4826 (1954).

[3] R. F. Walker, NBS Report 6297 to ARPA, January 1, 1959.

7. STUDIES ON ALUMINUM HYDRIDE-TRIMETHYLAMINE COMPLEXES

In 1959, aluminum hydride evoked considerable interest as a possible fuel, therefore, its heat of formation was of great interest.

Since aluminum hydride free of coordinated polar solvents had not been prepared at that time, it was felt that some idea of the heat of formation could be obtained by a study of the decomposition of the trimethylamine complexes of aluminum hydride. Samples of these materials were supplied by Dr. C. D. Marsel of New York University.

The vapor pressure of aluminum hydride bis(trimethylamine) was determined between 20° and 60°C as follows:

$$\log P = \frac{-3230}{T} + 11.15$$

From this equation was calculated the following value for the heat of sublimation of 14800 ±150 cal per mole.

A study was also made of the equilibrium reaction.

$$A\ell H_3 \cdot 2N(CH_3)_3(g) \rightleftharpoons A\ell H_3 \cdot N(CH_3)_3(g) + N(CH_3)_3(g)$$

using temperature-pressure data at 70° to 95°C. An equation for this reaction was determined as follows:

$$\text{Log } K = -2.9 \times 10^3/T + 6.0$$

It is felt that the accuracy of the measurements might be improved by more sensitive temperature control and the use of a cathetometer for reading pressures. However, the data was obtained at low pressures and under conditions of relatively low degrees of dis-association which tend to increase mathematical errors. It appears that for this reaction the heat of formation (ΔH_f) is about 14 K cal/mole, the entropy of formation (ΔS_f) is about 30 e.u. per mole and the free energy of formation (ΔF) about 4000 cal/mol.

Synthesis of Light-Metal Hydrides

A study was made of methods of synthesis of certain light metal hydrides. Theoretical calculations and unsuccessful experiments elsewhere indicated that synthesis by direct union of the elements was unlikely. Pyrolytic techniques had yielded products which assayed rather low in the desired hydride.

An apparatus was developed in which the entire operation took place in a closed system. By varying the technique a product was obtained assaying up to 85 weight percent hydride. Subsequent industrial development of this method raised this assay to 94 weight percent. Analytical studies of this material yielded information useful in the development of new ideas of the structure of this material. Studies were also made of decomposition rates.

A further study was attempted to determine the nature of the affiliated organic groups using a Knudsen Cell. Here the hydride was heated slowly from toom temperature up to 300°C and the gases escaping through the orifice were analyzed by a time-of-flight mass spectrometer. It was hoped that the varying of the peaks would yield information on the size and possibly the location of these groups. However, the mass spectrometer patterns were too complex and this project was suspended.

Decomposition and Analysis of Aluminum Borohydride

The development of interest in aluminum borohydride was accompanied by great interest in the heat of formation of this material.

Aluminum borohydride is a very reactive, spontaneous flammable material. It is very difficult to analyze this material quantitatively for aluminum, boron, and hydrogen. This is because too rapid decomposition will cause the release of boron hydrides and also the formation of difficult soluble aluminum borides. A great many experiments were run using many decomposing agents and techniques ofcontacting. The most successful was the reaction of aluminum borohydride with isopropyl alcohol in the vapor phase. After the initial reaction was complete the alcoholate was decomposed with 2N sulfuric acid. The gases were collected and measured. The gas produced by this procedure had a very slight boron hydride odor, but these hydrides could not be detected by instrumental means. Although this proved the most effective method of analysis, it still have a low hydrogen content.

Some attention was given to the possibility of analyzing aluminum borohydride by gas-chromatography. However, the reactivity of the material made it unsuitable for use in our instrument.

Literature Surveys

At the outset of the program a literature search was made for preparation and analytical data on the oxides and hydroxides of aluminum, beryllium, magnesium, and lithium. Later a continuing survey was made of the alloys and interstitial compounds of aluminum, beryllium, magnesium, and lithium with themselves and with titanium, tungsten, and zirconium.

8. PREPARATION OF PURE POLYMORPHS OF BeF_2

From Jan. 1962 to present, the time of one research worker has been devoted to the development of new apparatus, new precedures, and new techniques for the physico-chemical phase separations to 1000°C for the chemical pruification and the physical-state preparation of a pure polymorph (chemically pure and in one crystalline form) of polymorphic inorganic fluorides, such as BeF_2. This work has been fully supported by ARPA with emphasis on BeF_2 because of the inability to secure this compound as a high-purity, well-defined crystalline solid sought for in the establishment of very reliable physical and thermodynamic properties of BeF_2 in the ARPA light-element program at NBS.

In the achievement of the above goal for BeF_2 factors such as the toxicity and hygroscopicity of BeF_2 had to be considered as well as its reactivity at elevated-temperatures and the careful heat-control that is required for physical-state, solid phase, purity. Facilities developed have included: (1) an assembly for toxic materials (three-compartmental arrangement where high-temperature part of assembly is in hood with high-exhaust for safety); (2) furnace and temperature control (customed-designed, three-zone furnace whose temperatures for producing environmental heat-conditions with experimental vessels are automatically controlled and recorded by a remote panel); (3) controlled atmosphere dry box (altered to accommodate special experimental vessels for material addition or solid product removal under a controlled gaseous atmosphere such as N_2); (4) special cell for phase purifications (designed and fabricated from Inconel, Monel and Nickel at NBS for phase separations to 1000°C; equipped with thermocouples for monitoring temperatures of three areas of the cell during phase separations such as distillation, crystallization, sublimation and preferential decomposition and constructed for disassembly or assembly in a dry box whereby solid products can be added or removed in containers from three areas of the cell); and (5) apparatus for the "hydrofluorothermal" process (technique for anhydrous addition of HF from a rupture-disc ampoule to a closed bomb for use in the development of a process for the crystal growth of BeF_2 under HF pressure, similar to that used in the hydrothermal growth of quartz from SiO_2).

Distillations at 1000°C with BeF_2 in the special cell have been performed to obtain: a better analysis for BeO in the original sample; high-chemical-purity glassy BeF_2; and a small amount of pure polymorph, that was identified by microscopic and X-ray powder diffractometry as the (low-temperature), quartz-like, hexagonal form of BeF_2. In the above distillations, the above polymorph was the minor product in the condensation of the vapors; different heat-transfer conditions for the condensation of the vapors would be expected to produce the pure polymorph as the major product and thus offers a good method for producing the large quantity (150g) desired for the program. The glassy BeF_2 of high-chemical purity and free of gaseous or other inclusions is also very useful for other aspects of the program such as the determination

of the vapor pressure and heat of fusion and the comparison of glassy and crystalline BeF_2. Another important use for glassy BeF_2 would be as a chemical standard for beryllium and/or fluorine.

Generally, inorganic substances are polymorphic and the solid form of the material can exist in several different crystalline states; thus the procedures developed for BeF_2 would be applicable to a large number of other materials. The problem of hygroscopicity also is not uncommon and requires special handling techniques. Since fluorides are much more volatile than oxides, purification through the fluoride as an intermediate is applicable in the preparation of chemically-purer, crystalline oxides.

9. HIGH TEMPERATURE MASS SPECTROMETRY

Literature surveys had indicated that in many high temperature studies experimental identification of the species existing was absent. The study of selected light element compounds, for which thermodynamic data was non-existent, was undertaken by employing a mass spectrometer designed for high temperature use.

The Be-O-F System

The vapor species, arising from BeO and BeF_2 each studied separately, were available in the literature. It was confirmed that over BeO at 2200°K, the vapor species seen mass spectrometrically were Be^+, O^+, $(BeO)_3^+$, $(BeO)_4^+$, O_2^+, BeO^+, $(BeO)_2^+$, $(BeO)_5^+$, and $(BeO)_6^+$. Vaporization of BeF_2 provided the species BeF_2^+, Be^+, F^+, and $Be_2F_3^+$. The BeF_2 data produced a sublimation enthalpy of 55.79 ±0.53 kcal/mol at 0°K from BeF_2 that was predominately not crystalline.

The reaction of BeF_2 (g) with BeO in the temperature range 1520°-2170°K produced a new species, Be_2OF_2 (g). The enthalpy of formation for this compound was computed from a van't Hoff plot, $\Delta H^\circ_{\langle 1730 \rangle}$ = 39.25 ±3.5 kcal/mol and $\Delta H^\circ_{\langle 2035 \rangle}$ = 40.68 ±0.86 kcal/mol. Comparison of the enthalpy of formation computed from free energy functions and the van't Hoff plots indicated that an error existed in the free energy functions for BeF_2 (g). New matrix isolation data did give new bending frequencies from which improved free energy functions were obtained and the enthalpy computed from these functions gave good agreement with the experimentally obtained enthalpy value.

The Al_2O_3-BeO System

Mass spectrometric examination of the vapor species above the compound $Al_2O_3 \cdot BeO$ in the temperature range 2180-2570°K indicated the existence of $AlOBe^+$ (g) in addition to Be^+, O^+, Al^+, O_2^+, Al_2O^+, and $(BeO)_3^+$. Enthalpy changes for the following reactions were determined by the van't Hoff equation and from free energy functions:

(1) $Al(g) + Be(g) + O(g) = AlOBe\ (g)$

(2) $2Al\ (g) + O(g) = Al_2O(g)$

(3) $Al_2O(g) + Be(g) = AlOBe(g) + Al(g)$

(4) $\frac{1}{2}O_2(g) = O(g)$

(5) $Al_2O_3 \cdot BeO(l) = 2Al(g) + Be(g) + 4O\ (g)$

Reaction	van't Hoff Equation, ΔH_0°	Free Energy Functions, ΔH_0°
(1)	- 221.8	- 231.2 ±3.3
(2)	- 269.5	- 253.1 ±4.6
(3)	+ 25.5	+ 21.3 ±6.2
(4)		+ 59.3 ±1.0
(5)	+ 826.0 ($\Delta H^\circ_{<2350>}$)	

10. VAPORIZATION OF REFRACTORY MATERIALS; ARC-IMAGE RESEARCH

Accomplishments Since 1960

An arc-image furnace was acquired in 1960, and adapted for high-temperature studies. High-temperature research associated with the arc-image furnace was carried out in three areas: (1) solution of the problem of temperature measurement, (2) measurement of the rate of vaporization of liquid Al_2O_3 in vacuum and in gaseous atmospheres, and (3) investigation of the transparent film which condenses on the flask surrounding the alumina sample when liquid Al_2O_3 is vaporized *in vacuo*.

The temperature of a molten alumina drop formed on the end of a heated rod was measured with an optical pyrometer, sighting along the axis of the rod. Drops larger than about 3.5 mm were determined to be "infinitely thick," i.e., no radiation reflected or emitted by the liquid-solid interface penetrates the liquid to reach the pyrometer. Only a spectral emissivity for the liquid need be considered for these large drops. The absorption coefficient γ_λ for the liquid at 0.66μ wavelength is estimated to be 1.0 mm^{-1}. The apparent temperature observed in vacuum is higher than temperatures observed in air and in N_2 indicating that an ambient gas cools the surface of the liquid by convection. In both vacuum and ambient gases, the apparent temperature of drops about 1.00 mm thick or larger exceed the melting point temperature of liquid alumina.

The rate of vaporization of molten Al_2O_3 was measured in vacuum for a temperature range of 2491°-2604°K and a mean third law heat of vaporization was calculated for the process $Al_2O_3(l) = 2Al(g) + 3O(g)$

$$\Delta H_v^\circ\ (298) = 729.0 \text{ kcal mol}^{-1}$$

$$\text{standard deviation} = 2.8 \text{ kcal mol}^{-1}.$$

The heat of vaporization calculated from the JANAF Thermochemical Tables is 708.0 kcal mol^{-1}.

Liquid alumina was observed to absorb water vapor and to bubble it off when frozen in a water vapor atmosphere. This phenomenon of bubbling was not observed when molten Al_2O_3 froze in the presence of H_2, He, O_2, Ar, or air. However, comparison of the rate of vaporization on molten Al_2O_3 in $H_2O(g)$ with rates in He and Ar did not show any noticeable difference. An attempt was made to estimate the rate of vaporization in the presence of an ambient gas by treating the removal of Al, O, and AlO vapor species from the region of the liquid as purely a gaseous diffusion process. However, the estimated rates were too low, indicating that probably both convection and condensation play an important role.

The transparent film which condensed on the interior of the pyrex bulb surrounding alumina specimen when it was melted in vacuo was found to be "amorphous" within the limits of detectability by x-ray and electron diffraction. The film was isotropic with a refractive index of 1.614. It showed a water band at 2.9μ and lost 4% in weight when ignited to 1200°C, indicating that it was only slightly hygroscopic. The amorphous film began to crystallize at about 570°C after an anneal of 8 hours, passed through a form corresponding to a mixture of the delta and theta aluminas reported by Stumpf from 670°C up to about 900°C and was entirely converted to α-alumina by 1070°C.

Projected Plans

1. Completion of studies of the vaporization of liquid Al_2O_3 in gaseous atmospheres of Ar, He, Ne, H_2, O_2, and H_2O with emphasis on determining the influence of water vapor on the rate of vaporization.

2. Renewal of effort to melt BeO using a higher intensity of radiation, to measure its rate of vaporization and to investigate the vapor-deposited material.

3. Adaptation of quadrupole mass-spectrometer to the system to identify and study vapor species from liquid alumina under neutral conditions.

4. Determination of the density and surface tension of liquid alumina.

Publications

Several publications in books and journals have resulted from this phase of the program, and several others have been planned for the near future. Details (titles, authors, and references) may be found elsewhere in this report, among a list of publications for the entire program.

11. MICROWAVE AND INFRARED SPECTROSCOPIC STUDIES OF LIGHT-ELEMENT COMPOUNDS

This group has been engaged since the beginning of the Light-Element Thermodynamics Program in spectroscopic studies of various compounds which are of importance to the program. The general aim has been to obtain accurate structural information required for the calculation of ideal gas thermodynamic properties, as well as other molecular properties which might throw some light on the nature of the species present in high-temperature systems. Two classes of experiments have been involved: (a) the development of special apparatus for obtaining spectra of species which exist only in a high-temperature environment, and (b) the study of stable species whose spectra can be obtained with more or less conventional apparatus. The initial activity involved spectra in the microwave region, but more recently infrared work has also been carried out. In addition to the experimental program, members of the group have participated in the evaluation of published spectroscopic data for use in thermodynamic calculations.

Development of high-temperature microwave spectrometer. At the beginning of the Light-Element Program it appeared that microwave spectroscopy offered some promise for direct study of gaseous species present in high-temperature systems. This hope has to some extent been realized, although a number of limitations of the technique have become apparent.

The objective was to build a waveguide absorption cell which could be heated to as high a temperature as possible and then to measure the absorption spectra of gaseous species contained within the hot waveguide. The first plan was to construct a cell similar to that used by Mandel, Stitch, Honig, and Townes[1] for microwave studies on the heavier alkali halide molecules. This is essentially a conventional Stark-modulation waveguide made of materials which can withstand the high temperature and the inevitable chemical attack. This approach proved to be impractical; the complexity of the design resulted in a large number of experimental problems which added up to generally poor performance. A new type of waveguide was therefore developed[2] which is much better suited to high-temperature operation. A spectrometer was built around this new design which is capable of operating up to 1000°C and over a frequency range of 20,000 Mc to 60,000 Mc. The simple design of the spectrometer permits rapid cleaning and changing of samples.

Several investigations have been carried out successfully with the high-temperature microwave spectrometer. The rotational spectrum of LiCl vapor has been measured and analyzed.[3] These measurements provided very accurate values of the rotational constants B_e, α_e, and γ_e for LiCl, as well as values for the electric dipole moment in several vibrational states. Attention was then turned to the aluminum halides. While the

trihalides show no microwave spectrum because of their high symmetry, conditions of temperature and pressure were found where spectra of the monohalides could be detected. The monohalides were produced by reduction of the trihalides with elemental aluminum. Accurate rotational constants were obtained for both AlF and AlCl; electric dipole moments and nuclear quadrupole coupling constants were also measured, and some conclusions were drawn about the nature of aluminum-halogen bonds.[4] Finally, the conditions required for the observation of the AlF and AlCl spectra allowed estimates to be made of the dissociation energies of these molecules; the estimates were in excellent agreement with other data.

Application to polyatomic species. The more interesting potential application of the high-temperature microwave spectrometer was to the determination of the structure of polyatomic species present in high-temperature systems. However, little progress has been made in this direction. During the measurements on AlF and AlCl no trace was found of spectra of AlF_2 and $AlCl_2$, which were possible constituents under the conditions of study. This was not too surprising, since the spectra of the dihalides were expected to be quite weak because of the presence of complex fine structure.

Limited searches were made for spectra of several other polyatomic molecules, including $LiBO_2$ and $CsBO_2$. However, the major effort in this area was made on the alkali metal hydroxides. Extensive systematic searches were made on NaOH and KOH under a variety of conditions, but the results were completely negative. The reason for this is not clear. Although decomposition of the hydroxides and reaction with the waveguide materials caused serious problems, conditions were eventually achieved under which the hydroxide vapor could be contained satisfactorily in the waveguide cell. The most probable reason for the failure to observe alkali hydroxide spectra appears to be a high degree of dimerization (the dimers would show no spectrum). Calculations with the best available thermodynamic data predict sufficient monomer concentrations under the conditions used in the experiments. However, there are enough uncertainties in the thermodynamic data to leave open the possibility that the monomer concentration was too low under the accessible experimental conditions.

The prospect of applying microwave techniques to polyatomic species in high-temperature systems is therefore somewhat discouraging. This is rather unfortunate, since there are many interesting and important problems concerning the structure of gaseous polyatomic molecules of the light elements. The basic difficulty is one of sensitivity. The distribution of molecules over many internal states, which is an unavoidable feature of high-temperature spectroscopy, combined with various experimental difficulties which tend to reduce spectrometer sensitivity, make it very difficult to detect spectra of polyatomic molecules.

In spite of these discouraging results, the high-temperature microwave program will be continued. Very recent advances in techniques for detection of weak signals offer hope of an order-of-magnitude improvement in sensitivity of the existing spectrometer. Application of these

techniques will be explored during the next year. If they look promising, work on the alkali hydroxides may be re-opened. The possibility of detecting the spectrum of the ClO radical will also be considered.

Spectroscopic studies of stable compounds. Although the major effort of the group has been devoted to the development and application of the high-temperature microwave spectrometer, a certain amount of work has been done on stable compounds for which molecular constants were needed for thermodynamic calculations. The microwave spectrum of N_2F_4 was analyzed and the structure of the molecule determined.[5] During the last year infrared studies have been carried out on aluminum and beryllium borohydrides with the aim of obtaining the complete set of vibrational fundamentals. Considerable progress has been made with the analysis of these spectra, and the work should be concluded during the next six months. Other infrared and microwave studies are planned on interhalogen compounds in the near future.

Bibliography

1. Honig, Mandel, Stitch, and Townes, Phys. Rev. 96, 629 (1954).

2. D. R. Lide, Rev. Sci. Instr. 35, 1226 (1964).

3. Lide, Cahill, and Gold, J. Chem. Phys. 40, 156 (1964).

4. D. R. Lide, J. Chem. Phys. 42, 1013 (1965).

5. D. R. Lide and D. E. Mann, J. Chem. Phys. 31, 1129 (1959).

12. FAST MEASUREMENT METHODS FOR THE STUDY OF PROPERTIES OF MATTER AT HIGH TEMPERATURES

INTRODUCTORY ABSTRACT

Electrical discharge and similar methods are employed for the high-speed generation of high-temperatures (above 2000°K) for thermodynamic and spectroscopic studies. The ultimate goal of the project is the development of experimental methods for the measurement of properties of high-temperature solid, liquid, and gaseous substances, with emphasis on those substances which are of current interest in chemical propulsion work. Appropriate techniques of fast-measurement are developed where needed for observation of the systems under the extreme and transient conditions of experiment.

At the present time, spectroscopic studies are being performed in order to synthesize and determine the properties of selected diatomic molecules. Data such as electronic energy levels, vibrational frequencies, and moments of inertia, which facilitate computation of thermodynamic tables, will be determined for any new species observed. Also, design, construction and experimental work is underway to develop a system capable of measuring certain thermodynamic and transport properties of matter (in solid and liquid phases) at high temperatures (above 2000°K) and high speeds (millisecond and microsecond times). The major accomplishments to date are summarized in the following paragraphs.

DEVELOPMENT OF METHODS AND APPARATUS

Several suitable capacitor discharge systems, designed to meet the needs of the various stages of the project, have been designed and constructed. Of these a 10 kv, 400 μF bank (maximum energy storage 20,000 joules) and a 20 kv, 60 μF bank (12,000 joules maximum) have been used extensively. A faster (ringing frequency 300 kilohertz), 100 kv, 1 μF system has been used for exploratory development work. A heavy direct current electrical power supply system was designed and constructed. Special switching (spark gap), triggering, recording, and time delay (for synchronization of measurements and experiment) equipment have been designed and/or adapted. Vessels, complete with vacuum pumping and gas charging systems, have been designed for work with exploding wire, tube or foil samples.

TIME-RESOLVED PHOTOGRAPHIC STUDIES

The discharge-explosion process has been observed in high-speed photographic experiments in order to find time intervals and places in the explosion chamber which are suitable for direct experimental measurements. Fast-opening and closing shutters were developed to facilitate this work [1]. The various stages of the mixing process between exploding wire samples and a confined air environment were examined and correlated with simultaneous, time-resolved spectroscopic results.

SPECTROSCOPIC STUDIES

The high-temperature mixture generated by exploding aluminum wires in an air environment has been observed using both integrated and time-resolved spectrographic techniques. A six-channel photomultiplier system was designed and constructed for time-resolved intensity measurements at six different wavelengths of the spectra emitted by the explosion. Preliminary experiments with the system have suggested a method, which involves comparison (under a grey-body assumption) of intensity measurements at several wavelengths in the continuum, for determination of the average temperature of the discharge mixture at selected intervals during the explosion.

The integrated spectrographic results have shown Al-lines (3082, 3093, 3944, and 3962 Å) and AlO bands (the green system: $A\ ^2\Sigma \rightarrow X\ ^2\Sigma$ and part of the ultra-violet system at and below 3113 Å). A report on this and the photographic work is in preparation.

ELECTRICAL MEASUREMENTS

After considerable effort, reliable methods for measuring the discharge current and voltage have been developed. The latter method measures the resistive component of the voltage across the sample directly, and thereby permits time-resolved determination (without calculated corrections for induced effects) of sample resistance, power and energy dissipation in the explosion mixture. A series of experiments has been conducted with exploding aluminum wires at different levels of energy storage. The system was calibrated calorimetrically using a method developed earlier in the project [2]. The measuring system and exploding wire results are described in a paper recently submitted for editorial review and publication. [3]

MILLISECOND AND MICROSECOND CALORIMETRY*

The complete experimental system was designed and constructed for the measurement (with millisecond time resolution) of certain thermodynamic and transport properties (enthalpy, specific heat, and

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* This study is sponsored in part by ARPA.

electrical resistivity) of electrical conductors up to their melting points. The system and the preliminary results are summarized in Ref. [4]. A survey of the literature on fast measurement techniques, with emphasis on those pertaining to thermodynamic measurements, was made [5]. At present, refinements are being made in the photoelectric temperature measuring system having millisecond time resolution. Parallel with this, research is underway to develop a temperature measuring system with microsecond time resolution employing photographic methods. Also, design and construction of auxiliary components are underway for the development of a cascade system capable of measuring certain thermodynamic and transport properties of solids and liquids at high temperatures (above 2000°K) in millisecond and microsecond times.

THERMODYNAMIC CALCULATIONS

Calculations of the composition, entropy, enthalpy, and density (as functions of pressure and temperature) of the gaseous mixture produced by exploding an aluminum wire in an air environment have been performed for pressures between 0.01 and 1,000 atm and temperatures between 1,500 and 6,000 °K. A computer program suitable for future calculations with different components was written for this work. The method of calculation and results were described in NBS Report #8504.

PLANS FOR FUTURE WORK

In the next few months modifications and extensions of the apparatus, required for spectrographic studies of other discharge systems, will be completed. The aluminum-oxygen, aluminum-hydrogen, aluminum-nitrogen, and other systems will be explored. Electronic energy levels, vibrational frequencies, and moments of inertia will be determined for any new species observed. Concurrently, the recent spectroscopic literature on selected diatomic molecules will be searched and evaluated critically.

The development of a system for the measurement (with millisecond and microsecond time resolution) of certain thermodynamic and transport properties of matter (in solid and liquid phases) at high temperatures (above 2000°K) will be continued.

LIST OF PUBLICATIONS

[1]. "A Fast-Opening, Large-Aperture Shutter for High-Speed Photography" by E. C. Cassidy and D. H. Tsai, NBS J. Research 67C, Jan-Mar. 1963, reprinted in J. Soc. Motion Picture and Television Engineers, July 1963 and in Instrumentation and High-Speed Photography, Vol. 2, Soc. Motion Picture and Television Engineers, 9 East 41st Street, New York (1963).

[2]. "Calorimetric Calibration of the Electrical Energy Measurement in an Exploding Wire Experiment" by D. H. Tsai and J. H. Park, Exploding Wires, Vol. II, ed. W. G. Chace and H. K. Moore, Plenum Press, New York (1962).

[3]. "Time-Resolved Electrical Measurements in High-Current Discharges" by E. C. Cassidy, S. W. Zimmerman, and K. K. Neumann, submitted for publication in Rev. Sci. Intr.

[4]. "A High-Speed (milliseconds) Method for the Simultaneous Measurement of Enthalpy, Specific Heat, and Resistivity of Electrical Conductors at High Temperatures" by A. Cezairliyan, Advances in Thermophysical Properties at Extreme Temperatures and Pressures, p. 253, Amer. Soc. Mech. Eng., 345 East 47th St., N.Y. (1965).

[5]. "High-Speed Thermodynamic Measurements and Related Techniques" by C. W. Beckett and A. Cezairliyan, Experimental Thermodynamics, Vol. 1, John P. McCullough ed., (to be published).

[6]. "Photographic and Spectroscopic Studies of Exploding Wires in a Sealed Vessel", by E. C. Cassidy and K. K. Neumann. (To be submitted for publication in Proc. 7th Int. Cong. on High-Speed Photography, Zurich, Switzerland, Sept. 1965.)

PART B. THERMODYNAMIC PROPERTIES OF LIGHT-ELEMENT COMPOUNDS

Chapter B1

A LITERATURE SURVEY OF THE HIGH-TEMPERATURE THERMODYNAMIC PROPERTIES OF SELECTED HEAVY ELEMENTS (Ti, Zr, Hf, Th, W, U, Hg, and Pb) AND THEIR COMPOUNDS WITH LIGHT ELEMENTS

by H. W. Flieger, Jr., T. B. Douglas, and R. F. Krause, Jr.

Introduction

A number of the heavier elements and some of their compounds with multivalent non-metals have important refractory applications. In addition, for several years there has been an interest in the possibility of using certain heavy elements and their compounds as components of chemical-propulsion systems under special circumstances.

An attempt is made here to reference and abstract, in a single review, the more recent literature reporting information on their high-temperature thermodynamic properties. However, because of time limitations no attempt has been made by the authors to examine the data critically as to their accuracy, reliability, or interconsistency. But many references are made in the survey to excellent compilations in which more or less thorough critical selection was involved. The present survey is fairly up-to-date, but makes no claim of being complete.

The survey covers and is limited to the uncombined elements titanium, zirconium, hafnium, thorium, tungsten, uranium, mercury, and lead, together with their hydrides, fluorides, chlorides, iodides, oxyfluorides, oxychlorides, oxides, nitrides, carbides, borides, and gaseous oxygen-hydrogen compounds. The properties covered are enthalpy and heat capacity; heats and temperatures of transition, fusion, and vaporization; and both congruent and non-congruent vaporization equilibria -- all at or above room temperature. In addition, gas dissociation energies are included, since they are intimately related to many heats of vaporization. Omitted in general are low-temperature and reaction calorimetry, and absorption and emission spectroscopy.

Appearing after each element or compound listed in the survey is a short abstract of the pertinent information in the literature referenced. When reference is made to a work containing complete tables of thermodynamic functions (such as references [1], [10], and [102] through [120]), the abstract given here lists only the phases (crystal, liquid, gas) to which the table applies. Unless

otherwise stated, temperatures are given in deg K, heats in kcal per gram-formula-weight, and entropies in cal g^{-1} deg K^{-1} (e.u.) per gram-formula-weight.

In many instances reference is made to earlier compilations of data (references [1], [2], [3], [6], [7], [8], and [9]) which were assumed to cover adequately the prior literature. More recent literature references were acquired by searching Chemical Abstracts, Annual Review of Physical Chemistry, and The Bulletin of Thermodynamics and Thermochemistry through the 1964 edition. References [102] through [120] refer to tables of high-temperature (as well as low-temperature) thermodynamic properties which have appeared in earlier reports which together with the present report constitute a series. Current journals were not examined except in isolated instances.

For a summary of the apparent data status for each class of substance and property covered in the present chapter, the reader is referred to Chapter B4. For similar summaries of $\Delta Hf°$, $\Delta Gf°$, and $S°$ of the same substances, see Chapter B3.

Ti

[1] Enthalpy of crystal measured to 1476°; $\Delta H_{tr}(1155°) = 0.95$; $\Delta H_m(1940°) = 4.46$; Cp(liq.) given to 3000°; enthalpy of gas obtained from spectroscopic data.

[6] Ti(c,β) vapor pressure equation for range 1200° to 2000°; 2-constant vapor pressure equation for liquid; $T_m = 1933°$; $T_b = 3533°$; $T_{tr} = 1155°$; $\Delta H_m = 4.5 \pm 0.5$ (estimated); $\Delta H_{subl}(298°) = 111.7 \pm 8.0$; $\Delta H_{tr} = 0.83 \pm 0.1$.

[8] $T_m = 1950 \pm 20°$; $\Delta H_m = 3.70$ (estimated); Cp(liq.) is estimated; $\Delta H_{tr} = 0.95$ (measured); $T_{tr} = 1155°$; vapor pressure measurements by [11]; $\Delta H_{subl}(298°) = 112.60$; $T_b = 3550°$; $\Delta H_{vap}(3550°) = 102.5$ (calculated).

[10] Solid, liquid, and gas.

[12] Measured vapor pressure by Langmuir method of the crystal in the range 1373° to 1773°; gives a 2-constant P(T) equation.

[104] Crystal(α,β), and liquid

TiF

[10] Gas.

TiF_2

[2] Solid and gas disproportionates so extensively as to be unimportant.

[10] Gas.

TiF_3

[2] Estimates thermodynamic properties for gas.

[10] Crystal and gas.

TiF_4

[3] Estimates thermodynamic properties of the gas.

[6] Gives vapor pressure equation for the crystal in the range 298° to $T_{subl}(556°)$; $\Delta H_{subl}(298°) = 22.9 \pm 0.5$.

[10] Crystal and gas.

TiCℓ

[1] Gas calculated to 2000° from spectroscopic data.

[10] Gas.

$TiCℓ_2$

[1] Estimate for crystal to 1200°.

[2] Estimates thermodynamic properties of the gas, and indicates this is an important gas species at elevated temperatures.

[10] Crystal and gas.

$TiCℓ_3$

[1] Crystal measured to 1002° and tabulated to 1200°.

[2] Estimates thermodynamic properties of the gas, but indicates it is an unimportant gas species.

[6] Gives vapor pressure equation for the crystal from 298° to T_m (estimated as 1003°); $T_b = 1023°$ (estimated; $\Delta H_m = 5.0$ (estimated); $\Delta H_{subl}(1023°) = 33.0$ (estimated).

[10] Crystal and gas.

[13] Reduced $TiCℓ_4$ to $TiCℓ_3$ at three temperatures between 298° and 773°; for reduction with hydrogen at 773° obtains $\Delta H = -28.5$.

$TiCl_4$ [1] Liquid measured to 500°; gas calculated from molecular constant data to 2000°.
[6] Gives an equation for the vapor pressure of the liquid in the range 298° to T_b(410°); ΔH_{vap}(410°) = 8.65 ±0.5.
[10] Crystal, liquid, and gas.

TiI [14] Studied vapor pressure using a quartz spring manometer; gives a 2-constant P(T) equation for the reaction $4TiI(c) \rightarrow 3Ti(c) + TiI_4(g)$ at temperatures above 1073°.
[10] Gas.

TiI_2 [1] Crystal estimated to 1200°.
[2] Estimates thermodynamic properties of the gas.
[6] Gives vapor pressure equation for the crystal from 298° to 1000°; T_{sub1} = 1443°; ΔH_{sub1}(298°) = 56.3 ±6.0.
[14] Studied vapor pressure using a quartz spring manometer; gives P(T), 2-constant equation at temperatures greater than 723° for a reaction involving iodides of Ti.
[10] Crystal and gas.

TiI_3 [1] Crystal estimated to 1200°.
[2] Estimates thermodynamic properties of the gas, but indicates it is not an important species at high temperatures.
[14] Measured the vapor pressure using a quartz spring manometer; gives a 2-constant P(T) equation at temperatures above 573° for the reaction $2TiI_3(c) \rightarrow TiI_2(c) + TiI_4(g)$.
[10] Crystal and gas.

TiI_4 [1] Crystal and liquid estimated to 650°; gas estimated to 2000°; ΔH_m(423°) = 4.18.
[2] Says the gas is partially decomposed at 713°.
[6] Gives a 2-constant vapor pressure equation for the liquid in the temperature range 430° to 643°; T_m = 423°; T_b = 650°; ΔH_m = 4.2 ±0.8 (estimated); ΔH_{sub1}(298°) = 21.6 ±1.5.
[14] Measured the vapor pressure using a quartz spring manometer; gives a 2-constant P(T)equation for the reaction $TiI_4(\ell) \rightarrow TiI_4(g)$.
[10] Crystal, liquid, and gas.

TiOF [10] Gas.

$TiOF_2$ [10] Gas.

$TiOCl$ [10] Gas.

$TiOCl_2$ [10] Gas.

TiO [1] Crystal measured to 1771° and tabulated to 2000°; H_{tr}(1264°) = 0.82; properties of the gas to 2000° taken from [15].
[6] T_{tr} = 1264°; T_m = 2293°; ΔH_{tr} = 0.82 ±0.2; ΔH_m = 14.0 ±2.0 (estimated).

[9] Gives D_o = 127 ±23 (linear Birge-Sponer).

[16] By mass spectrometry measurements obtains for the reaction $2TiO(g) \rightarrow Ti(g) + TiO_2(g)$ that $\Delta G(298°)$ = 139.4 (by 2nd law) and 148.6 (by 3rd law); for the reaction $2TiO(g) \rightarrow Ti(g) + TiO_2(g)$ they obtain $\Delta H(298°)$ = 8.8 (3rd law) which with the value of D(298°) for $TiO_2(g)$ of [17] yields D(298°) = 162 for TiO(g).

[18] Calculated the ideal gas thermodynamic properties by a statistical-mechanical treatment.

[10] Solid, liquid, and gas.

[105] Crystal (α,β).

Ti_2O_3, Ti_3O_5, Ti_5O_9

[1] Ti_2O_3 crystal measured to 1750° and tabulated to 2000°; $\Delta H_{tr}(473°)$ = 0.215.

Ti_3O_5 crystal measured to 1340° and tabulated to 2000°; $\Delta H_{tr}(450°)$ = 2.240.

[4] For Ti_2O_3 crystal gave T_m = 2400° and ΔH_m = 38.4.

[6] Same T_{tr} and ΔH_{tr} as [1] for Ti_2O_3 and Ti_3O_5 crystals.

[19] For Ti_3O_5 crystal gives T_m > 2500°.

[20] Reduced TiO_2 with hydrogen and obtained ΔHf for Ti_2O_3; gives physical and chemical properties of Ti_5O_9.

[10] Ti_2O_3 solid and liquid. Ti_3O_5 solid only.

[106] Ti_2O_3 crystal (α,β).

[107] Ti_3O_5 crystal (α,β).

TiO_2

[1] Crystal measured to 2000°; rutile tabulated to 2000°; anatase tabulated to 1300°.

[5] D(298°) = 315 ±5 for gas. From [16] for TiO_2 gives $\Delta H_{vap}(298°)$ at 139.6 (by 2nd law).

[6] T_m = 2113°, ΔH_m = 15.5 ±2.5 (estimated).

[7] Gives $\Delta H_{vap}(298°)$ is 142.7 (by 2nd law) and 148.6 (by 3rd law).

[10] Anatase solid only. Rutile solid, liquid, and gas.

[108] Rutile.

[109] Anatase.

TiN

[1] Measured to 1738° and tabulated to 2000°.

[2] T_m = 3200°.

[22] Measured vapor pressure using a magnetically controlled balance.

[23] A mass spectrometric study of the vapor composition showed that TiN started to decompose at 1700°; P(TiN) = 2 x 10^{-8} atms. at 1800°.

[24] Steel containing Ti and N rapidly quenched from 1833°, 1873°, and 1923° was used to determine the decomposition of TiN; gives an equation for K(T).

[25] Gives a 2-constant equation for K(T) for the reaction: $TiN(sol.\ soln.) + C \rightarrow TiC(sol.\ soln.) + \frac{1}{2}N_2$.

[10] Solid and liquid.

[102] Solid and liquid.

TiC	[1]	Crystal measured to 1735° and tabulated to 2000°.
	[2]	T_m = 3450°.
	[26]	From a 3rd law treatment of mass spectrometry measurements obtained $\Delta H_{f_0}^{\circ}$ of crystal as -45.5 and $D_0 \leq 127$ for the gas.
	[27]	Measured the decomposition pressure of TiC at 2300° using the Langmuir method; accommodation coefficient approximately unity.
	[10]	Crystal and liquid.
	[103]	Solid and liquid.
TiB, TiB_2	[1]	TiB_2 crystal measured to 977° and tabulated to 1000°.
	[28]	Using mass spectroscopic data and the 3rd law, obtained ΔH_f° = -52 and $\Delta H_{subl}(298°)$ = 430 for TiB_2.
Zr	[1]	Crystal measured to 1371° and tabulated to 3000°; $\Delta H_{tr}(1135°)$ = 0.915; $\Delta H_m(2130°)$ = 4.9; gas tabulated to 8000° based on spectroscopic data.
	[6]	Gives a 3-constant equation for the vapor pressure of the crystal in the range 1950° to 2050°; T_{tr} = 1125°; T_m = 2133°; T_b = 5023° (estimated); ΔH_{tr} = 0.92 ±0.1; ΔH_m = 4.6 ±0.7; $\Delta H_{subl}(298°)$ = 141.6 ±6.0.
	[8]	T_{tr} = 1148°; T_m = 2125°; ΔH_{tr} = 1.04; ΔH_m = 4.00 (estimated); C_p(liq.) is estimated. Only vapor pressure measurements are those of [29]; $\Delta H_{subl}(298°)$ = 146.0; T_b = 4650°; $\Delta H_{vap}(4650°)$ = 139.0.
	[10]	Crystal, liquid, and gas.
	[110]	Crystal (α,β) and liquid.
	[119]	Crystal (α,β).
ZrH_x	[1]	Crystal measured to 1173° and tabulated to 800°.
	[10]	Gas only.
	[120]	Crystal (α+δ, β+δ, and β).
ZrF	[10]	Gas.
ZrF_2	[10]	Crystal, liquid, and gas.
ZrF_3	[3]	Estimated thermodynamic properties of the gas.
	[10]	Crystal and gas.
ZrF_4	[6]	Gives equation for the vapor pressure of the crystal in the range 295° to $T_{subl}(1181°)$; $\Delta H_{subl}(298°)$ = 64.3 ±4.0 and $\Delta H_{subl}(T_m)$ = 55.5 ±3.5.
	[30]	Measured vapor pressure of α-ZrF_4 by the Knudsen effusion method in the range 713° to 873°; for this temperature range gives a 2-constant P(T) equation; ΔH_{subl} = 49.05.
	[31]	Vaporization of ZrF_4 studied by torsion effusion method; gives $\Delta H_{subl}(298°)$ = 55.8; vapor is monomeric.
	[32]	Enthalpy measured 300° to 1200°. T_m = 1205° ±2°; ΔH_m = 15.35 ±0.1.
	[10]	Crystal and gas.
ZrCℓ	[10]	Gas.

$ZrCl_2$ [3] Estimated thermodynamic properties of the gas.
[10] Crystal, liquid and gas.

$ZrCl_3$ [3] Estimated thermodynamic properties of the gas.
[10] Crystal and gas.

$ZrCl_4$ [1] Crystal measured to 567° and tabulated to 700°; gas estimated to 2000°.
[3] Vapor density normal at 1393°.
[33] Measured infrared spectra 1000 to 190 cm^{-1}.
[10] Crystal and gas.
[113] Crystal only.

ZrI [10] Gas only.

ZrI_2 [3] Estimated thermodynamic properties of gas.
[10] Crystal, liquid, and gas.

ZrI_3 [3] Estimated thermodynamic properties of gas.
[10] Crystal and gas.

ZrI_4 [6] Gives a 4-constant equation for the vapor pressure of the crystal in the range 298° to T_{subl}(704°); $\Delta H_{subl}(298°) = 33.3 \pm 2.5$.
[3] Gas slightly decomposed at 1447°.
[10] Crystal and gas.

ZrO [7] Says that [34] gives D(0°) = 181 for the gas, although one set of their equations gives D(0°) = 174 (±10?) by a 3rd law treatment.
[10] Gas.

ZrO_2 [1] Crystal measured to 1841° and tabulated to 2000°; $\Delta H_{tr}(1478°) = 1.42$.
[5] D(298°) = 347 ±5 for the gas; based on the work of [34] $\Delta H_{vap}(298°)$ is 179.6 (by 2nd law) and 179.8 (by 3rd law); free energy functions estimated to 3000°.
[6] Gives an equation for the vapor pressure of the crystal in the range 298° to 2290°; T_{tr} = 1473°; T_m = 2993°; T_b = 4570°; $\Delta H_{tr} = 1.42 \pm 0.1$; $\Delta H_{subl}(298°) = 153.0 \pm 5.0$ based on the work of [35] who measured the vapor pressure of the crystal between 2013° and 2293°.
[7] D(0°) = 334 ±6 for gas; for the reaction $ZrO_2(c) \rightarrow ZrO_2(g)$ $\Delta H(0°)$ = 188.2 (by 2nd law) and 186 ±6 (by 3rd law); a good 2nd law check involving $ZrO_2(g)$, ZrO(g), and O(g) studied in tantalum at approximately 2300°.
[17] Measured the enthalpy of crystal to 1173° (unpublished).
[19] Apparently gives ΔH_m = 20.8.
[27] Langmuir evaporation at 2300°; accommodation coefficient approximately unity.
[10] Crystal, liquid, and gas.
[111] Crystal (α,β).

ZrN, Zr_3N_2	[1]	ZrN crystal measured to 1672° and tabulated to 2000°. Zr_3N_2 crystal measured to 773° and tabulated to 800°.
	[2]	For ZrN T_m = 3255°.
	[23]	Mass spectrometric study of composition of vapors from ZrN which was found to begin decomposing at 2073°; at 2373° P(ZrN) = 10^{-8} atm.
	[10]	Crystal, liquid, and gas.
	[112]	ZrN solid only.
ZrC	[2]	T_m = 3805°.
	[10]	Crystal and liquid.
ZrB_2	[27]	Volatilization studies by Langmuir method at 2300°; accommodation coefficient approximately unity.
	[36]	Studied reactions $ZrB_2(c) \rightleftarrows Zr(g) + 2\beta(g)$; P(Zr) = 2.38 x 10^{-10} atm. at 2000°; ΔH = 458.3 (by 3rd law).
	[10]	Crystal and liquid.
Hf	[1]	Crystal and liquid estimated to 3000°; $\Delta H_m(2495°)$ = 5.79 (estimated); gas estimated to 3000°.
	[8]	Cp estimated above 298°; ΔH_m = 5.20 (estimated); T_b roughly measured as 5400 which is compared to Brewer's estimate of 5500°; $\Delta H_{subl}(298°)$ = 168.0 (estimated); $\Delta H_{vap}(5500°)$ = 158.0 (estimated).
	[37]	Gives $\Delta H_{vap}(5500°)$ = 155.
	[38]	From effusion studies on the reaction $Hf(c) \rightarrow Hf(g)$ obtains ΔH = 142 ±7.
	[39]	Enthalpy of crystal precisely measured to 1346°.
HfF_4	[1]	Crystal estimated to 1500°; gas estimated to 1500°.
	[3]	Estimated thermodynamic properties of the gas.
	[40]	Measured enthalpy to 1200°.
$HfCl_4$	[1]	Crystal measured to 486° and tabulated to 700°; gas estimated to 1500°.
	[6]	T_m = 705° (under pressure); T_{subl} = 590°, $\Delta H_{subl}(298°)$ = 26.0 (estimated).
HfI_4	[1]	Crystal estimated to 800°; gas estimated to 1500°.
	[3]	Estimated thermodynamic properties of the gas.
	[41]	Vapor pressure studies by a metal diaphragm technique.
HfO_2	[1]	HfO_2 crystal measured to 1804° and tabulated to 2000°.
	[4]	For HfO_2 T_m = 3063°.
	[5]	For HfO_2 estimates D(298°) = 360 ±20; free energy functions estimated to 3000°.
HfN	[1]	Crystal estimated to 2000°.
	[2]	Gives T_m = 3580°.
	[42]	Studied the reaction $HfN + C \leftrightarrows HfC + \frac{1}{2}N_2$; gives a 2-constant equation for P(T) in the range 1973° to 2573°.

HfC [1] Crystal estimated to 2000°.
[42] Studied the equilibrium $HfN + C \leftrightarrows HfC + \frac{1}{2}N_2$ in the range 1973° to 2573°; gives a 2-constant equation for P(T).
[43] Manametric study of the reaction $HfO_2 + 2.9\ C \leftrightarrows HfC_{0.95}\ O_{0.05} + 1.95\ CO$ in the range 1200° to 2000°; gives $\Delta H = 132.8$, and $\Delta S = 66$ e.u. for the range 1750° to 2000°.

HfB_2 [38] Effusion study at temperatures above 2000° for the reaction $HfB_2(c) \leftrightarrows Hf(g) + 2B(g)$; gives $\Delta H_0^\circ = 477.8 \pm 5.5$.

Th [1] Crystal and liquid measured to 1474° and tabulated to 3000°; $\Delta H_{tr}(1673°) = 0.67$; $\Delta H_m(1968°) = 4.50$.
[8] $T_{tr} = 1673°$ (observed); $T_m = 1968°$ (observed); $\Delta H_{tr} = 0.67$ (estimated); $\Delta H_m = 3.74$ (estimated); Cp (liquid) was estimated. States that Brewer has calculated T_b as 4500° and $\Delta H_{vap}(4500°)$.
[44] Vapor pressure of the crystal measured in the range 1757° to 1956° by the Langmuir method; gives $\Delta H_{vap}(298°)$ as 137.3 ±2.8 (by 2nd law) and 136.6 ±0.5 (by 3rd law); believes all electronic levels of Th are known up to 10,000 cm^{-1}; the 16 lowest levels raise $-(G^\circ_{2000}-H^\circ_0)/T_{2000}$ by only 0.7 e.u.

ThF_3 [3] Estimated thermodynamic properties of the gas and believes it to be an important species.

ThF_4 [1] Heat capacity of crystal measured at 298°.

ThCℓ [3] Estimated the thermodynamic properties of the gas and believed it to be an important gas species.

$ThCℓ_4$ [6] Gives 2-constant equations for the vapor pressures of the crystal and liquid in the range 974° to 1186°; $T_m = 1038°$, $T_b = 1195°$; $\Delta H_m = 22.5$ (estimated); $\Delta H_{vap}(1195°) = 36.5 \pm 4.0$.

ThI_3 [3] Estimated thermodynamic properties of the gas and believes it might be an important gas species.

ThI_4 [6] Gives a 2-constant equation for the vapor pressure of the liquid in the range 856° to 1107°; $T_m = 839°$; $T_b = 1110°$; $\Delta H_m = 8.0 \pm 1.0$; $\Delta H_{vap}(1110°) = 31.5 \pm 3.0$

$ThOCℓ_2$ [45] The fusion diagram for ThO_2-$ThCℓ_4$ system showed $ThOCℓ_2$ to exist at 980°; for the solid $\Delta Hf° = -295 \pm 2.6$ and $S° = 27 \pm 1.3$ e.u.

ThO [19] T_m greater than 2500°.
[44] For the gas gives D_0 is 196 approximately.

ThO_2 [1] Crystal measured to 1787° and tabulated to 2000°.
[4] $T_m = 3225°$; $T_b = 4670°$; $\Delta H_m = 291.1$.

[5] D(298°) for the gas is 370° ±15; says that vapor pressure data has been published by two sets of investigators, but the assumption had to be made that the vapor contained little ThO(g) in it; free energy functions are tabulated to 3000°.

[6] Gives a 2-constant equation for the vapor pressure of the crystal in the range 2000° to 2800°.

[27] Evaporation studies by the Langmuir method at approximately 2300°; accommodation coefficient approximately unity.

[46] Measured enthalpy of crystal between 1200° and 2750°.

[47] Effusion studies on the vaporization of the crystal in the range 2268° to 2593°; gives an equation for P(T) for $ThO_2(c) \rightarrow ThO_2(g)$.

Th_3N_4 [1] Crystal measured to 773° and tabulated to 800°.

ThC_2 [21] Studied vaporization and thermodynamics.

[48] Studied $ThO_2(c) + 4C(graphite) \leftrightarrows ThC_2(c) + 2CO(g)$.

[49] Effusion pressures involving formation of ThC_2(crystal) in the range 2100° to 2500°.

[50] Studied the thermodynamics and identification of the species from ThC_2 in range 2300° to 2700°.

W [1] Crystal measured to 3655° and tabulated to 3000°; gas tabulated to 3000°.

[6] Vapor pressure of crystal represented by a 4-constant equation in the range 2000° to 3500°; T_m = 3650° (estimated); T_b = 5700° (estimated); ΔH_m = 8.4 (estimated); $\Delta H_{vap}(5700°)$ = 183.0 (estimated).

[8] The enthalpy data on the solid as reported by three investigators are in good agreement and have been extrapolated to 3000°; reports that Brewer lists T_m as 3650° and ΔH_m = 8.42. Vapor pressure measurements have been made by Jones, Langmuir, and Mackay; $\Delta H_{subl}(298°)$ = 200.0; Cp of liquid estimated; T_b = 5800°; $\Delta H_{vap}(5800°)$ = 191.0.

[51] Measured relative enthalpy of crystal in range 2680° to 3100° (following earlier measurements between 600° and 2600°. Claim 1.2% accuracy at highest temperature and say that the values reported by [52] are low by 3 to 9% between 1300° and 2900°.

[53] Measured enthalpy of the crystal between 600° and 2300° and claim an accuracy of ±0.6 to 0.9%.

[114] Solid only.

WF [10] Gas only.

WF_5 [3] Estimated the thermodynamic properties of the gas.

WF_6 [1] Gas tabulated to 1000° (obtained from molecular constant data).

[6] Gives a 3-constant equation for the vapor pressure of the liquid between T_m = 273° and T_b = 290°; $\Delta H_{vap}(290°)$=6.35 ±0.5.

[54] Vapor pressure measured by a static method using a sensitive gauge.

[10] Liquid and gas.

WCl_2 [3] States that gas is stable only at high temperature.
[55] ΔH_{subl} = 102 (estimated); ΔS_{subl} = 43 e.u. (estimated).
[10] Crystal and gas.

WCl_3 [3] Gas is quite unstable and need not be considered.

WCl_4 [3] Gas is unstable with respect to disproportionation, but is present in appreciable concentrations between 1000° and 2000°.
[55] ΔH_{subl} = 39 ±2; ΔS_{subl} = 50 ±2.
[56] For the reaction $WCl_6(g) \rightleftarrows WCl_4(g) + Cl_2(g)$ ΔH = 47 ±2.
[10] Crystal and gas.

WCl_5 [3] States that this is the most important gas specie among the tungsten chlorides.
[6] Gives 2-constant vapor pressure equations for the crystal and liquid between 413° and T_b; T_m = 513°; T_b = 571°; ΔH_m = 4.2 (estimated); $\Delta H_{vap}(571°)$ = 12.6 ±3.0.
[55] ΔH_{subl} = 18.5 ±0.1; ΔS_{subl} = 33.1 ±0.7 e.u.; ΔH_{vap} = 13.6 ±1; ΔS_{vap} = 23.9 ±1 e.u.
[10] Crystal, liquid, and gas.

WCl_6 [6] T_{tr} = 500°; T_m = 553°; T_b = 611°; ΔH_{tr} = 2.2 (estimated), ΔH_m = 4.8 (estimated); $\Delta H_{vap}(611°)$ = 13.9 ±2.0, $\Delta H_{subl}(553°)$ = 18.7 ±3.0; gives vapor pressure equations for crystal (α and β) and liquid in the range 425° to T_b.
[55] Various experimental methods for determining ΔHf and ΔSf. ΔHf disagrees and ΔSf agrees with NBS values.
$\Delta H_{subl}(\alpha)$ = 22.9 ±0.5; $\Delta S_{subl}(\alpha)$ = 38.9 ±0.5
$\Delta H_{subl}(\beta)$ = 17.3 ±0.5; $\Delta S_{subl}(\beta)$ = 28.0 ±0.5
ΔH_{vap} = 14.5 ±0.5; ΔS_{vap} = 23.2 ±0.5
[56] For the reaction $WCl_6(g) = WCl_5(g) + \frac{1}{2} Cl_2(g)$; ΔH = 24 ±1; and for $2WOCl_4(g) = WCl_6 + WO_2Cl_2$, ΔH = 11 ±2.
[10] Crystal, liquid, and gas.

WOF_4 [54] Vapor pressure measured by a static method using a sensitive gauge.
[10] Crystal, liquid, and gas.

$WOCl_4$, WO_2Cl_2 [6] For $WOCl_4$: T_m = 477°; T_b = 493°; $\Delta H_{vap}(493°)$ = 11.5 ±2.0.
[55] For $WOCl_4$: ΔH_{subl} = 18.3 ±0.5; ΔS_{subl} = 36.3 ±0.5
ΔH_{vap} = 16.3 ±0.5; ΔS_{vap} = 32.8 ±0.5.
For WO_2Cl_2: ΔH_{subl} = 21 ±2; ΔS_{subl} = 29 ±2.
[56] For the reaction $2WOCl_4(g) = WCl_6(g) + WO_2Cl_2(g)$. ΔH = 11 ±2.
[10] $WOCl_4$ crystal and gas. WO_2Cl_2 crystal and gas.

WO [58] Using mass spectroscopic data obtains D_0 as 154 ±10 for the gas by a 3rd law treatment.
[10] Gas only.

WO_2

[5] Gives D(298°) = 307 ±10 for the gas. For the reaction $W(c) + O_2(g) = WO_2(g)$ gives $\Delta H(298°) = 9.3$ (based on data of [59]) and $\Delta H(298°) = 12.4$ (based on data of [58a,b]). Free-energy functions estimated to 3000°.
For the gas gives $D_0 = 296 \pm 7$ (based on [58]) and $D_0 = 313 \pm 10$ (based on [59]).
[19] Gives $T_m = 1543°$; $T_{decomp} = 2125°$; $\Delta H_m = 11.5$.
[60] Estimates free energy of formation between 973° and 1493°.
[61] WO_2 crystal disproportionates to WO_3 (P = 1 atm.) at 2000°.
[10] Crystal and gas.
[115] Solid only.

W_3O_8, $W_{18}O_{49}$

[60] Standard heat of formation of $W_{18}O_{49}$. Phase diagram of tungsten-oxygen system.

WO_3

[1] Cp of crystal measured at 298° and estimated to 1746°.
[6] Gives a 2-constant equation for the vapor pressure of the crystal between 1000° and T_m; $T_{tr} = 993°$; $T_m = 1746°$; $\Delta H_{subl}(298°) = 122$ (estimated).
[19] T_b is greater than 2500°.
[58] From mass spectroscopic data obtains $\Delta H_0^\circ = 443 \pm 7$ (3rd law) for the reaction: $WO_3(g) \rightarrow W(g) + 3O(g)$.
[60] Gives free energy of formation of the crystal in the range 973° to 1493°.
[61] Says the pressure of oxygen over WO_3 at 2000° is negligible.
[62] From mass spectroscopic data gives: $3WO_3(c) \rightarrow W_3O_9(g)$, $\Delta H(1400°) = -130 \pm 2$ (2nd law); $4WO_3(c) \rightarrow W_4O_{12}(g)$, $\Delta H(1400°) = -151$ (2nd law).
[63] Gives $\Delta H_{298}^\circ(WO_{2.90},c) = -191$; $\Delta S_{298}^\circ = 24$ e.u.
[64] Investigated the sublimation behavior of the tungsten oxygen system in the range 1300° to 1600° by mass effusion, mass spectroscopy, chemical analyses, and X-ray diffraction. In all cases the thermodynamically important vapor species are W_4O_{12}, W_3O_9, W_3O_8, W_2O_6. In contrast to [62] obtains: $3WO_3(c) \rightarrow W_3O_9(g)$, $\Delta H^\circ = -107.5 \pm 2.3$; $4WO_3(c) \rightarrow W_4O_{12}(g)$, $\Delta H^\circ = -123.6 \pm 2.2$.
[10] WO_3 crystal, liquid, and gas; $(WO_3)_3$, gas only; $(WO_3)_4$, gas only.
[116] Crystal (α,β) and liquid.

H_2WO_4

[65] Studied $WO_3 - H_2O - H_2$(0-1 atm) system.
[66] Studied the volatilization of tungsten in the presence of water vapor to form H_2WO_4; gives the standard free energy of the reaction $W(s) + 4H_2O(g) \rightarrow H_2WO_4(g) + 3H_2(g)$.
[10] Crystal and gas.

W_2C, WC

[2] WC crystal decomposes at 2900°.
[37] Gives linear equation for Cp(T) in the range 298° to 2000°.
[67] Equilibrium studies on the reduction of $W_2C(c)$ and $WC(c)$ with hydrogen, and the formation of these carbides from W(c) and C(c) at approximately 1000°; $\Delta G°(T)$ equations are given.
[68] For the reaction $WC + CO_2 = W + 2CO$, gives $\Delta G(1215°-1266°) = -8.34 \pm 0.3$.

U

[1] Crystal and liquid measured to 1277° and tabulated to 3000°; $\Delta H_{tr}(935°) = 0.70$; $\Delta H_{tr}(1045°) = 1.145$; $\Delta H_m(1406°) = 3.25$. Gas tabulated to 3000° using spectroscopic data.

[4] Gives $T_b = 3800°$ and $\Delta H_{vap}(3800°) = 110$.

[6] Gives a 2-constant vapor pressure equation for the liquid in the range 1630° to 1970°. Confirm transition temperatures of [1]; $T_m = 1403°$; $\Delta H_m = 3.0 \pm 0.7$ (estimated). $\Delta H_{subl}(298°) = 115.7 \pm 3.0$

[8] $T_m = 1406° \pm 2°$ well established by three investigations. Heat capacity of liquid estimated to be the same as the solid at its melting point. From vapor pressure data calculated $\Delta H_{subl}(298°) = 117.16$, $\Delta H_m = 3.70$, $T_b = 4200°$, and $\Delta H_{vap}(4200°) = 101$.

UF_3

[2] Estimates $T_m = 1700°$; $T_b = 2550°$; $\Delta H_m = 8.5$; and $\Delta H_{vap}(2550°) = 61$.

UF_4

[1] Crystal measured at 298°.

[2] Gives $T_m = 1309°$; $T_b = 1690°$; $\Delta H_m = 5.7$; $\Delta H_{vap}(1690°) = 57.5$.

[69] Mass spectroscopic studies; vapor pressure equation in range 917° to 1041°; $\Delta H_{subl} = 71.45 \pm 1.05$.

[70] Gives a 3-constant equation for the vapor pressure of the liquid in the range 1291° to 1575°; $T_b = 1729°$, $\Delta S_{vap}(1729°) = 29.7$ e.u. Says vapor phase consists of non-associated molecules.

[71] Vapor pressure measured by a dynamic method in the range 1048° to 1273°. Gives two equations for vapor pressure within this range of temperatures.

UF_5, U_2F_9, U_4F_{17}

[72] Estimated $T_m = 600°$, $T_b = 1000°$, $\Delta H_m = 8.0$, and $\Delta H_{vap}(1000°) = 23$.

[73] Observed $T_m = 621°$, $\Delta H_m = 11.9 \pm 4.2$, $\Delta H_{vap} = 24.7 \pm 3.8$.

[74] The equilibrium disproportionation pressures of UF_6 over the following compounds in the indicated temperature ranges were measured: α-UF_5(373°-473°), β-UF_5(373°-525°), U_2F_9(498°-593°), and U_4F_{17}(543°-623°). $T_{tr} = 398°$ (α to β UF_5).

UF_6

[1] Crystal and liquid measured to 373°; $\overline{C}p(c,\ell)$ given in range 298° to 370°; $\Delta H_m(337.2°) = 4.59$. Gas tabulated to 1000° based on vibration spectrum studies.

[6] Gives an equation for the vapor pressure of the crystal between 273° and $T_{subl}(330°)$; $T_m = 337°$ (under pressure); $\Delta H_m = 4.59 \pm 0.05$; $\Delta H_{subl}(298°) = 11.85 \pm 0.1$.

[75] $\Delta H_{subl}(0°) = 12.965$.

UCl_3

[1] Crystal measured to 998°, and tabulated to 1000°.

[72] Gives $T_m = 1108$; $T_b = 2000°$; $\Delta H_m = 9.0$; $\Delta H_{vap}(2000°) = 41$.

UCl_4 [1] Crystal measured to 698° and tabulated to 700°.
[72] Gave T_m = 863°; T_b = 1060°; ΔH_m = 10.3; $\Delta H_{vap}(1060°)$ = 33.
[76] Cp of solid and liquid measured; ΔH_m = 11.938 ±0.022.
[77] Determination of thermodynamic properties of liquid from emf measurements. (No data in reference.)
[78] Determination of ΔH_m and ΔS_m. (No data in reference.)
[79] Vapor pressure measurements by transpiration method.

UCl_5 [72] Gave T_m = 600°; T_b = 800°; ΔH_m = 8.5; $\Delta H_{vap}(1800°)$ = 18.0 (estimated).

UCl_6 [72] Gave T_m = 452°; T_b = 550°; ΔH_m = 5.0 (estimated); $\Delta H_{vap}(550°)$ = 11.0 (estimated).
[79] Vapor pressure measured by transpiration method.

UI_3 [72] Estimated the following: T_m = 1030°; T_b = 1700°; ΔH_m = 7.5; $\Delta H_{vap}(1700°)$ = 40.8
[80] Studied the reaction $UI_4 \leftrightarrows UI_3 + \frac{1}{2}I_2$ in range 1097° to 1176° by the method of freezing the equilibrium states with subsequent analysis of the dissociation products. $\Delta Hf(1136°)$ = 5.2 ±0.7.

UI_4 [72] Gave T_m = 779°; T_b = 1032°; ΔH_m = 15.0; $\Delta H_{vap}(1032°)$ = 30.7.
[76] Measured Cp of solid measured in the range 380° to 723°; $\Delta H_{tr}(726°-778°)$ = 3.526 ±0.06; ΔH_m = 5.637 ±0.1.
[80] (See UI_3).

UO_2F_2 [1] Crystal measured to 425°; Cp tabulated 298° to 425°.

$UOCl_2$ [1] Cp of crystal measured at 298°.

UO_2Cl_2 [1] Cp of crystal measured at 298° only.

UO [81] Using mass spectroscopic studies on the reaction $2UO(g) \rightarrow U(c) + UO_2(g)$ obtained $\Delta H(0°)$ = 4.4 (by 2nd law).
[82] Vaporization studies for the reaction $UO_2(c) + US(c) \leftrightarrows UO(g) + UOS(g)$.

UO_2 [1] Crystal measured to 1463° and tabulated to 2000°.
[4] T_m = 3000° ±200.
[5] For $UO_2(g)$ gives D(298°) = 354 ±15. Three sets of data on the crystal gave $\Delta H_{vap}(298°)$ = 143.1 (by 2nd law), 148.9 (by 3rd law), and 157 (from mass spectroscopy studies). The above value of the dissociation energy was based on $\Delta H_{vap}(298)$ = 149. Free energy functions were estimated to 3000°.
[6] T_m = 2770° (estimated); $\Delta H_{subl}(298°)$ = 149.0 ±6.0.
[81] Mass spectroscopic studies of reactions involving UO(g), $UO_2(c,g)$, and $UO_3(g)$.
[83] Enthalpy of crystal measured to 1373°.
[84] T_m = 2973°.
[85] The heat capacity of UO_2 was measured in the range 433° to 876° by direct heating with the continuous addition of heat.

[89] Vapor-solid equilibrium studies for U-O system.
[90] Review of literature on phase diagram of UO_2-O system.

UO_3 [1] Crystal measured to 886° and tabulated to 1000°.
[2] Crystal decomposes at 925°.
[81] By mass spectrometric studies obtained $\Delta H_0 = 28$ (by 2nd law) for the reaction $2UO_2(g) \rightarrow UO(g) + UO_3(g)$.
[85] Measured the heat capacity in the range 392° to 673° by direct heating with the continuous addition of heat.
[91] Infrared spectrum, thermal stability, and other properties of the U_3O_8-UO_3 system are discussed.

UN [2] Gave $T_m = 2900°$ for UN.
[84] Gave $T_m = 2753° \pm 50°$ for UN.
[92] Gave an equation for P_{N_2} over crystalline UN for the range 1406° to 3125°.

U_3O_8, U_4O_9, UO [1] U_3O_8 crystal measured from 275° to 315°; $\overline{C}p$ given. Cp of U_4O_9 crystal measured at 298°.
[2] Crystalline U_3O_8 decomposes at 1950°.
[85] The heat capacity of U_3O_8 was measured. Two equations for Cp(T) cover the ranges 373° to 593° and 673° to 873°.
[86] Enthalpy of U_3O_8 measured by drop calorimetry in the range 523° to 1248°.
[87] Equilibrium pressure of oxygen for U-O system measured tensimetrically between 1273° and 1723°. Calculated thermodynamic functions for all phases between UO_2 and U_3O_8 are presented.
[88] Studied the equilibrium of uranium oxides between 1473° and 2073°. At high temperatures the solid solution $UO_{2.25}$ (or U_4O_9) is stable. The existence of two phases in the region of composition O/U = 2.25 -2.60 was confirmed by X-rays. At temperatures between 1400° and 2000° gave an equation for P_{O_2} for the decomposition $UO_{2.60} \rightarrow UO_{2.25} + 7/40\ O_2$ and gave $\Delta H°$, $\Delta G°$ and $\Delta S°$ for this reaction.

UC, U_2C_3, UC_2, UC_x [72] Gave the following melting points: UC(2550°), U_2C_3(2700°), and UC_2(2700°)
[84] $T_m = 2553° \pm 50°$ for UC.
[93] An effusion study of the decomposition $UC_{1.86}(c) = U(g) + 1.86\ C(graphite)$ in the range 1930° to 2365°; $\Delta H^\circ_{298} = 140.15 \pm 1.82$.
[94] Gave enthalpy of UC_2 between 1484° and 2581°.
[95] Modified Langmuir equilibrium study on $UC_{1.1}(c) = U(g) + 1.1\ C(graphite)$ around 2450°; $P_U(T)$ and $P_C(T)$ are given.

Hg [1] Liquid measured to 773° and tabulated to T_b(629.9°); $\Delta H_{vap}(629.9°) = 14.14$.
[6] Gave an equation for the vapor pressure of the liquid between 298° and T_b.
[8] Enthalpy and heat capacity of crystal and liquid taken from [96,97]. $T_b = 629.88°$; $\Delta H_{vap}(629.88°) = 14.137$; $\Delta H_{vap}(298°) = 14.652$. [98] gave $\Delta H_{vap}(T_b) = 13.595 \pm 0.023$ and claims a much larger gas imperfection than derived by [96].

[9] Gives $D_0 = 1.38 \pm 0.07$ for Hg_2.
[10] Liquid and gas.

HgH [1] Gas tabulated to 2000°K and based on molecular constant data.
[10] Gas only.

HgF [1] Based on molecular constant data tabulated gas to 2000°.
[10] Gas only.

HgF_2 [10] Crystal, liquid and gas.

HgCℓ [1] Crystal estimated to 798°. Gas tabulated to 2000° based on molecular constant data.
[9] Gave $D_0 = 25 \pm 7$.
[10] Gas only.

$HgCℓ_2$ [1] Crystal estimated to 550°. Gas tabulated to 1000° based on molecular constant data.
[6] Gave an equation for the vapor pressure of the crystal in the range 298° to T_m(550°).
[10] Crystal, liquid, and gas.

HgI [1] Crystal estimated to 563°. Gas tabulated to 2000° based on molecular constant data.
[9] $D_0 = 6.9 \pm 1$ but could be higher.
[10] Gas only.

HgI_2 [1] Crystal and liquid measured and tabulated to 600°; $\Delta H_{tr}(403°) = 0.65$; $\Delta H_m(523°) = 4.50$. Gas tabulated to 1000° from molecular constant data.
[6] Gave equations for the vapor pressure of crystal and liquid over the range 298° to T_b(627°); $T_{tr} = 403°$; $T_m = 523°$; $T_b = 627°$; $\Delta H_{tr} = 0.65 \pm 0.1$; $\Delta H_m = 45 \pm 0.5$; $\Delta H_{vap}(627°) = 14.3 \pm 0.5$; $\Delta H_{\alpha\text{-subl}}(298°) = 21.8$.
[10] Crystal, liquid, and gas.

Pb, Pb_2 [1] Crystal and liquid measured to 1273°, and tabulated to 2000°; $\Delta H_m(600.6°) = 1.14$. Pb(gas) tabulated to 3000° and Pb_2(gas) tabulated to 2000° (both based on molecular constant data).
[6] Gave an equation for the vapor pressure of the liquid between T_m(600°) and T_b(2013°); $\Delta H_m = 1.15 \pm 0.03$; $\Delta H_{vap}(2013°) = 42.5 \pm 0.5$; $\Delta H_{subl}(298°) = 46.9 \pm 0.7$.
[8] Gives thirteen references to vapor pressure measurements, six of which are thought to be too high. Adopted $\Delta H_{subl}(298°) = 42.80$; $T_b = 2024°$; $\Delta H_{vap}(2024°) = 42.88$.
[9] Gave $D_0 = 14 \pm 5$.
[10] Pb crystal, liquid, and gas. Pb_2 gas only.
[117] Crystal and liquid.

PbH [1] From molecular constant data tabulated gas to 2000°.
[9] Gave $D_0 = 41 \pm 5$.
[10] Gas only.

PbF [1] From molecular constant data tabulated the gas to 2000°.
[10] Gas.

PbF_2 [1] Crystal measured to 307° and estimated to 1097°.
[6] Gives an equation for the vapor pressure of the liquid between T_m(1097°) and T_b(1566°). For the crystal lists T_{tr} = 523°; ΔH_m = 1.9 (estimated); ΔH_{vap}(1566°) = 38.3 ±3.0.
[10] Crystal, liquid, and gas.

PbF_4 [2] Lists a few values of the thermodynamic properties.
[10] Gas only.

PbCℓ [1] Based on molecular constant data, the properties of the gas have been tabulated to 2000°.
[9] Gives D_0 = 60 ±9.
[10] Gas only.

$PbCℓ_2$ [1] Crystal and liquid measured to 1073° and tabulated to 1000°; ΔH_m(771°) = 5.80.
[6] Presents equation for the vapor pressure of the crystal and liquid between 298° and T_b. T_m = 771°; T_b = 1225°; ΔH_m = 5.8 ±0.3; ΔH_{subl}(298°) = 45.0 ±1.5; ΔH_{vap}(1225°) = 30.3 ±1.2.
[10] Crystal, liquid, and gas.

$PbCℓ_4$ [10] Gas only.

PbI [1] Gas tabulated to 2000° based on molecular constant data.
[10] Gas only.

PbI_2 [1] Crystal and liquid measured to 776° and tabulated to 1000°; ΔH_m(685°) = 6.01.
[6] Gives equation for the vapor pressure of the crystal and liquid between 298° and T_b; T_m = 685°; T_b = 1145°; ΔH_m = 6.0 ±0.6; ΔH_{subl}(298) = 41.2 ±1.5; ΔH_{vap}(1145°) = 24.6 ±1.0.
[10] Crystal, liquid, and gas.

PbI_4 [10] Gas only.

PbO [1] Crystal (red) measured to 823° and tabulated to 900°. Crystal (yellow) measured to 923° and tabulated to T_m(1159°); ΔH_m(1159°) = 7.00. Liquid tabulated to 1500°. Gas tabulated to 2000° (based on calculations with molecular constant data.
[6] Gives equations for the vapor pressures of the crystal and liquid in the range 298° to T_b (not given); T_m = 1159°; ΔH_m = 6.2 ±0.6; ΔH_{subl}(298°) = 65.6 ±5.0.
[9] For the gas D_0 = 76 ±9 (linear Birge-Sponer extrapolation).
[99] Measured the vapor pressure in the range 887° to 1151°; gave a 2-constant equation for the vapor pressure in this range.
[100] Studied the vapor pressure and gave a 2-constant equation for the range 887° to 1043°; ΔH_{subl}(0°) = 63.98.

[101] Studied the dissociation energies of $(PbO)_n$ (n = 1,2,3,4). (No data in reference.)
[10] Crystal (red), crystal (yellow), liquid, and gas.
[118] Crystal (yellow) and liquid.

Pb_2O_3, Pb_3O_4
[1] Heat capacity of Pb_2O_3(c) and Pb_3O_4(c) measured at 298°.
[10] Pb_3O_4 crystal only.

PbO_2
[1] Crystal measured to 542° and estimated to 1000°.
[10] Crystal only.

References

[1] K. K. Kelley, U. S. Bur. of Mines, Bull. 584, 232 pp (1960).

[2] L. Brewer, L. A. Bromley, P. W. Gilles, and N. L. Lofgren, Paper 6 in National Nuclear Energy Series IV, Vol. 19B, Chemistry and Metallurgy of Miscellaneous Materials: Thermodynamics, L. L. Quill (Ed.), McGraw-Hill Book Co., Inc., New York, 1950, p 76.

[3] L. Brewer. Paper 7 in National Nuclear Energy Series IV, Vol. 19B, Chemistry and Metallurgy of Miscellaneous Materials: Thermodynamics, L. L. Quill (Ed.), McGraw-Hill Book Co., Inc., New York, 1950, p 193.

[4] L. Brewer, Chem. Rev. 52, 1 (1953).

[5] L. Brewer and G. M. Rosenblatt, Chem. Rev. 61, 257 (1961).

[6] O. Kubaschewski and E. L. Evans, International Series of Monographs on Metal Physics and Physical Metallurgy, Vol. 1, 3rd ed., Metallurgical Thermochemistry, G. V. Raynor (Ed.), Pergamon Press, New York, 1958, 426 pp.

[7] M. G. Inghram and J. Drowart, Article in the International Symposium on High Temperature Technology. McGraw-Hill Book Co., Inc., New York, 1960, p 219.

[8] D. R. Stull and G. C. Sinke, Advances in Chemistry Series, Vol. 18, Thermodynamic Properties of the Elements. American Chemical Society, Washington, D. C., 1956, 234 pp.

[9] A. G. Gaydon, Dissociation Energies and Spectra of Diatomic Molecules, Chapman and Hall Ltd., London, 1947, 230 pp.

[10] JANAF Thermochemical Tables, The Dow Chemical Company, Midland, Mich., 1960 with quarterly supplements.

[11] J. W. Edwards, H. L. Johnston, and W. E. Ditmars, J. Am. Chem. Soc. 75, 2467 (1953).

[12] J. Morrison, Natl. Symposium Vacuum Technol. Trans. 1959, 291 (Pub. 1960).

[13] T. Ishino, H. Tamura, and O. Nakagawa, Kogyo Kagaku Zasshi 64, 1344 (1961).

[14] K. Funaki, K. Uchimura, and H. Matsunaga, Kogyo Kagaku Zasshi 64, 129 (1961.

[15] National Bureau of Standards, Selected Values of Chemical Thermodynamic Properties, Ser. III, 1956.

[16] J. Berkowitz, W. A. Chupka, and M. G. Inghram, J. Phys. Chem. 61, 1569 (1957).

[17] A. C. Victor and T. B. Douglas, Bull. of Thermodynamics and Thermochemistry, No. 7, IUPAC, 1964, p 62.

[18] D. Papousek, Trans. Faraday Soc. 57, 884 (1961).

[19] A. Glassner, U.S. AEC ANL-5750, 70 pp (1957).

[20] V. A. Reznichenko, F. B. Khalimov, and T. P. Ukolova, Titan i ego Splavy, Akad. Nauk S.S.S.R., Inst. Met. 1963, No. 9, 42.

[21] R. A. Kent, Diss. Absts. 25, 89 (1964).

[22] L. H. Dreger, Diss. Absts. 22, 3423 (1962).

[23] P. A. Akishin and Yu. S. Khodeev, Zhur. Neorg. Khim. 7, 941 (1962).

[24] A. Adachi, K. Mizukawa, and K. Kanda, Technol. Rept. Osaka Univ. 12, 419 (1962).

[25] K. I. Portnoi and Yu. V. Levinskii, Zhur. Fiz. Khim. 37, 2627 (1963).

[26] W. A. Chupka, J. Berkowitz, C. F. Giese, and M. G. Inghram, J. Phys. Chem. 62, 611 (1958).

[27] E. G. Wolff and C. B. Alcock, Trans. Brit. Ceram. Soc. 61, 667 (1962).

[28] P. O. Schissel and O. C. Trulson, J. Phys. Chem. 66, 1492 (1962).

[29] G. Skinner and H. L. Johnson, Bull. of Thermodynamics and Thermochemistry, No. 7, IUPAC, 1964, p 64.

[30] N. P. Galkin, Yu. N. Tumanov, V. I. Tarasov, and Yu. D. Shishkov, Zhur. Neorg. Khim. 8, 2021 (1963).

[31] D. L. Hildenbrand and L. P. Thread, U. S. Dept. Comm., Office Tech. Serv., AD-258,410, 24 pp (1961).

[32] R. A. McDonald, G. C. Sinke, and D. R. Stull, J. Chem. Eng. Data 7, 83 (1962).

[33] J. K. Wilmshurst, J. Mol. Spectroscopy 5, 343 (1960).

[34] W. A. Chupka, J. Berkowitz, and M. G. Inghram, J. Chem. Phys. 26, 1207 (1957).

[35] M. Hoch, N. Nakata, and H. L. Johnston, J. Am. Chem. Soc. 76, 2651 (1954).

[36] J. M. Leitnaker and W. G. Witteman, J. Chem. Phys. 36, 1445 (1962).

[37] C. E. Wicks and F. E. Block, U.S. Bur. Mines, Bull. 605, 146 pp (1963).

[38] M. C. Krupka, U.S. AEC LA-2611, 137 pp (1962).

[39] D. T. Hawkins, M. Onillon, and R. L. Orr, J. Chem. Eng. Data 8, 628 (1963).

[40] C. E. Kaylor, G. E. Walden, and D. F. Smith, J. Am. Chem. Soc. 81, 4172 (1959).

[41] F. D. Stevenson, Diss. Absts. 23, 5610 (1963).

[42] K. I. Portnoi and Yu. V. Levinskii, Zhur. Fiz. Khim. 37, 2467 (1963).

[43] V.P.I. Zhelankin, V. S. Kutsev, and B. F. Ormont, Zhur. Fiz. Khim. 35, 2608 (1961).

[44] A. J. Darnell, W. A. McCollum, and T. A. Milne, J. Phys. Chem. 64, 341 (1960).

[45] K.-F. Yen, S.-C. Li, and G. I. Novikov, Zhur. Neorg. Khim. 8, 89 (1963).

[46] M. Hoch and H. L. Johnston, Bull. of Thermodynamics and Thermochemistry, No. 7, IUPAC, 63 (1964).

[47] A. G. Darnell and W. A. McCollum, U.S. AEC NAA-SR-6498, 18 pp, (1961).

[48] N. W. Gregory, Bull. of Thermodynamics and Thermochemistry, No. 7, IUPAC, 94 (1964).

[49] H. A. Eick, Bull. of Thermodynamics and Thermochemistry, No. 7, IUPAC, 89 (1964).

[50] U. Merten, J. Norman, H. Lonsdale, W. E. Bell, P. Winchell, H. Staley, M. Tagami, J. Graves, R. Inyard, and M. Kirkbride, Bull. of Thermodynamics and Thermochemistry, No. 6, IUPAC, 77 (1963).

[51] V. A. Kirillin, A. E. Sheindlin, V. Ya. Chekhovskoi, and V. A. Petrov, Zhur. Fiz. Khim. 37, 2249 (1963).

[52] M. Hoch and H. L. Johnston, J. Phys. Chem. 65, 855 (1961).

[53] V. Ya. Chekhovskoi, B. Ya. Shumyatskii, and K. A. Yakimovich, Inzhener. Fiz. Zhur., Akad. Nauk Belorus. S.S.R. 5, No. 6, 43 (1962).

[54] G. H. Cady and G. B. Hargreaves, J. Chem. Soc. 1961, 1563.

[55] S. A. Shchukarev, G. I. Novikov, I. V. Vasil'kova, A. V. Suvorov, N. V. Andreeva, B. N. Sharupin, and A. K. Baev, Zhur. Neorg. Khim. 5, 1650 (1960).

[56] S. A. Shchukarev and A. V. Suvorov, Zhur. Neorg. Khim. 6, 1488 (1961).

[57] J. Drowart, G. Demaria, R. P. Burns, and M. G. Inghram, J. Chem. Phys. 32, 1366 (1960).

[58] G. DeMaria, R. P. Burns, J. Drowart, and M. G. Inghram, J. Chem. Phys. 32, 1373 (1960).

[59] W. A. Chupka, J. Berkowitz, and C. F. Giese, J. Chem. Phys. 30, 827 (1959).

[60] G. R. St. Pierre, W. T. Ebihara, M. J. Pool, and R. Speiser, Trans. AIME 224, 259 (1962).

[61] E. G. King, W. W. Weller, and A. V. Christensen, Jr., U.S. Bur. of Mines, Rept. Invest. 5664, 27 pp (1960)

[62] J. Berkowitz, W. A. Chupka, and M. G. Inghram, J. Chem. Phys. 27, 85 (1957).

[63] J. Bousquet and G. Perachon, Compt. rend. 256, 694 (1963).

[64] R. J. Ackermann and E. G. Rauh, J. Phys. Chem. 67, 2596 (1963).

[65] O. Glemser and H. Ackerman, Z. anorg. u. allgem. Chem. 325, 281 (1963).

[66] G. R. Belton and R. L. McCarron, J. Phys. Chem. 68, 1852 (1964).

[67] V. I. Alekseev and L. A. Shvartsman, Izvest. Akad. Nauk S.S.S.R., Otdel, Tekh. Nauk, Met. i Gorn. Delo 1963, No. 1, 91.

[68] M. Gleiser and J. Chipman, Trans. AIME 224, 1278 (1962).

[69] P. A. Akishin and Yu. S. Khodeev. Zhur. Fiz. Khim. 35, 1169 (1961).

[70] S. Langer and F. F. Blankenship, J. Inorg. Nuclear Chem. 14, 26 (1960(.

[71] M. M. Popov, F. A. Kostylev, and N. V. Zubova, Zhur. Neorg. Khim. 4, 1708 (1959).

[72] L. Brewer, L. A. Bromley, P. W. Gilles, and N. L. Lofgren, U.S. AEC, MDDC-1543, 84 pp (1945).

[73] A. S. Wolf, J. C. Posey, and K. E. Rapp, U.S. AEC, K-1448, 21 pp (1960).

[74] P. A. Agron, U.S. AEC, TID-5290, book 2, 610 (1958).

[75] B. Weinstock, E. E. Weaver, and J. G. Malin, J. Inorg. Nuclear Chem. 11, 104 (1959).

[76] M. M. Popov, G. L. Gal'chenko and M. D. Senin, Zhur. Neorg. Khim. 4, 1241 (1959).

[77] A. Kisza, Bull. Thermodynamics and Thermochemistry, No. 7, IUPAC, 15 (1964).

[78] W. Trzebiatwoski and A. Bogacz, Bull. Thermodynamics and Thermochemistry, No. 7, IUPAC, 114 (1964).

[79] O. Johnson, T. Butler, and A. S. Newton, U.S. AEC, TID-5290, book 1, 1 (1958).

[80] M. M. Popov and M. D. Senin, Zhur. Neorg. Khim 2, 1479 (1957).

[81] W. A. Chupka, Argonne National Laboratory Rept. 5786, 73 (1957).

[82] R. J. Thorn, R. J. Ackermann, E. D. Carter, H. A. Eick, R. Faircloth, E. Plante, and E. G. Rauh, Bull. Thermodynamics and Thermochemistry, No. 6, IUPAC, 73 (1963).

[83] A. Cabbage, F. H. Welsh, and J. B. Trice, U. S. Dept. Comm., Office Tech. Serv., RB Rept. 162,012, 11 pp (1949).

[84] H. W. Newkirk, Jr. and J. L. Bates, U.S. AEC, HW-59468, 5 pp (1959).

[85] M. M. Popov, G. L. Gal'chenko, and M. D. Sevin, Zhur. Neorg. Khim. 3, 1734 (1958).

[86] H. Powers, F. Welch, and J. B. Trice, U. S. Dept. Comm., Office Tech. Serv., PB Rept. 162,011, 16 pp (1949).

[87] L. E. Roberts and A. J. Walter, J. Inorg. Nuclear Chem. 22, 213 (1961).

[88] A. M. Anthony, R. Kiyoura, and T. Sata, Comp. rend. 255, 1606 (1962).

[89] C. A. Alexander, Diss. Absts. 22, 3864 (1962).

[90] C. A. Alexander and T. S. Shevlin, U.S. AEC, TID-7622, 139 (1962).

[91] H. R. Hoekstra and S. Siegel, J. Inorg. Nuclear Chem. 18, 154 (1961).

[92] W. M. Olson and R. N. R. Mulford, J. Phys. Chem. 67, 952 (1963).

[93] J. M. Leitnaker and W. G. Witteman, J. Chem. Phys. 36, 1445 (1962).

[94] L. S. Levinson, J. Chem. Phys. 38, 2105 (1963).

[95] P. A. Vozzella, A. D. Miller, and M. A. DeCrescente, U.S. AEC, PWAC-378, 51 pp (1962).

[96] R. H. Busey and W. F. Giauque, J. Am. Chem. Soc. 75, 806 (1953).

[97] T. B. Douglas, A. F. Ball, and D. C. Ginnings, J. Res. Natl. Bur. Standards 46, 334 (1951).

[98] A. F. Beale, Diss. Absts. 13, 295 (1953).

[99] A. P. Belykh and An. A. Nesmeyanov, Fiz.-Khim. Osnovy Proizv. Stali, Akad. Nauk S.S.S.R., Inst. Met., Tr. 5-oi [Pyatoi] Konf. 1959, 342 (Publ. 1961).

[100] A. N. Nesmeyanov, L. P. Firsova, and E. P. Isakova, Zhur. Fiz. Khim. 34, 1200 (1960).

[101] J. Drowart and P. Goldfinger, Bull. Thermodynamics and Thermochemistry, No. 7, IUPAC, 1 (1964).

[102] Preliminary Report on the Thermodynamic Properties of Selected Light-Element Compounds, Natl. Bur. Standards Rept. 6645, (January 1960, amended April 1960). Table 2-32.

[103] Preliminary Report on the Thermodynamic Properties of Selected Light-Element Compounds. Natl. Bur. Standards Rept. 6928, (July 1960). Table B-38.

[104] Ibid. Table B-40.

[105] Preliminary Report on the Thermodynamic Properties of Selected Light-Element Compounds, Natl. Bur. Standards Rept. 7093, (January 1961), p 231.

[106] Ibid. p 233.

[107] Ibid. p 235.

[108] Ibid. p 237.

[109] Ibid. p 239.

[110] Ibid. p 241.

[111] Ibid. p 248.

[112] Ibid. p 250.

[113] Ibid. p 252.

[114] Preliminary Report on the Thermodynamic Properties of Selected Light-Element Compounds, Natl. Bur. Standards Rept. 7587, (July 1962), p 137.

[115] Ibid. p 139.

[116] Ibid. p 141.

[117] Ibid. p 156.

[118] Ibid. p 158.

[119] Preliminary Report on the Thermodynamic Properties of Selected Light-Element Compounds, Natl. Bur. Standards Rept. 8186, (January 1964), p 154.

[120] Ibid. p 156.

Chapter B2

A LITERATURE SURVEY OF THE HIGH-TEMPERATURE THERMODYNAMIC PROPERTIES OF BARIUM, CALCIUM, CHROMIUM, AND IRON AND THEIR COMPOUNDS WITH LIGHT ELEMENTS

by H. W. Flieger, Jr.

Introduction

Iron and chromium have some importance as minor components of certain chemical-rocket systems. Calcium and barium (together with the alkali metals, which have been reviewed more extensively elsewhere) have relatively low first ionization potentials, and so, if present in small amounts, even as impurities, can contribute significantly to the free-electron concentration at high temperatures.

The present chapter constitutes a non-critical, fairly up-to-date literature survey (from approximately 1940 through 1964) of the high-temperature thermodynamic properties of barium, calcium, chromium, and iron and their important light-element compounds, and of a scope very similar to that of Chapter B1 for certain other heavy metals and their compounds. The survey covers and is limited to Ba, Ca, Cr, Fe, and their hydrides, oxides, fluorides, chlorides, nitrides, carbides, borides, borates, and aluminates. Information was found and is included for a few compounds containing more than one of the elements O, F, and Cl; but condensed-phase O-H compounds were omitted because of their instability at temperatures above a few hundred degrees. The properties covered are the same as in Chapter B1: high-temperature enthalpy, heat capacity, heats and temperatures of phase changes, vaporization equilibria -- and also gas dissociation energies. Omitted in general are low-temperature and reaction calorimetry, as well as absorption and emission spectroscopy. Unless otherwise stated, temperatures are given in deg K and heats in kcal per gram-formula-weight.

No claim can be made for complete literature coverage. The sources examined systematically were the chemical formula-property indices for the past several years in Annual Review of Physical Chemistry and The Bulletin of Thermodynamics and Thermochemistry (through the 1964 issues). An additional source examined systematically was the files, on published thermodynamic properties of all inorganic substances, maintained in the Thermochemistry Section of the National Bureau of Standards. It is estimated that these files covered the published literature up to October or November 1964 at the time that the present survey was made. There is a number of excellent compilations which were not specifically included here but which may be consulted for the earlier literature (see particularly references [1], [2], [3], [6], [7], [8], and [9] of Chapter B1).

Ba

[85] Measured the heat content and reported the mean heat capacities for the crystal and liquid; T_m determined.

[97] Free energy functions of Ba as an ideal monatomic gas are calculated for the range 0 to 8000°K.

[178] Measured the pressure of Ba over the equilibrium $4BaO + 2A\ell = 3Ba + BaO \cdot A\ell_2O_3$.

BaO

[15] Measured the vapor pressure by Knudsen method between 1526° and 1800°K.

[21] Gave the dissociation energy of BaO gas.

[22] Calculated the free energy function for BaO gas between 298° and 3000°K.

[29] From literature values calculated the binding energy, dissociation energy and heat of sublimation.

[32] By mass spectrometry obtained the dissociation energy and heat of vaporization.

[33] Obtained dissociation energy by mass spectrometry.

[48] Calculated entropy at 1200° and 1600°K.

[53] Phase diagram of $CaC\ell_2$-Ca system. Heat of fusion of $CaC\ell_2$ reported.

[83] Mass spectrometry study on the vapor from BaO(c) in a Knudsen cell in the range 1500° to 1800°K.

[91] Gave a two-constant equation for estimating the heat capacity.

[107] Experimental heat content in range 298° to 1299°.

[108] Gave dissociation energy.

[112] Measured heat of formation from elements.

[114] Reevaluated vapor pressure, mass spectrometry, and flame photometry data to obtain "best" values for the dissociation energy and heat of sublimation.

[123] Studied effusion of BaO from Knudsen cell. Used radioactive Ba to determine weight change. Gave an equation for vapor pressure in the range 1100° to 1500°K.

[147] Determined the heat of sublimation and vapor pressure in the range 1173° to 1473°K.

[165] Review paper on the thermodynamic properties of Ba compounds.

[168] Calculated the thermodynamic functions over the range 300° to 3500°K. Used RRHO plus excited states approximation.

BaO_2

[7] Measured the decomposition pressures for $BaO_2 \rightarrow BaO + \frac{1}{2}O_2$.

[102] Measured heat of decomposition.

[165] Review paper on the thermodynamic properties of barium compounds.

Ba_2O

[83] From Knudsen cell-mass spectrometry study obtain the heat of decomposition for $Ba_2O(g) \rightarrow BaO(g) + Ba(g)$.

Ba_2O_2

[83] From a mass spectrometric study on the effusion from a Knudsen cell containing BaO(c) obtained the heats associated with the reactions $2BaO(c) \rightarrow Ba_2O_2(g)$ and $Ba_2O_2(g) \rightarrow 2BaO(g)$.

BaH [168] Calculated the thermodynamic functions for the gas in the range 300° to 3500°K using an anharmonic RRHO plus excited states model.

BaH_2 [165] Review paper on the thermodynamic properties of barium compounds.

BaF [16],[18],[52] From mass spectrometry data obtained the dissociation energy of BaF, and the heats of reaction and equilibrium constants for
$Ba(g) + A\ell F(g) = BaF(g) + A\ell(g)$ and
$Ba(g) + BaF_2(g) = 2BaF(g)$.

BaF_2 [70],[71] Mass spectrometric study of vaporization. Vapor pressure in the range 1232° to 1505°K and the heat of sublimation were reported.

[80] Investigated the heat, entropy, and free energy associated with the reaction $HF(g) + \frac{1}{2}BaC\ell_2(s) = \frac{1}{2}BaF_2(s) + HC\ell(g)$ at 755°K.

[100] Calculated the thermodynamic functions for the gas in the range 298° to 2500°K using a RRHO approximation.

[131] Heat and temperature of fusion obtained from the freezing point depression studies on $NaF-BaF_2$ solutions.

[135] Determination of melting point.

$BaC\ell_2$ [49] Calorimetrically determined the heats and entropies of fusion and transition, the heat content of solid at the melting point, and the heat capacities of the solid and liquid in the vicinity of the melting and transition temperatures.

[84] Using a drop calorimeter determined the heat and entropy of fusion and transition.

[86] As part of phase equilibrium studies on $PuC\ell_3-BaC\ell_2$ system, determined freezing point of $BaC\ell_2$.

[100] Calculated the thermodynamic functions for the gas between 298° and 2500°K using an RRHO approximation.

[124] Measured the vapor pressure using the boiling point method in the range 1588° to 1710°K.

[134] Reported heat capacity data in the range 443° to 973°K.

[136] Measured the temperatures of transition and fusion by a differential thermal analysis method.

BaC_2 [79] Using the Knudsen effusion method measured the pressure of Ba over $BaC_2 + C$.

[176] Measured the equilibrium pressure of Ba over the equilibrium $BaC_2 = Ba + 2C$.

$BaO \cdot B_2O_3$ [87] Equilibrium studies on the $BaO-B_2O_3$ system. Melting point reported.

$BaO \cdot nB_2O_3$ [109] Phase equilibrium study on the $BaO-B_2O_3$ system. Melting points reported for $BaO \cdot 4B_2O_3$, $BaO \cdot 2B_2O_3$, $BaO \cdot B_2O_3$, and $3BaO \cdot B_2O_3$.

$BaO \cdot nAl_2O_3$ [159] Melting points reported for $BaO \cdot 6Al_2O_3$, $BaO \cdot Al_2O_3$, and $3BaO \cdot Al_2O_3$.

[178] Pressure of Ba measured over the equilibrium $4BaO + 2Al = 3Ba + BaO \cdot Al_2O_3$. Heat, entropy, free energy, and equilibrium constant reported.

Ca [46] Measured vapor pressure by Knudsen method in the range 800° to 920°.

[85] Reported heat content for liquid. Heat of fusion and mean heat capacity are given.

[93] Review of thermodynamic data for crystal, liquid, and gas from 298° to 2000°K. Vapor pressure of crystal and liquid reviewed.

[95] Using a drop calorimeter, measured the heat content of a high purity sample between 487° and 1283°K.

[97] Calculated the free energy functions of Ca as an ideal monatomic gas over the range 0° to 8000°K.

[115] Transitions in crystalline Ca shown by means of Debye-Scherrer photographs.

[116] Differential thermal analysis measurements on the Ca-Zn system. Determined melting point of Ca.

[130] Fusion and transition temperatures determined by thermal analysis method.

[132] Using an effusion method obtained the pressure of Ca in the range 1423° to 1473°K over the reaction $4CaO + 2Al = 3Ca + CaO \cdot Al_2O_3$.

[135A] Measured the vapor pressure by a Knudsen effusion method using radioactive tracers.

[150] Vapor pressure measured by a Knudsen effusion method in the range 844° to 965°K.

[151] Effects of impurities on the crystallographic modifications of Ca determined by X-ray diffraction.

[152] Allotropic forms of Ca studied by X-ray diffraction.

[153] Vapor pressure measured by a Knudsen effusion method in the range 730° to 965°K. Values obtained for the sigma function constants.

[158] A Knudsen method was used to obtain the vapor pressure in the range 801° to 877°K.

CaO [9] Determined the heat of sublimation from mass spectrometry studies over the range 2165° to 2259°K.

[12] Mass spectrometric Knudsen cell studies were made on the rate of vaporization of CaO as a function of temperature. Heat of vaporization reported.

[21] Gave the dissociation energy for $CaO(g) = Ca(g) + O(g)$.

[22] Free energy function calculated for the gas in the range 298° to 3000°K.

[29] From literature values calculated the binding energy, dissociation energy and the heat of sublimation.

[32] From some CaO in a sample of CaS were able by mass spectrometry to measure the dissociation energy and heat of vaporization in the range 2180° to 2386°K.

[33] Determined the dissociation energy from a mass spectrometry study.

[47] By mass spectroscopic studies on a Knudsen cell determined the appearance potential.

[81] Measure the heat of combustion of Ca.

[96] Determined the heat of oxidation.

[107] Reported the heat content over the range 560° to 1200°K.

[114] Reevaluated mass spectrometry, vapor pressure, and flame photometry data to obtain the "best" values for the heat of sublimation and dissociation energy.

[128] Melting point reported.

[143] Melting point reported.

[165] A review paper on the thermodynamic properties of Ca compounds.

[166],[167] From measurement of the dissociation equilibrium in Ca + O_2 flames at approximately 3000°K, gave the dissociation energy and equilibrium constant for CaO = Ca +O.

[168] Calculated the thermodynamic functions for the gas in the range 300° to 3500°K using an anharmonic RRHO approximation with excited states.

[178] Measured the pressure of Ca over the reaction $6CaO + 2A\ell = 3Ca + 3CaO \cdot A\ell_2O_3$.

CaO_2 [165] A review of the thermodynamic properties of calcium compounds.

CaH [168] Calculated the thermodynamic functions in the range 300° to 3500° using RRHO model with excited states and anharmonic corrections.

CaH_2 [38],[39] Measure the equilibrium pressure of hydrogen over the CaH_2-Ca system.

[130] An allotropic transformation was found by thermal analysis.

[160] Measured the decomposition pressure.

[165] A review paper on the thermodynamic properties of calcium compounds.

CaF [16],[17],[18] From mass spectrometric studies determined the dissociation energy of CaF, and reaction heats for $Ca(g) + A\ell F(g) = A\ell(g) + CaF(g)$ and $Ca(g) + CaF_2(s) = 2CaF(g)$.

CaF_2 [17] A vacuum microbalance and mass spectrometer were used to determine sublimation pressures and heats of sublimation for $CaF_2(s)$ over the range 1242°-1669°K.

[42] Heat, entropy, and temperature of fusion measured by a cryometric method.

[70] Mass spectrometric study on the effusion from a Knudsen cell. Vapor pressure and heat of sublimation were determined.

[77] Compared the entropy of gas derived from vapor pressure and condensed-phase data to that calculated from molecular constant and spectroscopic data.

[100] Calculated the thermodynamic functions in the range 298° to 2500°K using a RRHO approximation.

[111] Phase studies and melting point determination.

[122] Determined the heats and temperatures of transition and fusion.

[131] From the freezing point depression of $NaF-CaF_2$ solutions determined the heat and temperature of fusion.

[135] Melting point determination.

[145] Measured the vapor pressure in the range 1400° to 1850°K by the torsion effusion method. Heat of sublimation and boiling point are given.

$CaCl_2$ [13] Vapor pressure measured by the Langmuir method and heat of sublimation determined.

[26],[53] Phase studies. Melting point and heat of fusion reported.

[49] Calorimetrically determined the heat and entropy of fusion, and the heat capacities of the solid and liquid in the vicinity of the melting point.

[60] Measured the vapor pressure by the boiling point method in the range 1323° to 1673°K.

[77] Compared the entropy derived from vapor pressure and condensed-phase data to the entropy derived from molecular constant and spectroscopic data.

[78] Using the Knudsen method measured the vapor pressure in the range 1110° to 1281°K. Calculated the heat of sublimation.

[86] Determined the freezing point by thermal analysis.

[100] Calculated the thermodynamic functions for the range 298° to 2500°K using the RRHO approximation.

[118] Reported the heat content in the range 298° to 1667°K and determined the heat of fusion. Other thermodynamic properties were derived.

[124] Measured the vapor pressure using the boiling point method in the range 1591° to 1701°.

[149] Measured the heat of chlorination of Ca directly at 293°K.

[169] Using the Knudsen method determined the vapor pressure in the range 886° to 998°K.

CaC_2 [20] Review of the literature on polymorphism of CaC_2.

[89] Preparation and melting point.

[113] Measured the pressure of Ca over the dissociation $CaC_2(c) \rightarrow Ca(g) + 2C(s)$.

[119] Used a drop calorimeter to measure the heat content and heat of tetragonal to cubic transition.

[176],[177] Measured the pressure of Ca over the dissociation $CaC_2(c) \rightarrow Ca(g) + C_2(s)$.

$mCaO \cdot nB_2O_3$ [94] Calorimetrically measured the heat contents of $3CaO \cdot B_2O_3$, $2CaO \cdot B_2O_3$, $CaO \cdot B_2O_3$, and $CaO \cdot 2B_2O_3$ from 298°K to above their melting points. Heats of fusion, heat capacities and melting points were derived.

$mCaO \cdot nAl_2O_3$ [19] Reported the heat contents of $3CaO \cdot Al_2O_3$ (298° to 1800°K), $12CaO \cdot 7Al_2O_3$ (298° to 1700°K), and $CaO \cdot Al_2O_3$ (298° to 1800°K).

Cr

[2] Measured the vapor pressure by a torsion effusion method over the range 1376° to 1592°K.

[5] Determined the heat capacity between 273° and 1073°K by adiabatic calorimetry.

[28] Obtained vapor pressure and heat of evaporation from open surface in vacuum.

[55] Vapor pressure measurements.

[67] Calculated the thermodynamic functions from 298° to 6000°K for the ideal gas.

[74] Measured the vapor pressure in the range 1273° to 1373°K. Heat of vaporization reported.

[82] Measured vapor pressure by Knudsen method between 1373° and 1573°K.

[103] The vapor pressure was measured using the Knudsen method for the range 1443° to 1670°K. Heats and entropies of sublimation and vaporization, melting and boiling points were given.

[110] Using an ice calorimeter the heat content and heat capacity was determined between 291° and 1922°K.

[133] Measured the vapor pressure by the Knudsen method.

[155] Measured the vapor pressure between 1283° and 1561°K. Thermodynamic functions were given.

[170] Measured the vapor pressure in the range 1373° to 1673°K using the Knudsen method.

[171] Using a Knudsen cell with radioactive tracers measured the vapor pressure between 1373° and 1573°K.

Cr_2

[1] Measured P_{Cr}/P_{Cr_2} at 1909°K and obtained the upper limit for $D_0^\circ(Cr_2)$.

[90] Used a combined effusion and mass spectrometry technique to estimate the dissociation energy.

CrO

[21] Gave the dissociation energy.

[22] Free energy function calculated for the gas in range 298° to 3000°K.

[67] Calculated the thermodynamic functions for the ideal gas between 300° and 6000°K.

[72] From a mass spectrometric study on Cr_2O_3 vaporization obtains the dissociation energy of CrO.

CrO_2

[21] Gave the dissociation energy.

[30] Calculated the free energy function to 3000°K assuming a linear symmetrical molecule.

[67] Calculated the thermodynamic functions for the ideal gas between 300° and 6000°K.

[72] From a mass spectrometric study on the vaporization of Cr_2O_3 obtained the dissociation energy of CrO_2.

[104] Studied the decomposition pressure in the range 723° to 823°K for the reaction $2CrO_2 \rightarrow Cr_2O_3(c) + \frac{1}{2}O_2(g)$.

[121] Calculated the thermodynamic functions between 200° and 2000°K for the ideal gas.

CrO_3 [6] Vapor pressure measurements.
[65] Measured the vapor pressure by the transport method over the range 448° to 468°K. Derived the heats of sublimation, vaporization, and fusion.
[67] Calculated the thermodynamic functions for ideal gas between 300° and 6000°K.
[72] From a mass spectrometric study on the vaporization of Cr_2O_3 obtained the dissociation energy of CrO_3.
[121] Calculated the thermodynamic functions of the ideal gas between 200° and 2000°K.

Cr_2O_3 [66] Measure the heat of combustion of Cr at 298°K.
[67] Calculated the ideal gas thermodynamic functions.
[72] The vaporization of Cr_2O_3 under neutral and oxidizing conditions were investigated using mass spectrometric methods. The principal gaseous species are Cr, CrO, CrO_2, O, and O_2.
[73] Determination of high temperature heat content.
[76] Measured the equilibrium pressure of CO over the reaction of Cr_2O_3 with $Cr_{23}C_6$ and Cr_7C_3.
[112A] Measured the heat of combustion of Cr in O_2.
[143] Melting point reported.
[173] Studied the sublimation of Cr_2O_3 using a Langmuir free evaporation method in the range 1597° to 1821°K.

CrH [67] Calculated the thermodynamic functions for the ideal gas between 300° and 6000°K.

CrF [67] Calculated the ideal gas thermodynamic functions between 300° and 6000°K.

CrF_2 [157] Melting point reported.

CrF_3 [157] Melting point reported.

CrF_5 [50] Melting point reported.

$CrOF_2$ [101] Melting point determined.

CrO_2F_2 [54] Preparation and sublimation point.

$CrC\ell$ [67] Calculated the thermodynamic functions for the ideal gas in the range 300° to 6000°K.

$CrC\ell_2$ [67] Calculated the thermodynamic functions for the ideal gas in the range 300° to 6000°K.
[105] Melting point determined.
[148] Determined the melting point.

$CrC\ell_3$ [67] Calculated the ideal gas thermodynamic functions between 300° and 6000°K.

$CrOC\ell$ [67] Calculated the thermodynamic functions between 300° and 6000°K for the ideal gas.

$CrO_2FC\ell$ [59] Obtains the equilibrium constant for the reaction $CrO_2F_2 + CrO_2C\ell_2 \rightarrow 2CrO_2FC\ell$.

Cr_2N [140] Measured the dissociation pressure between 1229° and 1398°K.

[146] Studied the solid solution of nitrogen in chromium between 1173° and 1673°K.

Cr_3C_2 [61] Measured the dissociation pressure between 1908° and 2237°K in a Knudsen apparatus.

[92] Reported the high temperature thermodynamic properties.

[129] Measured the heat content to high temperatures.

Cr_7C_3 [92] Reported the high temperature thermodynamic functions.

$Cr_{23}C_6$ [3] Studied the reduction of $Cr_{23}C_6$ by hydrogen. Gave equilibrium constant.

CrB [117] Reported high temperature heat content.

CrB_2 [23] Reactions with nitrogen and graphite studied.

[117] Reported high temperature heat content.

Fe [4] Heat content measured between 300° and 1433°K. Temperatures and heats of transition and fusion reported.

[8] Heat capacity determined to 1223°K. Temperature and heat of α to γ transition was given.

[21] Reported the heat of sublimation.

[28] Obtained the vapor pressure and heat of evaporation and 99.99% pure Fe.

[41] Thermodynamic functions for the liquid and two crystalline states were calculated using literature data for the range 298° to 2000°K.

[45] Using original and literature data reported the heat capacity, heats and temperatures of transition.

[51] Measured the vapor pressure between 1356° and 1519°K.

[56] Reviews literature data on Fe-P, Fe-S, and Fe-C systems and proposes values for the heat of fusion and melting point.

[62] Calorimetric study on the Fe-C system. Obtained the heat of the austenite to pearlite transition in iron.

[68] Measured the vapor pressure by an effusion method.

[74] Measured the vapor pressure by a modified Langmuir free evaporation method.

[93] Review of the heat content and entropy data for the crystal and liquid between 298° and 2000°K.

[97] Free energy function for the ideal monatomic gas calculated between 0° and 8000°K.

[98] Using radioactive iron as a tracer in a Knudsen apparatus determined the heat of sublimation.

[99] Measured the vapor pressure by the Knudsen method employing radioactive tracers.

[120] Sublimation pressure of iron measured by a torsion effusion method in the range 1450° to 1680°K.
[125] Measured the heat content over the range 353° to 1323°K.
[126] Reported heat content and heat of the γ-δ transformation.
[138] Melting point reported.
[142] Using a drop calorimeter measured the heat content between 521° and 1073°K.
[156] Measured transformation temperature while cooling at 5000 to 8000°C/sec.
[170] Measured vapor pressure using a Knudsen effusion method in the range 1423° to 1623°K.

FeO_{1+x} [63] Direct measurement of the heat of formation of the nonstoichiometric oxides at 1073°K.

FeO_x [162] Calculated the values of enthalpy and entropy for x = 1.0451 to 1.0733 and over the range 890° to 1673°K.
[163],[164] Partial pressure of oxygen in equilibrium with Wüstite and solid Fe.

FeO [21] Gave the dissociation energy.
[22] Calculated the free energy function for the gas between 298° and 3000°K.
[24] Measured the decomposition pressure.
[40] Derived heat of fusion from literature data.
[154] Obtained the heat of sublimation from spectroscopic and thermochemical data.
[174] Determined the vapor species in equilibrium with solid samples of Fe_3O_4 and Wüstite. The only vapor species found were O, O_2, Fe and FeO. The ratio P_{FeO}/P_{Fe} varied inversely with temperature.

$Fe_{0.95}O$ [31] Offered a "best value" for the melting point.
[37] Reported the heat content between 298° and 1650°K.
[75] Studied the equilibrium $2Fe_{0.947}O = 1.894\ Fe(\gamma) + O_2(g)$ between 1373° and 1573°K. Partial pressure of O_2 obtained.

FeO_2 [21] Reported the dissociation energy.

Fe_2O_3 [25] Heat content and heats of transition measurements between 273° and 923°K.
[37] Measured the high temperature heat contents from 298° to 1750°K of the α, β, and γ forms.
[106] Discusses the effect of pressure on the crystalline modifications.
[139] Studied the oxygen dissociation pressure on the iron oxide system. Established the relationship between thermodynamic properties, composition and structure of iron oxide at elevated temperatures.
[161] Reported on the dissociation pressure of Fe_2O_3 between 1373° and 1673°K.

Fe_3O_4 [37] Measured the heat contents of the α and β crystalline forms.
[139] Studied the oxygen dissociation pressure on the iron oxide system. Established the relationship between thermodynamic properties, composition and structure of iron oxide at elevated temperatures.
[162] Calculated the enthalpy and entropy between 890° and 1673°K.
[174] Determined the vapor species in equilibrium with samples of Fe_3O_4 and wüstite. The only vapor species found were O, O_2, Fe, and FeO.

FeH, FeH_2 [137] Measured the dissociation pressures for $2FeH = 2Fe + H_2$ and $FeH_2 = Fe + H_2$.

FeCℓ [141] From attempts to measure the transport of Fe by FeCℓ at 1173°K was able to estimate the heat of formation of FeCℓ(g).

$FeCℓ_2$ [14] Determined the vapor pressure and partial pressure of dimer above liquid $FeCℓ_2$. Gave an equation for the heat of vaporization.
[105] Melting point reported
[118] Measured the heat content for the crystal and liquid. Obtains the heat of fusion and other thermodynamic properties.
[179] Vapor pressure measurements and estimate of boiling point.

$FeCℓ_3$ [35],[36] Temperature and heat of fusion reported.
[88] Obtained the vapor pressure and heat of sublimation for $2FeCℓ_3(s) = Fe_2Cℓ_6(g)$.
[180] Determined the heat content between 298° and 561°K.

$Fe_2Cℓ_6$ [34] Pressures of $Fe_2Cℓ_6(g)$ above solutions of $FeCℓ_2$ in $Fe_2Cℓ_6(ℓ)$ were measured. Reported the vapor pressure, heat and entropy of fusion, and estimated the boiling point.
[93] Reviewed the thermodynamic data for crystal, liquid and gas.
[175] Measured the vapor pressure by a flow method.

Fe_4N [27] Studied the reaction $2Fe_4N + 3H_2 = 2NH_3 + 8Fe$.

$FeO \cdot Aℓ_2O_3$ [58] By a calorimetric method measured the heat of reaction for $FeO + Aℓ_2O_3 \rightarrow FeO \cdot Aℓ_2O_3$ at elevated temperatures.

References

[1] M. Ackerman, F. E. Stafford and G. Verhaegen, J. Chem. Phys. 36, 1560 (1962).

[2] A. T. Aldred and K. M. Myles, Trans. AIME 230, 736 (1964).

[3] V. I. Alekseev and L. A. Shvartsman, Fiz. Met. i Metalloved Akad. Nauk SSSR 11, 545 (1961).

[4] P. D. Anderson and R. Hultgren Trans. Met. Soc. AIME 224, 842 (1962).

[5] L. D. Armstrong and H. Grayson-Smith, Can. J. Res. 28A, 51 (1950).

[6] S. M. Ariya, S. A. Shchukarev, and V. B. Glushkova, Zhur. Obshch. Khim. 23, 2063 (1953).

[7] B. D. Averbukh and G. I. Chufarov, Zhur. Obshch. Khim. 21, 626 (1951).

[8] J. H. Awbery and E. Griffiths, Proc. Roy. Soc. (Lond.) A174, 1 (1940).

[9] T. P. Babeliowsky, J. Chem. Phys. 38, 2035 (1963).

[10] T. P. J. H. Babeliowsky, Physica 28, 1150 (1962).

[11] T. P. J. H. Babeliowsky and A. J. H. Boerboom, Advan. Mass Spectrometry, Proc. Conf., 2nd, Oxford, 1961 2, 135 (Publ. 1963).

[12] T. P. J. H. Babeliowsky, A. J. H. Boerboom, and J. Kistemaker, Physica 28, 1135 (1962).

[13] R. G. Bautista and J. L. Margrave J. Phys. Chem. 67, 2411 (1963).

[14] C. Beusman, U.S. AEC ORNL-2323, 100pp (1957).

[15] J. P. Blewett, H. A. Liebhafsky, and E. Hennelly,
J. Chem. Phys. 7, 478 (1939).

[16] G. D. Blue,
Thesis University of Wisconsin (1963), Diss. Abstr. 23, 4123 (1963).

[17] G. D. Blue, J. W. Green, R. G. Bautista, and J. L. Margrave,
J. Phys. Chem. 67, 877 (1963).

[18] G. D. Blue, J. W. Green, T. C. Ehlert, and J. L. Margrave,
Nature 199. 804 (1963).

[19] K. R. Bonnickson,
J. Phys. Chem. 59, 220 (1955).

[20] M. A. Bredig
Z. anorg. u. allgem. Chem. 298, 254 (1959).

[21] L. Brewer,
U.S. AEC UCRL-8356, 4pp (1958).

[22] L. Brewer and M. S. Chandrasekharaiah,
U.S. AEC UCRL-8713, 17pp (1959).

[23] L. Brewer and H. Haraldsen,
J. Electrochem. Soc. 102, 399 (1955).

[24] L. Brewer and D. F. Mastick,
J. Chem. Phys. 19, 834 (1951).

[25] G. C. Brown and C. C. Furnas,
Trans. Am. Inst. Chem. Engrs. 18, 309 (1926).

[26] P. P. Budnikov, P. L. Volodin, and S. G. Tresvyatskii,
Ukrain. Khim. Zhur. 22, 292 (1956).

[27] A. Burdese,
Ann. chim. (Rome) 49, 1873 (1959).

[28] V. D. Burlakov,
Fiz. Met. i Metalloved 5, 91 (1957).

[29] M. S. Chandrasekharaiah,
J. Phys. Chem. 68, 2021 (1964).

[30] M. S. Chandrasekharaiah and L. Brewer,
U. S. AEC UCRL-8736, 5pp (1959).

[31] J. Chipman and S. Marshall,
J. Am. Chem. Soc. 62, 299 (1940).

[32] R. Collin, P. Goldfinger, and M. Jeunehomme,
Trans. Faraday Soc. 60, 306 (1964).

[33] R. Collin, M. Jeunehomme, and P. Goldfinger,
Univ. of Brussels, Annual Summary Report, No. 3, Contract AF 61(052)-225, March 1961- Feb. 1962, p. 16-17.

[34] C. M. Cook, Jr.,
J. Phys. Chem. 66, 219 (1962).

[35] C. M. Cook, Jr. and W. E. Dunn, Jr.
J. Phys. Chem. 65, 1505 (1961).

[36] C. M. Cook, Jr. and R. B. Hand,
J. Phys. Chem. 65, 1467 (1961).

[37] J. P. Coughlin, E. G. King, and K. R. Bonnickson,
J. Am. Chem. Soc. 73, 3891 (1951).

[38] R. W. Curtis,
Thesis Iowa State Univ. of Sci. and Technol. (1961),
Diss. Abstr. 23, 3142 (1963).

[39] R. W. Curtis and P. Chiotti,
J. Phys. Chem. 67, 1061 (1963).

[40] L. S. Darken and R. W. Gurry,
J. Am. Chem. Soc. 68, 798 (1946).

[41] L. S. Darken and R. P. Smith,
Ind. Eng. Chem. 43, 1815 (1951).

[42] F. Delbove,
Compt. rend. 252, 2192 (1961).

[43] E. Deltombe, N. de Zoubov and M. Pourbaix,
CEBELCOR, Rapp. tech. No. 41, 24pp (1956).

[44] E. Deltombe and M. Pourbaix,
CEBELCOR, Rapp. tech. No. 8, 5pp (1954).

[45] W. A. Dench and O. Kubaschewski,
J. Iron Steel Inst. (Lond.) 201, 140 (1963).

[46] P. E. Douglas,
Proc. Phys. Soc. (Lond.) B67, 783 (1954).

[47] J. Drowart, G. Exsteen and G. Verhaegen,
Trans Faraday Soc. 60, 1920 (1964).

[48] G. Drummond and R. F. Barrow,
Trans. Faraday Soc. 47, 1275 (1951).

[49] A. S. Dworkin and M. A. Bredig,
J. Phys. Chem. 67, 697 (1963).

[50] A. J. Edwards
Proc. Chem. Soc. 1963, 205.

[51] J. W. Edwards, H. L. Johnston, and W. E. Ditmars,
J. Am. Chem. Soc. 73, 4729 (1951).

[52] T. C. Ehlert, G. D. Blue, J. W. Green, and J. L. Margrave,
J. Chem. Phys. 41, 2250 (1964).

[53] H. H. Emons, D. Richter, W. Grothe, and U. Reckzeh,
Z. Chem. 2, 313 (1962).

[54] A. Engelbrecht and A. V. Grosse,
J. Am. Chem. Soc. 74, 5262 (1952).

[55] G. B. Fedorov, E. A. Smirnov, and F. I. Zhomov,
Met. i Metalloved Chistykh. Metal., Sb. Nauchn. Rabot No. 4,
110 (1963).

[56] A. Ferrier,
Compt. rend. 254, 104 (1962).

[57] V. V. Fesenko and A. S. Bolgar,
Poroshkovaya Met., Akad. Nauk Ukr.SSR 3, No. 1, 17 (1963).

[58] W. A. Fischer and G. Lorenz,
Arch. Eisenhüt. 27, 375 (1956).

[59] G. D. Flesch and H. J. Svec,
J. Am. Chem. Soc. 80, 3189 (1958).

[60] S. A. Frid, O. G. Polyachenok, G. I. Novikov,
Zhur. Neorg. Khim. 9, 1017 (1964).

[61] S. Fujishiro and N. A. Gokcen,
Trans. Met, Soc. AIME 221, 275 (1961).

[62] M. Genot,
Mem. Sci. Rev. Met. 60, 416 (1963).

[63] P. Gerdanian and M. Dode,
Compt. rend. 258, 1492 (1964).

[64] H. H. Glascock, Jr.,
J. Appl. Phys. 33, 3296 (1962).

[65] O. Glemser, A. Müller, and U. Stocker,
Z. anorg. u. allgem. Chem. 333, 25 (1964).

[66] Yu. M. Golutvin and L. Tszin'-Kui,
Zhur. Fiz. Khim. 35, 129 (1961).

[67] J. S. Gordon and R. Robinson,
Western States Sect. Combust. Inst., Paper WSS/CI, No. 62-11,
75pp (1962).

[68] A. Granovskaya and A. Lyubimov,
Zhur. Fiz. Khim. 27, 1443 (1933).

[69] W. Grattidge and H. John,
J. Appl. Phys. 23, 1145 (1952).

[70] J. W. Green,
Thesis Univ. of Wisconsin (1963), Diss. Abstr. Abstr. 23, 4548 (1963).

[71] J. W. Green, G. D. Blue, T. C. Ehlert, and J. L. Margrave,
J. Chem. Phys. 41, 2245 (1964).

[72] R. T. Grimley, R. P. Burns, and M. G. Inghram,
J. Chem. Phys 34, 664 (1961).

[73] G. Grube and M. Flad,
Z. Elektrochem. 48, 377 (1942).

[74] E. A. Gulbransen and K. F. Andrew,
Trans. AIME 221, 1247 (1961).

[75] W. C. Hahn, Jr. and A. Muan,
Trans. Met. Soc. AIME 224, 416 (1962).

[76] H. A. Hancock and L. M. Pidgeon,
Trans. AIME 227, 608 (1963).

[77] D. L. Hildenbrand,
J. Chem. Phys. 40, 3438 (1964).

[78] D. L. Hildenbrand and N. D. Potter,
J. Phys. Chem. 67, 2231 (1963).

[79] M. Hoch,
J. Appl. Phys. 29, 1588 (1958).

[80] G. C. Hood and M. M. Woyski,
J. Am. Chem. Soc. 73, 2738 (1951).

[81] E. J. Huber, Jr. and C. E. Holley, Jr.
J. Phys. Chem. 60, 498 (1956).

[82] D. V. Ignayov and Yu. N. Lebedev,
Fiz.-Khim. Osnovy Proizv. Stali, Akad. Nauk SSSR, Inst. Met.,
Tr. 5-oi (Pyatoi) Konf. 1959, 305 (Publ. 1961).

[83] M. G. Inghram, W. A. Chupka, and R. F. Porter,
J. Chem. Phys. 23, 2159 (1955).

[84] C. J. Janz, F. J. Kelly, and J. L. Perano,
Trans. Faraday Soc. 59, 2718 (1963).

[85] R. Jauch,
Unpublished data quoted by O. Kubaschewski in Z. Elektrochem. 54,
275 (1950).

[86] K. W. R. Johnson, M. Kahn, and J. A. Leary,
J. Phys. Chem. 65, 2226 (1961).

[88] H. F. Johnstone, H. C. Weingartner, and W. E. Winsche,
J. Am. Chem. Soc. 64, 241 (1942).

[89] R. Juza and H.-U. Schuster,
Z. anorg. u. allgem. Chem. 311, 62 (1961).

[90] A. Kant and G. Strauss,
J. Chem. Phys. 41, 3806 (1964).

[91] K. K. Kelley,
U.S. Bur. Mines, Rept. Invest. 3776, 33pp (1944).

[92] K. K. Kelley, F. S. Boericke, G. E. Moore, E. H. Huffman,
and W. M. Bangert,
U.S. Bur. Mines, Tech. Papers no. 662, 43 pp (1944).

[93] K. K. Kelley and A. D. Mah,
U.S. Bur. Mines, Rept. Invest. 5490, 48pp (1959).

[94] E. G. King, D. R. Torgeson, and O. A. Cook,
J. Am. Chem. Soc. 70, 2160 (1948).

[95] P. V. Kocherov and P. V. Gel'd,
Zhur. Neorg. Khim. 5, 1774 (1960).

[96] P. V. Kocherov, Yu. M. Gertman, and P. V. Gel'd,
Zhur. Neorg. Khim. 4, 1106 (1959).

[97] H. G. Kolsky, R. M. Gilmer, and P. W. Gilles,
J. Chem. Phys. 27, 494 (1957).

[98] Yu. V. Kornev,
Doklady Akad. Nauk SSSR 93, 467 (1953).

[99] Yu. V. Kornev and V. N. Golubkin,
Fiz. met. i Metalloved 1, 286 (1955).

[100] K. S. Krasnov and V. I. Svettsov,
Izvest. Vysshikh Ucheb. Zavedenii Khim. i Khim. Tekh.
6, No. 1, 167 (1963).

[101] H. L. Krauss and F. Schwarzbach,
Chem. Ber. 94, 1205 (1961).

[102] C. Kröger and W. Janetzko,
Z. anorg. u. allgem. Chem. 284, 83 (1956).

[103] O. Kubaschewski and G. Heymer,
Acta Met. 8, 416 (1960).

[104] B. Kubota,
J. Am. Chem. Soc. 44, 239 (1961).

[105] H. Kühnl and W. Ernst,
Z. anorg. u. allgem. Chem. 317, 84 (1962).

[106] I. Kushiro,
J. Geomagnet. Geoelect. Kyoto 11, 148 (1960).

[107] J. J. Lander
J. Am. Chem. Soc. 73, 5794 (1951).

[108] B. B. Laud,
Indian J. Phys. 36, 639 (1962).

[109] E. M. Levin and H. F. McMurdie,
J. Research Nat. Bur. Standards 42, 131 (1949).

[110] C. F. Lucks and H. W. Deem
ASTM Spec. Tech. Publ. No. 227, 29pp (1958).

[111] W. J. McCreary,
J. Am. Chem. Soc. 77, 2113 (1955).

[112] A. D. Mah,
U.S. Bur. Mines, Rept. Invest. 6171, 8pp (1963).

[112A] A. D. Mah,
J. Am. Chem. Soc. 76, 3363 (1954).

[113] B. Mauderli, E. Moser, and W. D. Treadwell,
Helv. Chim. Acta 27, 105 (1944).

[114] V. A. Medvedev,
Zhur. Fiz. Khim. 35, 1481 (1961).

[115] H. Melsert, T. J. Tiedema, and W. G. Burgers,
Acta Cryst. 9, 525 (1956).

[116] A. F. Messing, M. D. Adams, and R. K. Steunenberg,
Am. Soc. Metals, Trans. Quart. 56, 345 (1963).

[117] R. Mezaki, E. W. Tilleux, D. W. Barnes, and J. L. Margrave,
Symp. Thermodyn. Nucl. Mtls., Vienna, 27pp(1962).

[118] G. E. Moore,
J. Am. Chem. Soc. 65, 1700 (1943).

[119] G. E. Moore,
Ind. Eng. Chem. 35, 1292 (1943).

[120] K. M. Myles and A. T. Aldred,
J. Phys. Chem. 68, 64 (1964).

[121] G. Nagarajan,
Australian J. Chem. 16, 908 (1963).

[122] B. F. Naylor,
J. Am. Chem. Soc. 67, 150 (1945).

[123] B. P. Nikonov and N. G. Otmakhova,
Zhur. Fiz. Khim. 35, 1494 (1961).

[124] G. I. Novikov and F. G. Gavryuchenkov,
Zhur. Neorg. Khim. 9, 475 (1964).

[125] W. Oelsen, K. H. Rieskamp, and O. Oelsen,
Arch. Eisenhüt. 26, 253 (1955).

[126] M. Olette and A. Ferrier,
Nat'l. Phys. Lab. Symp. No. 9, II, 4H, 1 (1958).

[127] F. L. Oetting and N. W. Gregory,
J. Phys. Chem. 65, 138 (1961).

[128] Ya. I. Ol'shanskii,
Doklady Akad. Nauk SSSR 59, 1105 (1948).

[129] R. A. Oriani and W. K. Murphy,
J. Am. Chem. Soc. 76, 343 (1954).

[130] D. T. Peterson and V. G. Fattore,
J. Phys. Chem. 65, 2062 (1961).

[131] G. Petit and A. Cremieu,
Compt. rend. 243, 360 (1956).

[132] L. M. Pidgeon and J. T. N. Atkinson,
Can. Minning and Met. Bull. 41, 14 (1948).

[133] G. O. Piloyan, A. M. Evseev, and Ya. Gerasimov,
Zhur. Fiz. Khim. 34, 1768 (1960).

[134] M. M. Popov and G. L. Gal'chenko,
Zhur. Obshch. Khim. 21, 2220 (1951).

[135] B. Porter and E. A. Brown,
J. Am. Ceram. Soc. 45, 49 (1962).

[135A] Yu. A. Priselkov and A. N. Nesmeyanov,
Doklady Akad. Nauk SSSR 95, 1207 (1954).

[136] D. E. Rase and R. Roy,
12th Tech. Rept. on U.S. Army Signal Corps Contract DA 36-039,
SC63099. College of Mineral Industries, Penn. State University,
Oct. 1956.

[137] R. C. Ray and R. B. N. Sahai,
J. Indian Chem. Soc. 23, 67 (1946).

[138] W. F. Roeser and H. T. Wensel,
J. Research Bur. Standards 26, 273 (1941).

[139] O. N. Salmon,
J. Phys. Chem. 65, 550 (1961).

[140] K. Sano,
Nippon Kagaku Zasshi 58, 981 (1937).

[141] H. Schäfer and K. Etzel,
Z. anorg. u. allgem. Chem. 301, 137 (1959).

[142] E. Scheil and W. Normann,
Arch. Eisenhüt. 30, 751 (1959).

[143] S. J. Schneider,
J. Am. Ceram. Soc. 46, 354 (1963).

[144] R. C. Schoonmaker, A. H. Friedman, and R. F. Porter,
J. Chem. Phys. 31, 1586 (1959).

[145] D. A. Schulz and A. W. Searcy,
J. Phys. Chem. 67, 103 (1963).

[146] A. U. Seybolt and R. A. Oriani,
J. Metals 8, 556 (1956).

[147] S. A. Shchukarev and G. A. Semenov,
Zhur. Neorg. Khim. 2, 1217 (1957).

[148] J. C. Shiloff,
J. Phys. Chem. 64, 1566 (1960).

[149] H. Siemonsen,
Z. Elektrochem. 55, 327 (1951).

[150] J. F. Smith,
U.S. AEC IS-440, 26pp (1962).

[151] J. F. Smith and B. T. Bernstein,
J. Electrochem. Soc. 106, 448 (1959).

[152] J. F. Smith, O. N. Carleson, and R. W. Vest,
J. Electrochem. Soc. 103, 409 (1956).

[153] J. F. Smith and R. L. Smythe,
Acta Met. 7, 261 (1959).

[154] M. S. Sodha and Y. P. Varshni,
Indian J. Phys. 27, 520 (1953).

[155] R. Speiser, H. L. Johnston, and P. Blackburn,
J. Am. Chem. Soc. 72, 4142 (1950).

[156] L. P. Srivastava and J. G. Parr,
Trans. AIME 224, 1295 (1962).

[157] B. J. Sturm,
Inorg. Chem. 1, 665 (1962).

[158] D. H. Tomlin,
Proc. Phys. Soc. (Lond.) B67, 787 (1954).

[159] N. A. Toropov and F. Ya Galakhov,
Doklady Akad. Nauk SSSR 82, 69 (1952).

[160] W. D. Treadwell and J. Sticher,
Helv. Chim. Acta 36, 1820 (1953).

[161] Yu. D. Tret'yakov and K. G. Khomyakov,
Zhur. Neorg. Khim. 7, 1219 (1962).

[162] P. Vallet, C. Carel, and P. Raccah,
Compt. rend. 258, 4028 (1964).

[163] P. Vallet, M. Kleman, and P. Raccah,
Compt. rend. 256, 136 (1963).

[164] P. Vallet and P. Raccah,
Compt. rend. 258, 3679 (1964).

[165] J. Van Muylder and M. Pourbaix,
CEBELCOR, Rapp. tech. No. 72, 11pp (1958).

[166] I. V. Veits and L. V. Gurvich,
Optika i Spektrosk. 2, 145 (1957).

[167] I. V. Veits and L. V. Gurvich,
Zhur. Fiz. Khim. 31, 2306 (1957).

[168] I. V. Veits, L. V. Gurvich, and N. P. Rtishcheva,
Zhur. Fiz. Khim. 32, 2532 (1958).

[169] B. K. Veselovskii,
Zhur. Priklad. Khim. 15, 422 (1942).

[170] E. Z. Vintaikin,
Doklady Akad. Nauk SSSR 118, 977 (1958).

[171] E. Z. Vintaikin,
Fiz. Met. i Metalloved 13, 157 (1962).

[172] E. Z. Vintaikin,
Fiz. Met. i Metalloved 16, 144 (1963).

[173] K.-C. Wang, L. H. Dreger, V. V. Dadape, and J. L. Margrave,
J. Am. Ceram Soc. 43, 509 (1960).

[174] C. A. Washburn,
U.S. AEC UCRL-10991, 20pp (1963).

[175] L. E. Wilson and N. W. Gregory,
J. Phys. Chem. 62, 433 (1958).

[176] Y. Yamanaka,
Denki Kagaku 28, 501 (1960).

[177] Y. Yamanaka,
J. Electrochem. Soc. Japan 28, 427 (1960).

[178] V. V. Zhukovetskii,
Tr. Severo-Kaukaz. Gornomet. Inst. 1957, No. 15, 210.

[179] R. C. Schoonmaker and R. F. Porter,
J. Chem. Phys. 29, 116 (1958).

[180] S. S. Todd and J. P. Coughlin,
J. Am. Chem. Soc. 73, 4184 (1951).

Chapter B3

STATUS OF THERMOCHEMICAL DATA ON SOME HEAVY-METAL OXIDES AND HALIDES

(from the Proceedings of the Third Meeting of the Interagency Chemical Rocket Propulsion Group on Thermochemistry, El Segundo, California, March 1965)

by Donald D. Wagman

In view of the increasing interest in the heavy-metal elements as components of high-energy fuels we have conducted a review of the available published data on the chemical thermodynamic properties (heats and free energy of formation, and entropy) of the oxides and halides of mercury, lead, thorium, uranium, tungsten, and tantalum. In this survey we have assembled all of the pertinent data on these substances from the files of the Chemical Thermodynamic Data Group. These data have been reviewed and values of $\Delta Hf°$, $\Delta Gf°$ and S° selected where possible. While these values will not be identically the same as those finally issued by the Chemical Thermodynamic Data Group as the result of their current review of the literature in this field, the values will be sufficiently close to be useful. Furthermore the gaps in the tables, indicating the absence of useful data, will be of significance to this Panel as an indication of needed research.

The following sections of this report contain a summary of the available significant data on the compounds of each element considered. No attempt was made to list all references. The final selected values are listed in Tables I - VI.

LEAD (Table I)

PbO(c, red) The more precise data on this substance come from the various cell measurements [1, 2, 3, 4]. The temperature coefficient measurements are consistent with the calorimetric S° for PbO. The calorimetric measurements [5, 6, 7, 8] show considerable scatter, from -49.8 to -53.1 kcal/mole for ΔHf.

PbO_2(c) The calorimetric entropy is not consistent with the various cell measurements [9, 10, 11]. The equilibrium data of Krustinsons [12] yield much too large a value of ΔS. The cell data have been used for the final selections.

Pb_3O_4(c) The cell data of Andrews and Brown [13] yields ΔHf = -170.5 and -174.0 kcal/mole; the decomposition pressure data of Reinders and Hamburger [14] yield -172.6 kcal/mole. Recent high-temperature cell data by Chartier [15] indicate a somewhat more negative value of ΔHf than the one selected. The value of S° is taken from Kelley [16].

PbF_2(c) The measurements of Gross, Haymann and Levi [17] on Al + PbF_2, von Wartenberg [18] on the heat of solution of PbO in HF(aq), and Jellinek and Rudat [19] on the PbF_2-H_2 equilibrium yield values of ΔHf = -158.4, -158.7, and -158.9 kcal/mole, respectively. The cell data of Jahn-Held and Jellinek [20] have been used to calculate S°. The equilibrium data of [19] lead to somewhat too high a value of S°.

$PbCl_2$(c) There is a small uncertainty in the value of S°. The calorimetric value is slightly higher than the value obtained from the temperature coefficient of the EMF data by Priepke and Vosburgh [21], Gerke [22],

Jahn-Held and Jellinek [20], Delimarskii and Roms [23] and the $PbCl_2$-H_2 gas equilibrium data of Jellinek and Rudat [19] and Bagdasarian [24].

PbI_2(c) The values are based on the cell data of Cann and Taylor [25], Vosburgh and Dibeler [26] and Gerke [22]. We have selected the calorimetric value of S°; the cell data lead to a value within 0.5 cal/deg mole.

MERCURY (Table II)

HgO(c, red) Most early measurements do not distinguish clearly between the red and yellow forms of HgO. However the cell data of Fried [2], Shibata et al. [27] and Ishikawa and Kimura [28] lead to values of ΔGf° from -13.984 to -13.999 kcal/mole; the temperature coefficient data of [27, 28] yield S° = 16.78, 16.92, and 17.27 cal/deg mole in good agreement with the calorimetric value [29] of 16.80 cal/deg mole.

HgO(c, yellow) The difference between the red and yellow forms is taken from the measurements of Fried [2] and Garrett and Hirschler [30]. The calorimetric measurements are of low precision. The decomposition pressure measurements of Taylor and Hulett [31] yield ΔHf = -21.85 kcal/mole, presumably for the yellow form.

HgF_2(c) No measurements on this substance. There are various estimates available.

Hg_2F_2(c) The cell data of Koerber and DeVries [32] using Cu and Cd amalgam electrodes lead to inconsistent ΔGf values. The temperature coefficient data lead to an unreasonable value of S°.

$HgCl_2$(c) The vapor pressure data of Shibata and Niwa [33] and earlier measurements have been combined with calculated S° values for $HgCl_2$(gas) to calculate S°. The value of ΔHf comes from the measurements of Thomsen [5] and Troost and Hautefeuille [34] on the Hg_2Cl_2-Cl_2 reaction.

Hg_2Cl_2(c) There are a large number of cell measurements of ΔGf that are very consistent (-50.362 to -50.388 kcal/mole). The cell data of Gupta, Hill and Ives [35] yield S° = 45.83 cal/deg mole. The data of Gerke [22] yield an average value of 46.4. The available calorimetric data extrapolate to 46.0.

HgI_2(c) The calorimetric data of Varet [36] on the heat of reaction of Hg with I_2-KI solution yield data which are consistent with similar measurements on Hg_2I_2. The entropy is calculated from data for S°(gas) and sublimation measurements of Shibata [33], Magee [37] and the other data reviewed by Kelley [38].

Hg_2I_2(c) The data of Vosburgh [39] on PbI_2-Hg_2I_2 and CdI_2-Hg_2I_2 cells yield values of S° = 56.4 and 56.3 cal/deg mole, respectively. Calorimetric heat of formation data (relative to HgI_2) yield ΔHf = -28.89 kcal/mole; the cell data yield -28.93 kcal/mole.

THORIUM (Table III)

ThO(c) No data available.

$ThO_2(c)$ The heat of combustion has been measured by Roth and Becker [40] and Huber and Holley [41], obtaining ΔHf = -292.6 and -293.2 kcal/mole, respectively. The entropy was measured by Osborne and Westrum [42].

$ThF_4(c)$ Darnell [43] has studied the SiO_2-ThF_4 equilibrium from which we calculate ΔHf = -503.5 kcal/mole. The entropy was measured by Lohr, Osborne, and Westrum [44].

$ThCl_4(c)$ There is wide disagreement between the calorimetric measurements of Chauvenet [45] and Eyring and Westrum [46] on the heats of solution of Th and $ThCl_4$ in aqueous HCl. Von Wartenberg [47] obtained ΔHf = -300 kcal/mole by the direct reaction of Th + Cl_2. The cell data of Egan and McCoy [48] have been used to obtain an approximate value of S°.

$ThI_4(c)$ The equilibrium between TiO_2 and ThI_4 was studied by Landis and Darnell [49]. The direct reaction of Th + I(g) was studied by Allen and Yost [50] but their data appear to be inconsistent.

URANIUM (Table IV)

$UO_2(c)$, $UO_3(c)$, $U_3O_8(c)$ The values of ΔHf for these oxides are linked through the combustion measurements of Huber, Holley, and Meierkord [51], Gerdamian et al. [52], Popov and Ivanov [53], and the solution measurements of Burdese and Abbatista [54]. Calorimetric S° values have been taken from Jones, Gordon and Long [55] and Westrum and Gronwald [56].

$U_3O_7(c)$ Mukaibo et al. [57] obtained -843. and -817. kcal/mole for $U_3O_7(c)$ based on DTA calorimetry for reactions involving U_3O_8 and UO_2, respectively. Westrum and Gronwold [58] measured S°.

$U_4O_9(c)$ The heat of formation has been calculated from the solution calorimetry of Burdese and Abbatista [54]. The decomposition pressure data of Duquesnoy et al. [59] are not internally consistent. The entropy was measured by Osborne, Westrum, and Lohr [60].

$UF_4(c)$ The equilibrium measurements of Doniange and Wohlhuter [61] yield ΔHf = -451.5 kcal/mole; the solution calorimetry of Mal'tsev [62] yields -450.7 kcal/mole, based on the value selected for $UCl_4(c)$. The entropy was measured by Burns, Osborne, and Westrum [63].

$UF_5(c)$ Priest [64] studied the disproportionation of $UF_5(c)$ to $UF_4(c)$ and $UF_6(g)$. The data do not distinguish between α- and β-forms of UF_5.

$UF_6(c)$ Settle, Feder and Hubbard [65] measured the direct heat of fluorination. The entropy is taken from the heat capacity measurements of Brickwedde, Hoge, and Scott [66].

$U_2F_9(c)$, $U_4F_{17}(c)$ The values of ΔHf are calculated from the heats of disproportionation measured by Agron [67]. The data are not very self-consistent; values for U_2F_9 range from -936. to -948. kcal/mole.

$UCl_3(c)$ The heat of solution measurements of MacWood [68] yield ΔHf = -212.2 kcal/mole; the equilibrium data of Altman [69] on UCl_4-UCl_3-H_2-HCl yield -213.0 kcal. The high temperature disproportionation data of Shchukarev et al. [70] are somewhat low. There is no entropy data.

$UCl_4(c)$ The data of MacWood [68] and Argue et al. [71] are in good agreement.

$UCl_5(c)$ MacWood [68] obtained ΔHf = -262.3 kcal/mole from heat of solution data. Martin and Eldau [72] measured the decomposition pressure of Cl_2 over UCl_5-UCl_4; from their data we calculate ΔHf = -259.4 kcal/mole.

$UCl_6(c)$ See MacWood [68].

$UOCl_2(c)$ The value is based principally on the heat of solution data of MacWood [68]. Mueller [73] and Shchukarev et al. [74] measured the pressure of $UCl_4(g)$ over $UOCl_2$. The entropy was measured by Greenberg and Westrum [75].

$UO_2Cl_2(c)$ The value of ΔHf is based on the heats of solution in $FeCl_3$-HCl mixtures by Shchukarev [70].

TUNGSTEN (Table V)

$WO_2(c)$ Values of ΔHf obtained by bomb combustion are -137., -140.94, -134.8 kcal/mole [76, 77, 78]. High temperature equilibrium data yield -135., -137., -133., -136.6, -137.1 kcal/mole [76, 79, 80, 81, 82]. King, Weller and Christiansen [83] measured the entropy.

$WO_3(c)$ The values of ΔHf obtained by combustion are -201.46 and -200.84 kcal/mole by Mah [77] and Huff, Squitieri and Snyder [84], respectively. The value of S° is from King et al. [83]; Seltz et al. [85] report S° = 19.9 cal/deg mole.

$H_2WO_4(c)$ From the decomposition pressure measurements of Hüttig and Kurre [86].

$WF_6(liq)$ The value of ΔHf is calculated from the data of Myers and Brody [87] on the heats of solution in aqueous NaOH.

$WCl_2(c)$, $WCl_4(c)$, $WCl_5(c)$ The heats of formation are calculated from the reduction equilibria measurements of Novikov et al. [88], the combustion data of Shchukarev et al. [89] on $WCl_2(c)$ and the disproportionation equilibria measurements of Shchukarev, Novikov et al. [90].

$WCl_6(c)$ We have calculated ΔHf from the heat of solution data of Shchukarev, Vasil'kova and Novikov [91] for $WCl_6(c)$ in NaOH. The phosphorus reduction equilibrium measurements of Novikov et al. [88] lead to ΔHf = -150. kcal/mole. Vernon [92] studied the high temperature decomposition of $WCl_6(g)$ to W(c) and $Cl_2(g)$. From his data we have calculated ΔHf $WCl_6(g)$ = -130. kcal/mole, in good agreement with the available sublimation data for WCl_6.

TANTALUM (Table VI)

$TaO_2(c)$ The only data are those of Samsonov [93] on the reduction by C.

$Ta_2O_5(c)$ The three most recent heat of combustion measurements [94, 95, 96] are in satisfactory agreement, -488.8, -487.7, and -489.3 kcal/mole. The earlier measurements range from -479 to -500 kcal/mole. Kelley [97] measured S°.

$TaF_5(c)$ Greenberg et al. [98] measured directly the heat of fluorination.

$TaCl_2(c)$ Shchukarev et al. [99] measured the heat of oxidation of $TaCl_2$ to $Ta_2O_5(c)$; his data yield ΔHf = -93 kcal. They also studied the disproportionation to $TaCl_5(c)$ and obtained -96. kcal/mole.

$TaCl_3(c)$ From the disproportionation reaction studied by Kurbanov [100].

$TaCl_4(c)$, $TaCl_5(c)$ Schäfer and Kahlenberg [101] measured the heats of solution in aqueous HF. Their value for ΔHf of $TaCl_5$, -205.0 kcal/mole, is in fair agreement with the value -205.52 kcal/mole reported by Gross, Hayman, Levi and Wilson [102].

BIBLIOGRAPHY

1. I. A. Makolkin, Zhur. Fiz. Khim. 16, 13 (1942).
2. F. Fried, Z. physik. Chem. 123, 406 (1926).
3. D. F. Smith and H. K. Woods, J. Am. Chem. Soc. 45, 2632 (1923).
4. H. M. Spencer and J. H. Mote, J. Am. Chem. Soc. 54, 4618 (1932).
5. J. Thomsen, "Thermochem. Untersuch.," J. A. Barth, Leipzig (1882-6).
6. W. A. Roth, J. prakt. Chem. [2], 158, 117 (1941).
7. K. K. Kelley, L. H. Adami and E. G. King, U.S. Bur. Mines RI6197 (1963).
8. L. Shartsis and E. S. Newman, J. Am. Ceram. Soc. 31, 213 (1948).
9. W. J. Hamer, J. Am. Chem. Soc. 57, 9 (1935).
10. S. J. Bone, K. P. Singh, and W. F. K. Wynne-Jones, Electrochim. Acta 4, 1288 (1961).
11. D. J. Brown and J. C. Zimmer, J. Am. Chem. Soc. 52, 1 (1930).
12. J. Krustinsons, Z. Elektrochem. 43, 65 (1937).
13. L. V. Andrews and D. J. Brown, J. Am. Chem. Soc. 56, 388 (1934).
14. W. Reinders and L. Hamburger, Z. anorg. Chem. 89, 71 (1914).

15. P. Chartier, Ber. Bunsenges. physik. Chem. 68, 404 (1964).

16. K. K. Kelley and E. G. King, U.S. Bur. Mines Bull. 592 (1961).

17. P. Gross, C. Hayman, and D. L. Levi, Met. Soc. Conf. 8, 903 (1961).

18. H. von Wartenberg, Z. anorg. Chem. 244, 337 (1940).

19. K. Jellinek and A. Rudat, Z. anorg. Chem. 175, 281 (1928).

20. W. Jahn-Held and K. Jellinek, Z. Elektrochem. 42, 401 (1936).

21. R. J. Priepke and W. C. Vosburgh, J. Am. Chem. Soc. 52, 4831 (1930).

22. R. H. Gerke, J. Am. Chem. Soc. 44, 1684 (1922).

23. Y. K. Delimarskii and Y. G. Roms, Ukrain. Khim. Zhur. 29, 781 (1963).

24. A. G. Bagdasarian, Trans. Am. Electrochem. Soc. 51, 449 (1927).

25. J. Y. Cann and A. C. Taylor, J. Am. Chem. Soc. 59, 1987 (1937).

26. W. C. Vosburgh and V. H. Dibeler, J. Am. Chem. Soc. 61, 2522 (1939).

27. F. L. E. Shibata, Y. Kobayashi, and S. Furukawa, J. Chem. Soc. (Japan) 52, 404 (1931).

28. F. Ishikawa and G. Kimura, Sexagint. Y. Osaka Chem. Inst. Kyoto Imp. Univ. 1927, 255.

29. T. W. Bauer and H. L. Johnston, J. Am. Chem. Soc. 75, 2217 (1953).

30. A. B. Garrett and A. E. Hirschler, J. Am. Chem. Soc. 60, 299 (1938).

31. G. B. Taylor and G. A. Hulett, J. Phys. Chem. 17, 565 (1913).

32. G. G. Koerber and T. DeVries, J. Am. Chem. Soc. 74, 5008 (1952).

33. Z. Shibata and K. Niwa, J. Fac. Sci., Hokkaido Univ. Ser. III. 2, 183 (1938).

34. L. Troost and P. Hautefeuille, Compt. rend. 8D , 700 (1875).

35. S. R. Gupta, G. J. Hills, and D. J. G. Ives, Trans. Faraday Soc. 59. 1886 (1963).

36. R. Varet, Ann chim. phys. [7] 8, 79 (1896).

37. D. W. Magee, Ph.D. Thesis, Ohio State University (1955).

38. K. K. Kelley, U.S. Bur. Mines Bull. 383, (1935).

39. W. C. Vosburgh, J. Am. Chem. Soc. 50, 2386 (1928).

40. W. A. Roth and G. Becker, Z. physik Chem. A159, 1 (1932).

41. E. J. Huber, Jr., and C. E. Holley, Jr., J. Am. Chem. Soc. 74, 5530 (1952).

42. D. W. Osborne and E. F. Westrum, Jr. , J. Chem. Phys. 21, 1884 (1953).

43. A. J. Darnell, J. Inorg. Nucl. Chem. 15, 359 (1960).

44. H. R. Lohr, D. W. Osborne, and E. F. Westrum, Jr., J. Am. Chem. Soc. 76, 3837 (1954).

45. E. Chauvenet, Ann. chim. phys. [8] 23, 425 (1911).

46. L. Eyring and E. F. Westrum, Jr., J. Am. Chem. Soc. 72, 5555 (1950).

47. von Wartenberg, Z. Elektrochem. 15, 866 (1909).

48. J. J. Egan, W. McCoy and J. Bracker, Symp. Thermodyn. Nucl. Mater., Vienna (1962).

49. A. L. Landis and A. J. Darnell, unpublished data.

50. T. L. Allen and D. M. Yost, J. Chem. Phys. 22, 855 (1954).

51. E. J. Huber, Jr., C. E. Holley, Jr., and E. H. Meierkord, J. Am. Chem. Soc. 74, 3406 (1952).

52. P. Gerdamian, F. Marucco and M. Dode, Compt. rend. 256, 2591 (1963).

53. M. M. Popov and M. I. Ivanov, Atomnaya Energ. 2, 360 (1957).

54. A. Burdese and F. Abbatista, Ricerca Sci. 28, 1634 (1958).

55. W. M. Jones, J. Gordon, and E. A. Long, J. Chem. Phys. 20, 695 (1952).

56. E. F. Westrum, Jr., and F. Gronwald, J. Am. Chem. Soc. 81, 1777 (1959).

57. T. Mukaibo, K. Naito, K. Sato, and T. Uchijima, Symp. Thermodyn. Nucl. Materials, Vienna (1962).

58. E. F. Westrum, Jr., and F. Gronwald, J. Phys. Chem. Solids 23, 39 (1962).

59. A. Duquesnoy and F. Marion, Compt. rend. 258, 5657 (1964).

60. D. W. Osborne, E. F. Westrum, Jr., and H. R. Lohr, J. Am. Chem. Soc. 79, 529 (1957).

61. L. Domange and M. Wohlhuter, Compt. rend. 228, 1591 (1949).

62. V. A. Mal'tsev, Y. V. Gagarinskii, and M. M. Popov, Zhur. Neorg. Khim. 5, 228 (1960).

63. J. H. Burns, D. W. Osborne and E. F. Westrum, Jr., J. Chem. Phys. 33, 387 (1960).

64. H. F. Priest, in U.S.A.E.C. TID 5290, Katz and Rabinowitz, ed. p. 738 (1958).

65. J. L. Settle, H. M. Feder, and W. N. Hubbard, J. Phys. Chem. 67, 1892 (1963).

66. F. G. Brickwedde, H. J. Hoge, and R. B. Scott, J. Chem. Phys. 16, 429 (1948).

67. P. A. Agron, U.S. AECD-1878 (Jan. 1948).

68. G. E. MacWood, MDDC-657, (1946).

69. D. Altman, in M.E. Mueller, U.S.AECD-2029 (1948).

70. S. A. Shcnukarev, I. V. Vasil'kova, N. S. Martynova, and Y. G. Mal'tsev, Zhur. Neorg. Khim. 3, 2647 (1958).

71. G. R. Argue, E. E. Mercer and J. W. Cobble, J. Phys. Chem. 65, 2041 (1961).

72. H. Martin and K. H. Eldau, Z. anorg. Chem. 251, 295 (1943).

73. M. E. Mueller, AECD-2029 (1948).

74. S. A. Shchukarev, I. V. Vasil'kova, A. I. Efimov, and V. P. Kerdyashev, Zhur. Neorg. Khim. 1, 2272 (1956).

75. E. Greenberg and E. F. Westrum, Jr., J. Am. Chem. Soc. 78, 5144 (1956).

76. R. C. Griffis, J. Electrochem. Soc. 105, 398 (1958).

77. A. D. Mah, J. Am. Chem. Soc. 81, 1582 (1959).

78. M. P. Morozova and L. Getskina, Vestnik Leningrad Univ. 14, Ser. Fiz. i Khim. No. 4, 128 (1959).

79. G. R. St. Pierre, W. T. Ebihara, M. J. Pool, and R. Speiser, Trans. AIME 224, 259 (1962).

80. J. Bousquet and G. Perachon, Compt. rend. 258, 934 (1964).

81. Y. I. Gerasimov, I. A. Vasil'eva, T. P. Chusova, V. A. Geiderikh, and M. A. Temofeeva, Doklady Akad.Nauk SSR 134, 1350 (1960).

82. R. J. Ackermann and E. G. Rauh, J. Phys. Chem. 67, 2596 (1963).

83. E. G. King, W. W. Weller, and A. U. Christensen, U.S. Bur. Mines RI 5664, (1960).

84. G. Huff, E. Squitieri, and P. E. Snyder, J. Am. Chem. Soc. 70, 3380, 4279 (1948).

85. H. Seltz, F. J. Dunkerley, and B. J. DeWitt, J. Am. Chem. Soc. 65, 600 (1943)

86. G. F. Hüttig and B. Kurre, Z. anorg. Chem. 126, 167 (1923).

87. O. E. Myers and A. P. Brady, J. Phys. Chem. 64, 591 (1960).

88. G. I. Novikov, N. V. Andreeva, O. G. Polyachenok, Zhur. Neorg. Khim. 6, 1990 (1961).

89. S. A. Shchukarev, G. I. Novikov, and I. V. Vasil'kova, Zhur. Neorg. Khim. 5, 1650 (1960).

90. S. A. Shchukarev, G. I. Novikov, and N. V. Andreeva, Vestnik Leningrad Univ. 4, Ser. Fiz. i Khim. 1, 120 (1959).

91. S. A. Shchukarev, I. V. Vasil'kova, and G. I. Novikov, Zhur. Neorg. Khim. 3, 2642 (1958).

92. A. A. Vernon, J. Am. Chem. Soc. 59, 1832 (1937).

93. G. V. Samsonov, Ukrain. Khim. Zhur. 23, 287 (1957).

94. G. L. Humphrey, J. Am. Chem. Soc. 76, 978 (1954).

95. E. J. Huber, Jr., E. L. Head, and C. E. Holley, Jr., J. Phys. Chem. 67, 793 (1963).

96. A. N. Kornilov, V. Y. Leonidov, and S. M. Skuratov, Doklady Akad. Nauk SSR 144, 355 (1962).

97. K. K. Kelley, J. Am. Chem. Soc. 62, 818 (1940).

98. E. Greenberg, C. A. Nathe, and W. N. Hubbard (to be published).

99. S. A. Shchukarev, E. K. Smirnova, and A. R. Kurbanov, Doklady Akad. Nauk Tadzhik SSR 5, No. 4, 14 (1962).

100. A. R. Kurbanov, A. V. Suvorov, S. A. Shchukarev, and G. I. Novikov, Zhur. Neorg. Khim. 9, 520 (1964).

101. H. Schäfer and F. Kahlenberg, Z. anorg. Chem. 294, 242 (1958).

102. P. Gross, C. Hayman, D. L. Levi, and G. L. Wilson, Trans. Faraday Soc. 56, 318 (1960).

Table I

LEAD COMPOUNDS

Compound	State	$\Delta Hf°$ kcal/mol	$\Delta Gf°$ kcal/mol	S° cal/deg mol
PbO	c,red	-52.34	-45.16	15.92
	c,yellow	-51.94	-44.91	16.4
PbO_2	c	-66.3	-51.95	16.4
Pb_3O_4	c	-171.7	-143.7	50.5
PbF_2	c	-158.7	-147.5	26.4
$PbCl_2$	c	-85.90	-75.08	32.5
PbI_2	c	-41.94	-41.50	41.79

Table II

MERCURY COMPOUNDS

Compound	State	$\Delta Hf°$ kcal/mol	$\Delta Gf°$ kcal/mol	S° cal/deg mol
HgO	c,red	-21.65	-13.99	16.8
	c,yellow	-21.65	-13.96	16.7
HgF_2	c	---	---	---
Hg_2F_2		-117.	---	---
$HgCl_2$	c	-53.5	-42.5	34.5
Hg_2Cl_2	c	-63.39	-50.377	46.0
HgI_2	c	-25.1	-24.6	44.
Hg_2I_2	c	-28.90	-26.58	56.3

Table III

THORIUM COMPOUNDS

Compound	State	ΔHf° kcal/mol	ΔGf° kcal/mol	S° cal/deg mol
ThO	c	---	---	---
ThO_2	c	-293.2	-279.4	15.59
ThF_4	c	-503.5	-480.9	33.95
$ThCl_4$	c	-291.	-273.	58.
ThI_4	c	-200.	---	---

Table IV

URANIUM COMPOUNDS

Compound	State	ΔHf° kcal/mol	ΔGf° kcal/mol	S° cal/deg mol
UO_2	c	-258.5	-245.9	18.63
UO_3	c	-293.4	-274.9	23.57
U_3O_7	c	-819.	-775.	59.5
U_3O_8	c	-853.4	-804.3	67.53
U_4O_9	c	-1084.	-1028.	80.29
UF_4	c	-451.1	-429.4	36.25
UF_5	c	-488.6	---	---
UF_6	c	-522.64	-491.91	54.3
U_2F_9	c	-942.	---	---
U_4F_{17}	c	-1850.	---	---
UCl_3	c	-212.2	---	---
UCl_4	c	-251.2	---	---
UCl_5	c	-261.	---	---
UCl_6	c	-272.6	---	---
$UOCl_2$	c	-262.	---	---
UO_2Cl_2	c	-290.	---	---

Table V

TUNGSTEN COMPOUNDS

Compound	State	$\Delta Hf°$ kcal/mol	$\Delta Gf°$ kcal/mol	S° cal/deg mol
WO_2	c	-139.	-125.7	12.08
WO_3	c	-201.0	-182.2	18.14
H_2WO_4	c	-280.2	---	---
WF_6	c	-427.	---	---
WCl_2	c	-62.	---	---
WCl_4	c	-118.	---	---
WCl_5	c	-132.	---	---
WCl_6	c	-151.8	-120.0	61.

Table VI

TANTALUM COMPOUNDS

Compound	State	$\Delta Hf°$ kcal/mol	$\Delta Gf°$ kcal/mol	S° cal/deg mol
TaO_2	c	-190.	---	---
Ta_2O_5	c	-488.5	-456.3	34.2
TaF_5	c	-454.98	---	---
$TaCl_2$	c	-94.	---	---
$TaCl_3$	c	-135.	---	---
$TaCl_4$	c	-168.8	---	---
$TaCl_5$	c	-205.3	---	---

Chapter B4

A SURVEY OF THE THERMODYNAMIC DATA ON HEAVIER ELEMENTS AND THEIR COMPOUNDS: HIGH-TEMPERATURE ENTHALPY AND VAPORIZATION EQUILIBRIA

(from the Proceedings of the Third Meeting of the Interagency Chemical Rocket Propulsion Working Group on Thermochemistry, El Segundo, California, March 1965)

by Thomas B. Douglas

ABSTRACT

A comprehensive, though not all-inclusive, survey of the published literature was undertaken for the purpose of determining where high-temperature enthalpy and vaporization-equilibrium data appear to be lacking or inadequate for Ti, Zr, W, Pb, Hg, I, Hf, Th, U, and their light-element compounds considered to be of possible importance in chemical propulsion and refractory applications. The results of this survey are summarized, and several examples are presented of the effects of uncertainties in the standard thermodynamic properties on calculated equilibria at high temperatures. It is pointed out that the first ionization potential of a molecule containing one alkali atom can be expected to exceed that of the free alkali atom by approximately the dissociation energy of the neutral molecule; and this relation is verified, within experimental uncertainty, for several examples.

INTRODUCTION

Three major areas of interest relative to the use of heavier elements and their compounds in chemical-propulsion applications are:

(1) Contribution to propulsion efficiency
(2) Suitability as stable refractories
(3) Efficiency as sources of or sinks for electrons

In the sense that these areas emphasize the ensemble of thermodynamic properties somewhat differently, the greater part of the material of this paper is included with item (1) primarily in mind, though items (2) and (3) will receive limited comment.

For present purposes the term "heavier elements" may be taken to comprise the elements below the first two rows in the Periodic Table. Elsewhere in this meeting the bearing of heavier chemical elements on propulsion efficiency was discussed, and several promising such elements were identified [1]. Those reviewed in the present paper are:

(1) Ti, Zr, W ("active-element" propellants)
(2) Pb, Hg, I ("inert-element" propellants)
(3) Hf, Th, U ("active-element" propellants receiving secondary consideration)
(4) Na, K (impurities important as electron sources)

JANAF tables have been issued for these elements and many of their compounds -- except none thus far for Hf, Th, U, and their compounds [4].

The species reviewed here are limited to the free elements and their compounds with F, Cl, O, H, N, C, and/or B, and in addition the iodides of Be, Al, and Li. Since the calorimetrically determined heats of formation and entropies are discussed elsewhere in this meeting [2], the present review will be limited to the high-temperature data on enthalpy and on congruent and non-congruent vaporization equilibria, including the properties often derivable using such data (gas dissociation energies, etc.). Such data as are available for mixed systems (phase diagrams, etc.), which are important in multi-component applications, were not examined.

While it is hoped that the following summarized review will constitute a picture of the existing-data situation which is fairly accurate in general, it should be emphasized that some particular statements as to lack or adequacy of data will be incorrect, partly because some important investigations in the area covered did not come to our attention and partly because a much greater time would be required to review the existing data critically enough to justify independent judgments as to their interconsistency and relative merit. Principal reliance was placed on several important reviews, compilations, and bibliographies published within the past 15 years [4-15]. Many of these reviews and compilations include expert evaluation, but most can hardly be considered up-to-date at the present time. The recent bibliographies [14,15] that were used systematically, which do not cover the published literature beyond 1963, indicate an accelerated output of thermodynamic data on the heavier elements within the past few years, and also that approximately half of these publications are by Russian investigators.

In systematically examining thermodynamic data for a specific application, one should of course try to judge their adequacy or lack of it not by laboratory standards but in relation to the practical needs. In most cases the most important way in which the standard heat of formation and entropy of each species contribute to the total energy of the high-temperature equilibrium system may be said to be in determining how much of the species will be present -- in other words, the contribution of the species to the equilibrium constants of all reactions involving it. In trying to pay particular attention to those species which may be important in this sense, we have chosen two rather extreme high temperatures, 2000° and 5000°K. From the fundamental thermodynamic relation

$$R \ln K_p = \Delta S^\circ - (\Delta H^\circ/T) \qquad (1)$$

it is apparent that, other things being correct, an error of a factor of ten in the calculated equilibrium constant of formation of a gas at 2000°K is made by an error of 9 kcal/mole in the standard heat of formation. The same error in K_p at 5000°K requires an error of 23 kcal/mole (1 eV), and the same error in K_p at any temperature arises from an error in the standard entropy of about 5 e.u./mole.

Next the data status will be summarized, taking the six elements Ti, Zr, Hf, Th, W, and U together but discussing separately each class of their compounds. Many of the oxides and halides are important in oxidizing but not in reducing atmospheres, but it will be assumed that both conditions must be considered.

DATA STATUS: Ti, Zr, Hf, Th, W, U

Free Elements. Good heat-capacity measurements on the solid metals extend to about 1400°K for Ti, Hf, and Th, and to near the melting point for Zr, U, and W. No directly measured heats of fusion nor liquid heat capacities were found, though vapor-pressure measurements on both solid and liquid uranium seem to provide an experimental value for its heat of fusion. Some vaporization data exist for all six metals, and although the uncertainties in the heats of vaporization of Ti, Zr, and Hf have been variously estimated as from 5 to 10 kcal/mole, the vapor pressures of these metals below 4000° or 5000°K are so low that uncertainties of this order are hardly serious.

Hydrides. These metals all form solid hydrides whose compositions are variable over continuous ranges, and whose tendency to be rather decidedly exothermic may limit their importance as fuels. However, they are not stable enough at high temperatures to be important combustion products. The gaseous hydrides may not be important high-temperature species even under reducing conditions, but there appear to be no data on them.

Oxides. The solid-oxide phases show continuously variable regions of composition whose limits tend to be rather complex. The solid oxides approximating the dioxide composition are probably the most important, and heat-capacity data on those of Ti, Zr, Hf, Th, and U exist up to at least 1500°K (and up to 900°K for UO_3). But we found no calorimetric heats of fusion nor liquid heat capacities. Experimental values for their heats of fusion are available from phase diagrams, but this source is usually not very reliable. The principal known gaseous oxides have the empirical formulas MO and MO_2 -- with MO_3 also in the cases of tungsten and uranium, which can be hexavalent. Numerous vaporization studies have been made which give thermodynamic data for all these gaseous oxides except, apparently, for those of hafnium. The data for TiO, ThO, UO, and UO_3 are poor or deficient, but those for TiO_2, ZrO, and ZrO_2 apparently show fair precision or agreement. The several studies yielding data for ThO_2 and UO_2 show poor agreement, and Brewer and Rosenblatt [12] assigned uncertainties of ±15 kcal/mole to their dissociation energies. Of these six metals, the greatest number of vaporization studies seems to have been made on the oxides of tungsten, and some of the large discrepancies for these oxide species suggest that had more work been done on the oxides of the other five metals, their existing data might seem to be less satisfactory.

O-H Compounds. The only gaseous compound of any of these six metals with hydrogen and oxygen for which we found any thermodynamic data is H_2WO_4, tungstic acid (discussed later). It might be expected that simpler gas molecules (such as MOH) are of some importance at very high temperatures, though, so far as we know, no such species have been reported.

Fluorides and Chlorides. The halides are in general considerably more volatile than the oxides, so that condensed-phase high-temperature enthalpy data are less essential. The following remarks apply to vaporization data unless otherwise qualified.

The data are most complete for the fluorides and chlorides of titanium,

zirconium, and tungsten, and apparently are quite satisfactory for the saturated compounds (TiX_4, ZrX_4, and WX_6), as well as for WCl_4, WCl_5, and probably WF. The vibrational spectrum of TiCl has been observed, and yields a dissociation energy which, however, appears of low reliability. But the data for the subhalides of titanium seem to be of poor quality, and the dissociation energies of (gaseous) WCl_2 and the subhalides of zirconium are estimated only, though some of these are probably rather important high-temperature species. Very few data were found for any of the halides of hafnium and thorium. Vaporization data exist for the tetrahalides and hexahalides of uranium; solid UF_4, however, seems to lack high-temperature heat-capacity data.

Oxyfluorides and Oxychlorides. Many of these are probably species of considerable importance, but about the only existing data are for WOF_4, $WOCl_4$, and WO_2Cl_2, which seem fairly good. The only data found for uranium compounds in this class were heat-capacity measurements on solid UO_2F_2 up to 425°K.

Nitrides, Carbides, and Borides. The only existing high-temperature enthalpy data seem to be on TiC, TiN, TiB_2 (to 1000°K only), Th_3N_4, ZrN, Zr_3N_2, ZrB_2, and UC_2. An estimated dissociation energy of ZrN(g) suggests its lack of importance at high temperatures; but no data were found for any gaseous species in this class. Some scattered vaporization-equilibrium studies have been reported which provide some data on solid nitrides, carbides, and borides of titanium and zirconium and on the solid carbides of hafnium, thorium, tungsten, and uranium. However, it appears that all the solid compounds in this class vaporize by decomposition to the free elements, and that such equilibria, if they involve pure solid phases (as is usually assumed), could be much more reliably calculated with the use of good thermal data on the solid compounds. This situation is illustrated by a critical discussion by G. T. Furukawa of the various data for solid Al_4C_3, which also decomposes to the free elements [16].

DATA STATUS: Pb, Hg, I

Lead, mercury, and iodine are all relatively volatile elements, and their thermodynamic data in the free state are in excellent shape. Although often referred to as "inert" elements, some of their compounds are sufficiently important under certain conditions at high temperatures as to require attention. The thermodynamic data seem good and fairly complete, for the condensed and gaseous states, for PbO and its gaseous polymers, $PbCl_2$, HgCl, $HgCl_2$, HI, IF, ICl, IF_5, and the various iodides of aluminum and lithium. The data for PbCl(g) appear to need improvement, and better data are needed for gaseous HgF and the fluorides of lead. On the other hand, the dissociation energies of the iodides of beryllium are probably still in the estimation stage, and no data were found for simple molecules such as IO, IF_2, IOF, and PbOF which, without convincing arguments to the contrary, probably should be considered of some possible importance in oxidizing atmospheres at high temperatures.

SOME EXAMPLES

Certain thermodynamic properties of a few substances covered above are discussed below in three cases, not because the specific cases

themselves are uniquely important but because they illustrate three general problems.

A Recent Thermodynamic Table for $H_2WO_4(g)$. An earlier JANAF table [4] for this species was based on three high-temperature studies of the equilibrium

$$WO_3(c) + H_2O(g) = H_2WO_4(g) \qquad (2)$$

and, in the absence of spectroscopic data on H_2WO_4, on estimated molecular constants, including the 15 vibrational frequencies, by analogy with experimental ones reported for H_2SO_4. Recently the table was revised to accord with a more precise study, published last year, of the equilibrium

$$W(c) + 4H_2O(g) = H_2WO_4(g) + 3H_2(g); \qquad (3)$$

the frequencies were still estimated by analogy with H_2SO_4, but were adjusted so as to give the Second-Law entropy value S°_{1600} derived from the new equilibrium data. Compared with the earlier table, the new one gives higher values of ΔHf°_{1600} and S°_{1600} by approximately 14 kcal and 10 e.u. per mole respectively; and as a consequence $H_2WO_4(g)$ is represented in the new table as being many times as important a high-temperature species.

We have not examined the basic data mentioned and hence are not prepared to pass an opinion on the wisdom of the data treatments which led to the two tables. It can be said, however, that there are cases where such high-temperature equilibrium studies are (or could be made) sufficiently reliable and precise as to establish fairly good Second-Law heat-of-formation and entropy values for the gas species at some elevated temperature in the range of the measurements. When this is true, the heat capacity (as that of H_2WO_4) is likely to be so near equipartitional above the temperature in question that extension of the thermodynamic properties of the gas to all higher temperatures is quite insensitive to a completely estimated frequency assignment. (This assumes that the usual harmonic-oscillator rigid-rotor approximation for such polyatomic gases is used.) The thermodynamic parameters at 298°K may still be in considerable doubt, but it is doubtful whether a species such as $H_2WO_4(g)$ will ever be observed in equilibrium at such low temperatures anyhow. However, it would be unrealistic not to realize, in connection with a survey of available thermodynamic data, that the existence of a complete but bare-minimum set of precise data would be deceptive if they contain large systematic errors which might be revealed only by additional data of the same type or, better, of another type (spectroscopic in the present case).

Important Tungsten Species in the W-O-H System. On the basis of the latest JANAF tables [4] and the results of an additional investigation [17], we have examined the relative stabilities of known tungsten species in the W-O-H system. The more important of these are listed for 2000° and 5000°K in Table I — approximately in the order of relative importance, though this obviously depends on the composition and total pressure of the system. A somewhat similar table was presented elsewhere in this meeting, and was used to point out that even at high temperatures the gaseous oxides of tungsten are sufficiently important species to justify, for practical reasons, careful evaluation of their properties [3].

TABLE I. IMPORTANT TUNGSTEN SPECIES IN THE W-O-H SYSTEM

2000°K	5000°K
$W(c)^*$	$W(\ell)^*$
$WO_2(c)^*$	$WO(g)$
$WO_3(\ell)$	$WO_3(g)$
$W_3O_9(g)$	$WO_2(g)$
$W_3O_8(g)^*$	$W_2O_6(g)$
$W_4O_{12}(g)$	$W_3O_9(g)$
$H_2WO_4(g)$	$W_4O_{12}(g)$

*Under reducing conditions only

It appears that WO(g), which is highly unimportant at 2000°K, is the most important tungsten-oxide species at 5000°K under both oxidizing and reducing conditions. As is well known, this fact exemplifies the common increasing relative importance of the simpler species at the highest temperatures, owing to their relatively higher entropy of formation and the increasing predominance of this factor (equation 1). At the same time, the case of WO(g) serves to point out that the failure to detect experimentally some simpler gaseous species at relatively low temperatures (say, 2000°) is generally not reliable evidence of its unimportance at considerably higher temperatures.

The Dissociation Energy of ZrF(g). The difficulties in estimating sublimation or dissociation energies need no introduction, and so can be illustrated dramatically by an older and a revised preliminary table for ZrF(g) [4] without reflecting discredit on those who generated the tables. The two tables differ essentially only in their two widely different values for the dissociation energy of the molecule, which were estimated using the dissociation energies listed in Table II, parts (a) and (b) respectively.

TABLE II. COMPARISON OF TWO TABLES FOR ZrF(g)

(a) Correlation Used for Older Tables

ZrF:	D = 1 x 174 ±30	kcal/mole	(estimated)
ZrF_2:	D = 2 x 164 ±25	" "	(")
ZrF_3:	D = 3 x 157 ±30	" "	(")
ZrF_4:	D = 4 x 154 ±3	" "	("thermochemical")

(b) Correlation Used for Newer Tables

ZrF:	D = 47.5 ±10 (estimated)	TiF:	D = 38 ±20 (estimated)
ZrCℓ:	D = 36.2 ±10 (")	TiCℓ:	D = 30 ±20 (spectrosc.)
ZrO:	D = 183 ±5 (Mass spec.)	TiO:	D = 186 ±5 (exptl.)

(c) Tabulated log K_pf° for ZrF(g)

Table	2000°K	5000°K
Older	+5.9	+3.9
Newer	-8.0	-1.6

On the basis of the mean experimental Zr-F bond energy in ZrF_4, the dissociation energy of ZrF was taken to be 174 ±30 kcal/mole in the older table, but was revised to 47.5 ±10 kcal/mole in the newer table on the basis of more recent experimental data on a few diatomic zirconium and titanium species. As shown in part (c) of Table II, the two thermodynamic tables differ, with respect to the amount of ZrF(g) predicted to be present under given conditions, by a factor of 10^{14} at 2000° and by a factor of $10^{5.5}$ at 5000°K! The example of ZrF recalls the comparably large spread of dissociation-energy values for BeF advocated until quite recently. It should be easy to distinguish between two such large values by a rough experimental determination of the abundance of the molecule under suitable conditions.

A FEW SELECTED REFRACTORIES

No attempt is made here to review the data status on all the heavy elements and their compounds which are used or have potential use as refractories in high-temperature applications. The nominal formulas of a few such substances which are said to have outstanding qualifications are listed in Table III — together with, in °K, their approximate melting points (some averaged from different sources) and the highest temperatures to which experimentally determined heat capacities seem to be available. According to our information TiC, ZrB_2, and ZrO_2 lack heat-capacity data for considerable temperature ranges below their melting points.

TABLE III. SOME IMPORTANT REFRACTORIES

Nominal Formula	Melting Point (°K)	C_p Measured to (°K)
Ta	3260	2940
Mo	2880	M.P.
W	3680	M.P.
TiC	3490	1735
ZrB_2	3310	1125
ThO_2	3320	2750
ZrO_2	3000	1840

According to Jaffee [9], large heavy forgings of the more refractory metals such as tantalum, molybdenum, and tungsten have found recent application for nozzles and control surfaces for solid-fuel propellant rocket systems, since the stresses are not high and oxidation protection is not a problem there. The good thermal conductivity of molybdenum and tungsten is a particular advantage. Westbrook [9] states that ZrB_2 is the boride in which so far the most practical interest has been shown, and that its high melting point, corrosion resistance, and excellent wear resistance make it particularly attractive for high-performance burner systems and rocket nozzles. According to Litz [9], TiC is the metallic carbide which has been studied most exhaustively for high-temperature applications. In addition to its low density, a major advantage is its fairly good thermal shock resistance as compared with other carbides and with oxides; and it is markedly superior to ZrC in high-temperature oxidation resistance.

Of the refractory oxides, ThO_2 is the one whose lack of excessive cost, thermodynamic stability against decomposition, and high melting

point most recommend it for high-temperature use where chemical stability is the chief requirement (Kingery [9]). ZrO_2 has been included in Table III because according to data presented by Schneider [11] it has, when stabilized against transition (as by a few percent of MgO), a much lower brittleness and hence a higher thermal shock resistance (at least up to 1000°C) than Al_2O_3, BeO, MgO, ThO_2, and TiC.

Other thermodynamic properties of the last five substances in Table III have been discussed earlier in this paper. The existing-data status seems to be as good for tantalum and molybdenum metals as for tungsten.

SOME COMMENTS ON IONIZATION

Various aspects of the problems associated with electron production and capture are discussed elsewhere in this meeting. Relative to these problems, the present paper concerns itself only with the adequacy of the thermodynamic data as they affect the predicted electron concentrations, and that only in a limited way.

Taking sodium or potassium as a "heavier" element important as an electron source because of its low atomic ionization potential, one may say that from a thermodynamic standpoint there are three important questions in a given case:

(1) What is the total amount of the element present?

(2) Does its ionization potential change considerably when the free element becomes chemically combined?

(3) What percentages of the element exist free and in various chemical combinations?

Since the answer to the second question is positive, the answer to the third question is important, and this is determined by the thermodynamic data. However, rather than survey the status of these data for sodium, potassium, and their light-element compounds, which is in general quite good, we shall point out here one aspect of the second question above which, despite its simplicity, seems to have gone generally unrecognized.

<u>A Relation Between Ionization Potentials and Dissociation Energies.</u> The relation

$$I(AB) - I(A,B) = D(AB) - D(AB^+) \qquad (4)$$

relates the ionization potential of a molecule AB, the ionization potential of some (or all) of its separated component atoms or radicals A and B, the dissociation energy of the neutral molecule AB, and the dissociation energy of the molecule-ion AB^+. Equation 4 is obviously exact so long as the right-hand side refers to the same dissociation products as are involved in the ionization process whose energy change is I(A,B); it was used thirty years ago to establish consistency (to 0.006 eV) between the quantum-mechanically calculated dissociation energies of H_2 and H_2^+, using accurate experimental values for the two ionization potentials. Furthermore, if it is correct to represent the binding energy of a molecule-ion AB^+ by the electrostatic energy between an ion and a neutral atom or

radical (say A^+ and B), then the coulomb term is zero, the attraction produced by polarization of B by A^+ would ordinarily be small, and equation 4 would simplify to

$$I(AB) - I(A,B) \cong D(AB) \text{ (assuming } D(AB^+) \cong 0) \qquad (5)$$

An example providing quantitative magnitudes is furnished by LiH^+. By a quantum-mechanical calculation Browne [18] recently found that the dissociation energy lies between 0.038 and 0.15 eV and that it is due almost entirely to polarization. (Wilkinson [19] previously estimated the binding energy to be 1.3 ±0.5 eV, but he did so by the use of equation 4 and a value of I(LiH) which Price and his associates [19,20] had obtained by interpolation along an isoelectronic sequence of molecules and which they regarded as uncertain.)

Three Tests of Equation 5. An enlightening test is to calculate the energy of the molecule-ion (at 0°K), relative to neutral atoms, by assuming it to be formed from the ion and the neutral atom (or radical) with zero binding energy. This equals the experimental energy on the same basis, I(AB)-D(AB), if equation 5 holds, but will be higher if $D(AB^+) > 0$. This test was applied to Li_2^+ and LiF^+ using molecular dissociation energies given in the JANAF tables [4] and ionization potentials given in a recent critical summary by Beckett and associates [21], and was applied to MgF^+ with corresponding data from recent work of Ehlert, Blue, Green, and Margrave [22]. Alternative energies of these molecule-ions were calculated also on the basis of formation from other ionic and atomic dissociation products likely to be important, with inclusion of an estimated coulomb term when the combining particles are both ions.

The results for Li_2^+ are as follows:

Form	Relative Energy (eV)
$(Li^+)Li$	5.4
$Li(Li^+)$	5.4
Exptl.	3.8 ±0.2

In this case the molecule-ion is more stable than indicated by equation 5, but this is the result qualitatively expected from quantum-mechanical resonance when two low-energy electronic forms have the same or nearly the same energy.

The results for LiF^+ proved to be:

Form	Relative Energy (eV)
$(Li^+)F$	5.4
$Li(F^+)$	17.4
$(Li^{++})(F^-)$	>55
Exptl.	5.2 ±0.5

In this case equation 5 holds within the experimental uncertainty when applied to the form $(Li^+)F$. (The less stable covalent form (not listed)

is ignored.) $(Li^+)F$ has by far the lowest energy among the different forms, presumably rendering the resonance energy negligible. The form $Li(F^+)$ has a much higher energy because the ionization potential of fluorine is much greater than that of lithium, and in $(Li^{++})(F^-)$ the coulomb attraction is far insufficient to overcome the second ionization potential of lithium, whose unusually large magnitude can be attributed to the absence of a second electron in the valence shell of the atom. (The citation of a lower bound for $(Li^{++})(F^-)$ reflects the negligence of the repulsive energy, which is not germane to the arguments here.)

Replacing LiF^+ by an example of a Group II monofluoride, MgF^+, the results obtained are:

Form	Relative Energy (eV)
$(Mg^+)F$	7.6
$Mg(F^+)$	17.4
$(Mg^{++})(F^-)$	> 2.5
Exptl.	3.2 ±0.3

Here equation 5, applied to the form $(Mg^+)F$, does not hold, a fact which can be traced to the superior stability of the form $(Mg^{++})(F^-)$ because the second ionization potential of Mg, unlike that of an alkali atom, is comparatively low.

Generalization, and Test of Six Cases. From the foregoing three tests it may be supposed that equation 5 is a good approximation for a molecule containing just one atom with a comparatively low first ionization potential but a very high second ionization potential (typically, an alkali atom). This generalization is tested in Table IV for the six such molecules for which both experimental ionization potentials and fairly reliable dissociation energies were readily found (in references [4] and [21]).

TABLE IV. TESTS OF EQUATION 5

Molecule	I (eV) Obs.	I (eV) Calcd. (eq. 5)
LiH	7.85 ±0.2	7.9
NaH	6.5 ±1	7.2
LiF	11.1 ±0.5	11.3
LiI	8.55 ±0.4	8.95
LiO	9.0 ±0.4	8.7
NaOH	9.0 ±1.	9.0

Aside from the fact that uncertainties of the dissociation energies should have been estimated and attached to column 3, columns 2 and 3 agree in all six cases within the uncertainties recorded in column 2. Several other molecule-ions not of this type (OH^+, H_2^+, BeO^+, etc.) were similarly examined, and in every such case, as expected from the foregoing arguments, the reported ionization energy is substantially lower than the value calculated assuming that the dissociation energy of the molecule-ion is neglible.

It appears that the proper application of equation 5 affords a simple approximate check on the consistency between the dissociation energies and the ionization potentials of alkali-containing molecules, and a useful estimate of such an ionization potential if an experimental value is lacking, provided the dissociation-energy value can be relied on. Remembering that D and I apply to 0°K, equation 5 constitutes an easily remembered rule for estimating the decrease of a gaseous alkali metal as an electron source when it enters into a given chemical combination. Furthermore, the fact that such molecule-ions have very low dissociation energies emphasizes their unimportance in high-temperature systems in thermodynamic equilibrium and the corresponding lack of need, in equilibrium applications, for accurate tables of their thermodynamic functions.

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During the assembling of material for this paper Howard W. Flieger, Jr., repeated many of the calculations and checked the conclusions drawn from them, and he and Ralph F. Krause, Jr., assisted in reviewing the published literature.

REFERENCES

[1] J. P. Coughlin, Proceedings of the Third Meeting (March 1965), ICRPG Working Group on Thermochemistry, Vol. I, Chemical Propulsion Information Agency, Silver Spring, Maryland.

[2] D. D. Wagman, ibid.

[3] W. Weltner, Jr., ibid.

[4] JANAF Interim Thermochemical Tables, The Dow Chemical Co., Midland, Mich. (including revisions through Dec. 31, 1964).

[5] "The Chemistry and Metallurgy of Miscellaneous Materials: Thermodynamics," ed. by L. L. Quill, McGraw-Hill Book Co., New York, 1950: L. Brewer, "The Fusion and Vaporization Data of the Halides," pp. 193-275; L. Brewer, L. A. Bromley, P. W. Gilles, and N. F. Lofgren, "The Thermodynamic Properties of Molybdenum and Tungsten Halides and the Use of These Metals as Refractories," pp. 276-311.

[6] G. Herzberg, "Molecular Spectra and Molecular Structure: Diatomic Molecules," 2nd ed., Prentice-Hall, New York, 1950.

[7] D. R. Stull and G. C. Sinke, "Thermodynamic Properties of the Elements," Amer. Chem. Soc., Washington, D. C., 1956.

[8] O. Kubaschewski and E. Ll. Evans, "Metallurgical Thermochemistry," 3rd ed., Pergamon Press, New York, 1958.

[9] "Proceedings of an International Symposium on High Temperature Technology," McGraw-Hill Book Co., New York, 1960: R. I. Jaffee, "Refractory Metals," pp. 61-75; W. D. Kingery, "Oxides for High Temperature Applications," pp. 76-89; L. M. Litz, "Graphite, Carbide, Nitride and Sulfide Refractories," pp. 90-112; J. H. Westbrook, "Silicides, Borides, Aluminides, Intermetallics and Other Unique Refractories," pp. 113-128; M. G. Inghram and J. Drowart,

"Mass Spectrometry Applied to High Temperature Chemistry," pp. 219-240.

[10] K. K. Kelley, "High-Temperature Heat-Content, Heat-Capacity, and Entropy Data for the Elements and Inorganic Compounds," Bureau of Mines Bull. 584, U. S. Government Printing Office, Washington, D.C., 1960.

[11] "Thermoelectricity," ed. by P. H. Egli, John Wiley and Sons, New York, 1960: S. J. Schneider, "Mechanical Properties of Ceramics and Their Measurement at Elevated Temperatures," pp. 342-357; A. W. Searcy and D. J. Meschi, "Chemical Considerations in High Temperature Thermoelectric Power Development," pp. 159-179.

[12] L. Brewer and G. M. Rosenblatt, "Dissociation Energies of Gaseous Metal Dioxides," Chem. Rev. 61, 257-263 (1961).

[13] C. E. Wicks and F. E. Block, "Thermodynamic Properties of 65 Elements — Their Oxides, Halides, Carbides, and Nitrides," Bureau of Mines Bull. 605, U. S. Government Printing Office, Washington, D.C., 1963.

[14] "Annual Review of Physical Chemistry," Annual Reviews, Inc., Palo Alto, Calif.: Vol. 11 (1960); vol. 12 (1961); vol. 13 (1962).

[15] "Bulletin of Thermodynamics and Thermochemistry," ed. by H. A. Skinner, International Union of Pure and Applied Chemistry: No. 6 (1963); no. 7 (1964).

[16] G. T. Furukawa, T. B. Douglas, W. G. Saba, and A. C. Victor, "Heat Capacity and Enthalpy Measurements on Aluminum Carbide (Al_4C_3) from 15° to 1173°K. Thermodynamic Properties from 0° to 2000°K," NBS Report 8186, National Bureau of Standards, Washington, D. C., 1 January 1964, pp. 21-49 (submitted to J. Research NBS, Section A).

[17] R. J. Ackermann and E. G. Rauh, "A Thermodynamic Study of the Tungsten-Oxygen System at High Temperatures," J. Phys. Chem. 67, 2596-2601 (1963).

[18] J. C. Browne, "Binding Energy of LiH^+ and the Ionization Potential of LiH: Mixed Basis Set Calculation," J. Chem. Phys. 41, 3495-3498 (1964).

[19] P. G. Wilkinson, "Diatomic Molecules of Astrophysical Interest: Ionization Potentials and Dissociation Energies," Astrophys. J. 138, 778-800 (1963).

[20] W. C. Price, P. V. Harris, and T. R. Passmore, "The Ionization and Dissociation Energies of Molecules and Radicals," J. Quant. Spectry. and Radiative Transfer 2, 327-333 (1962).

[21] C. W. Beckett and E. C. Cassidy, "List of Ionization Potentials or Electron Affinities of Light Element Compounds," NBS Report 8628, National Bureau of Standards, Washington, D. C. 1 January 1965, pp. 89-111.

[22] T. C. Ehlert, G. D. Blue, J. W. Green, and J. L. Margrave, "Mass Spectrometric Studies at High Temperatures. III. Dissociation Energies of the Alkaline Earth Monofluorides," J. Chem. Phys. 41, 2250-2255 (1964).

Chapter B5

HIGH TEMPERATURE MATRIX SPECTROSCOPY

D. E. Mann and G. V. Calder

1. MgF_2: Magnesium Difluoride

An intensive investigation of the matrix spectrum of gaseous MgF_2 has been underway for some time and is now near completion. While final results may not yet be quoted it is possible to indicate the trend of our present conclusions.

MgF_2 was vaporized at relatively low temperatures (1225-1250°C) in a double-oven Knudsen cell in which the upper stage was about 250°C above the lower portion. It was isolated in fairly dilute Kr matrices at 20°K on a CsI substrate and examined over the range 140-1200 cm^{-1} with infrared spectrometers which had demonstrable resolving power of 0.6 cm^{-1} in the 240 cm^{-1} region and 0.4 cm^{-1} from 400-900 cm^{-1}. In order to examine the Mg^{24} - Mg^{26} isotope effects with requisite care a sample of MgF_2 highly enriched in Mg^{26} was studied under similar conditions.

It now appears that absorption bands near 840 and 240 cm^{-1} are correctly assigned to ν_3 and ν_2, respectively. Convincing evidence for ν_1 has not yet been obtained though there are indications that it may lie in the vicinity of 550 cm^{-1}. It also appears, contrary to the conclusions drawn from electric deflection experiments, that MgF_2 may be bent.

Chapter B6

TIME-RESOLVED ELECTRICAL MEASUREMENTS IN HIGH-CURRENT DISCHARGES

By E. C. Cassidy, S. W. Zimmerman, and K. K. Neumann

ABSTRACT

A method for measurement of the resistive component of the instantaneous voltage across a sample installed in a high-voltage, high-current circuit is described. Simultaneous measurement of the current permitted time-resolved determination of electrical energy dissipation, power, and resistance of the sample. The system was calibrated calorimetrically, and measurements were made with exploding wire samples.

INTRODUCTION

Accurate determination of voltage, power, and energy dissipation in a transient high-current discharge has long been a difficult task. Fünfer et al. [1] used an ordinary voltage-divider arrangement to measure the voltage drop across a sample in series with a current-measuring resistor. They estimated an error of less than 8% in electrical energy measurements integrated between times when the electromagnetic field was zero. Bennett et al. [2] employed a shielded divider and introduced a correction [LdI/dt] to the voltage data. They estimated that the error in their results did not exceed 5%. Ostroumov and Shteinberg [3] corrected for the induced emf by inserting (directly in the voltage-measuring circuit) a toroidal coil which introduced an equal and opposite compensating emf. Moses and Korneff [4] used a similar but more sophisticated system, equipped with two voltage dividers and several amplifiers. Neither of the latter groups assigned an accuracy to their measurements.

Since the reactive component of the voltage makes no contribution to energy expenditure, we undertook to make direct measurements of the resistive component by a method which is an extension of an earlier technique by Zimmerman [5]. A two-divider system was used for the voltage measurements. The double divider arrangement was preferable because it precluded the possibility of arcing within the recording oscilloscope, and it facilitated establishment of a common ground for the voltage- and current-measuring circuits. A small coil, inserted in the circuit, provided compensation for the emf induced by the discharge in the sample and the voltage-measuring circuit. The resistive component of the voltage was recorded on a dual-beam oscilloscope.

The voltage across a coaxial Park-type current shunt [6] was recorded simultaneously in order to permit calculation of the instantaneous discharge current. Instantaneous power and energy were determined directly from these measurements.

APPARATUS AND MEASURING CIRCUITS

The voltage divider system was designed for exploding wire experiments using a 60 μF, 20 kV capacitor bank. The main discharge circuit with the voltage- and current-measuring circuits are shown in the schematic diagram in Fig. 1. The ringing frequency and calculated inductance of the discharge circuit were about 50 kHz and 0.16 μH, respectively.

The construction of the voltage divider and compensating coil are shown in Fig. 2. The high-voltage portion (high side) of each divider was made from several resistors connected in series. Although non-inductive resistors of the type described by Park and Cones [7] are preferable, ordinary 2 watt carbon-composition resistors sufficed for the present work. Three resistors in parallel were used for the low voltage portions. The total resistance of each divider was about 1100 ohms. The divider ratios (about 200:1 with cable impedance included) were matched to within 1%. The reactance of the compensating coil was not a significant factor since its inductance was only about 10 μH and the frequency of the oscillatory discharge was only about 50 kHz.

The compensating coil was installed in the high side of Divider No. 1. The coil (20 turns of No. 24 wire) was wound on a lucite rod (1-1/2 in. dia. x 1-1/2 in. long), and mounted on a rotatable fiber shaft. Stops limited rotation to 180°. An external dial with divisions from 0 to 100 indicated the orientation of the coil, with the axis of the coil parallel to the current path (the position of no compensation) at 50. In practice, the coil was adjusted to the unique position in which the coil-induced voltage was equal and opposite to the reactive component in the measurement. At this point, simultaneous display (on a dual-beam oscilloscope) of the current (I) through and the voltage (E) across the sample showed similar, in-phase waveforms. With the present setup, about four discharge experiments were required to adjust the coil for results with $\Phi < 6$ deg, where Φ is the angular displacement between E and I.

The divider probes (not shown), which were 1/8 inch diameter brass rods, were inserted at the positions indicated, in sturdy insulating (Delrin), bushing assemblies. Firm electrical connection between the probes and the circuit directly adjacent to the wire sample was insured

by spring loading. The entire assembly was fixed rigidly on a thick plastic sheet and mounted in a fixed position with respect to the discharge circuit. The rigid assembly prevented small changes in the areas of the divider loops. Repeated adjustment of the compensating coil was therefore not required when identical samples were used.

The divider signals were carried to the measuring oscilloscope by shielded, concentric cables (see Fig. 1). The cable sheaths and fittings were insulated from the main circuit by Teflon bushings. Grounding gaps (N2 neon tubes) were installed as shown in Fig. 1, in order to prevent arcing within the divider and/or a safety hazard at the ends of the cables when a discharge was fired with the voltage probes connected, but without connecting the measuring cables.

The voltage attenuation provided by the system may be seen from Fig. 3, which indicates the relative voltage levels of the various points. For matched dividers,

$$\frac{E_{AO}}{E_{BO}} = \frac{e_1}{e_2} ,$$

where E_{AO}, E_{BO}, e_1 and e_2 are the voltage drops indicated in the figure. Therefore,

$$E_{AB} = (e_1 - e_2) \frac{E_{BO}}{e_2} = (e_1 - e_2)R_2,$$

where the divider ratio $R_2 = R_1$. With the use of differential amplifiers, the monitoring oscilloscope displays $(e_1 - e_2)$. The voltage across the wire sample is therefore

$$E_{AB} = \text{CRO Voltage X } R_{1,2}.$$

Should the divider ratios R_1 and R_2 differ:

$$\frac{E_{AO}}{e_1} = k \frac{E_{BO}}{e_2} ,$$

where

$$k = \frac{R_1}{R_2} ;$$

then

$$E_{AB} = (ke_1 - e_2) \frac{E_{BO}}{e_2} .$$

In this case, evaluation of E_{AB} requires a knowledge of both of the divider ratios, measurement of $e_1 - e_2$, and measurement of either e_1 or e_2. The percentage error Δ introduced to measurements by divider mismatch may be determined from

$$\Delta = (1 - k) \frac{e_1}{(ke_1 - e_2)} \times 100.$$

CALIBRATION

Calorimetric experiments of the type described by Tsai and Park [8] were performed in order to determine the accuracy of the voltage- and current-measuring systems. A carefully machined Inconel tube was used in place of the sample as the "resistance calorimeter." The temperature rise in the tube as a result of the capacitor discharge was determined by extrapolating thermocouple readings to the time of the discharge. It was estimated that, for the usual 20 deg C increase, the temperature was determined with an error not in excess of 0.5%. The heat was calculated as $q = Mc_p \Delta T$, where M is the mass and c_p the specific heat of the tube. With errors in the determination of M and c_p of 0.1% and 0.3% (c_p measurement by Douglas and Victor [9]) respectively, the energy calculated (q) was thought to be in error less than 1%.

The measured voltage, current, electrical energy input, and instantaneous power from one of the calibration experiments are shown in Fig. 4. Effective cancellation of the reactive components in the voltage measurements is evident; the power curve and the slope of the energy curve are always positive.

For the calibration, the electrical measurements were compared with the heat measurements which were taken as the "standard." The total electrical energy input to the "calorimeter" ($\int_0^\tau EI\,dt$) was determined by integrating the simultaneous measurements of the voltage (E) across and the current (I) through the "calorimeter" sample over the duration (τ) of the discharge. The ohmic heating ($\int_0^\tau I^2R\,dt$) was determined from the current measurements and known resistance (R) of the "calorimeter." The results of several experiments are given in the following table:

$Mc_p\Delta T$ joules	$\int_0^\tau I^2R dt$ joules	Deviation from q	$\int_0^\tau EIdt$ joules	Deviation from q
268	270	+0.7%	276	+2.9%
412	416	+1.0%	423	+2.7%
417	419	+0.5%	429	+2.9%

With the uncertainty in R less than 0.2%, the error in the current measurements is estimated from the $\int_0^T I^2 R dt$ determinations to be less than 1%. The error in the voltage measurements is estimated from the $\int_0^T EI\, dt$ results to be less than 2%.

EXPLODING WIRE RESULTS

Preliminary discharge experiments with the "calorimeter" and with aluminum rods showed that the proper setting of the compensating coil was distinctly different with different samples. Identical wire samples were therefore used in adjusting the coil for exploding wire experiments. The voltage and current records from two of the coil-adjusting experiments (with $\Phi = 2$ deg and $\Phi = 24$ deg) are given in Fig. 5. The first portions ("first pulse" and "dark pause") of the voltage curves were not included in order to show the details of the gaseous, second portion ("restrike") of the discharge where about 99% of the energy was delivered. The extent of the errors introduced to the energy and power calculations by the rather large phase angle may be seen from Fig. 6. The power curves differ, particularly during the first half of the discharge. Also, the dashed power curve is at times negative (indicated by arrows). However, the energy curves are similar, even with the 24 deg displacement. For example, the total energy for the interval from $t = 0$ through $t \approx 20$ μsec as measured with $\Phi = 24$ deg differed from that measured with $\Phi = 2$ deg by only about 15 joules out of 1000 joules. The total energies determined at the end of the discharge, which should of course be the same regardless of Φ, differed by about 3% (1,640 joules for $\Phi = 24$ deg and 1,595 joules for $\Phi = 2$ deg). This difference may be attributed in part to the difference in the energies stored by the capacitor bank.

On the basis of these calculations, it was concluded that precise adjustment of the compensating coil is not always essential for determination of total energy input to the sample if a large portion of the final total energy has been delivered. However, more precise adjustment of the coil is required for measurement of power, for determination of

$$\int_{t_1}^{t_2} EI dt \text{ where } t_1 \text{ and } t_2 \text{ are times (where } I \neq 0)$$

early in the discharge, or for measurement of $\int_0^t EI dt$ where t is a time ($I \neq 0$) before much of the stored energy has been delivered (i.e., when a given error would be a greater percentage of the total energy delivered to that point.)

Energy and power determinations from experiments with energy storage at three different voltages are given in Fig. 7. The resistance of the exploding sample as a function of time from the 8kV

experiment is given in Fig. 8. Since corrections for the reactive component of the voltage were provided by the action of the compensating coil, the resistance was determined directly from Ohm's law. The resistance of the Inconel tube ("calorimeter"), which is also shown in Fig. 8, was determined in the same manner as a check on the method. The resistance of this tube, as measured by standard steady-state methods, is 0.00153 ohms at 26°C and 0.00154 ohms at 50°C. During the discharge experiment performed for Fig. 8, the temperature of the tube rose from 20.2°C to 41.5°C. In the absence of skin effects (considered negligible under the conditions of the experiment), one would expect the resistance of the tube to be between these values. The "calorimeter" resistance curve indicates a variation from about 0.00153 to 0.00160 ohms, with larger deviations from the expected results during periods when E and I are small. The accuracy was reduced at these times because the measuring instrumentation was adjusted for viewing very large values of E and I. Further, since Φ was not exactly zero ($\Phi \approx 2$ deg), the calculated instantaneous resistance was periodically infinite (at $I = 0$), zero (at $E = 0$), and negative. With both the wire and the tube sample, the curves were not plotted in the vicinities of these points.

DISCUSSION

Rather than requiring a choice between applying corrections and accepting more limited information, the present method provides direct compensation for most of the induced effects. However, the authors feel that errors may occur due to the changing (exploding) sample. For more accurate measurements with a changing sample, one may, for example, be limited to short intervals during which a given setting of the compensating coil is nearly perfect ($\Phi \approx 0$). Fortunately, the present experiments, with a single coil setting, have shown that the changes in sample geometry did not introduce large errors during the "restrike" portion of the exploding wire experiments. However, during the "restrike," changes in the geometry of the hot gas column (arc) were relatively insignificant, and adjustment of the compensating coil to a single setting which provided adequate compensation was a rather simple matter. During the early ("first pulse" and "dark pause") portions of the explosion, the wire expanded from 1 to about 50 diameters with the present setup. With faster, higher voltage systems, expansion may be even more rapid and more work may be required to establish a reliable procedure for voltage measurements, particularly in cases where the discharge is non-oscillatory.

In the present work the errors in the voltage and current measurements are estimated, from the calibration experiments in the section on Calibration, to be about 2% and 1% respectively. The errors in the energy and power calculations are thought to be less than 3%. The

exploding wire resistance determinations are in general agreement with earlier results by Reithel and Blackburn [10], Webb et al [11] and others, who have shown that the resistance of the wire first increases rapidly as the temperature rises and as the interatomic distance is increased by the rapid expansion of the wire material. According to O'Day et al [12], the pressure of the expanding vapor soon (within a microsecond or so) drops to the point where an arc forms and ionization by impact produces ample carriers for the current. In Fig. 8, the "restrike" follows and the resistance drops to a very small value where it remains nearly constant for a relatively long period of about 30 μsec (from $t = 10$ μsec to $t \approx 40$ μsec). Recent calculated results (by a different method) by Good [13] show a similar behavior. The resistance determinations during the "restrike" are thought to be accurate to the same degree as those for the resistance "calorimeter," i.e. to a few percent during the first half of the discharge and to about 4% during the latter half of the discharge when E and I are relatively small.

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REFERENCES

[1]. V. E. Fünfer, M. Keilhacker, and G. Lehner, Z. fur Angew. Physik 10, 157 (1958).

[2]. F. D. Bennett, H. S. Burden, and D. D. Shear, Phys. Fluids 5, 102 (1962).

[3]. G. A. Ostroumov and A. A. Shteinberg, Pribory i Tekhnika Eksperimenta 3, 85 (1963).

[4]. K. G. Moses and T. Korneff, Rev. Sci. Instr. 34, 849 (1963).

[5]. S. W Zimmerman, IEEE Conference Paper, CP64-168, presented at winter meeting of IEEE, New York City, February 1964.

[6]. J. H. Park, J. Research NBS 39, 191 (1947).

[7]. J. H. Park and H. N. Cones, "Sphere-Gap Volt-Time Curves. Reference Standards for Steep Front Measurements," AIEE paper No. CP57-215, 1957.

[8]. D. H. Tsai and J. H. Park, Exploding Wires 2, 97, Plenum Press, Inc., 227 West 17th St., New York (1962).

[9]. T. B. Douglas and A. Victor, J. Research NBS 65C, 65 (1961).

[10]. R. J. Reithel and J. H. Blackburn, Exploding Wires 2, 21 (1962).

[11]. F. H. Webb, Jr., H. H. Hilton, P. H. Levine, and A. V. Tollestrup, Exploding Wires 2, 37 (1962).

[12]. M. O'Day, W. G. Chace, and E. H. Cullington, Proced. Internat. Conf. on Ionization Phenomena in Gases, Third, Venice 1957, p. 784.

[13]. R. G. Good, Jr., Exploding Wires 3, 23, Plenum Press, Inc. 227 West 17th St., New York (1964).

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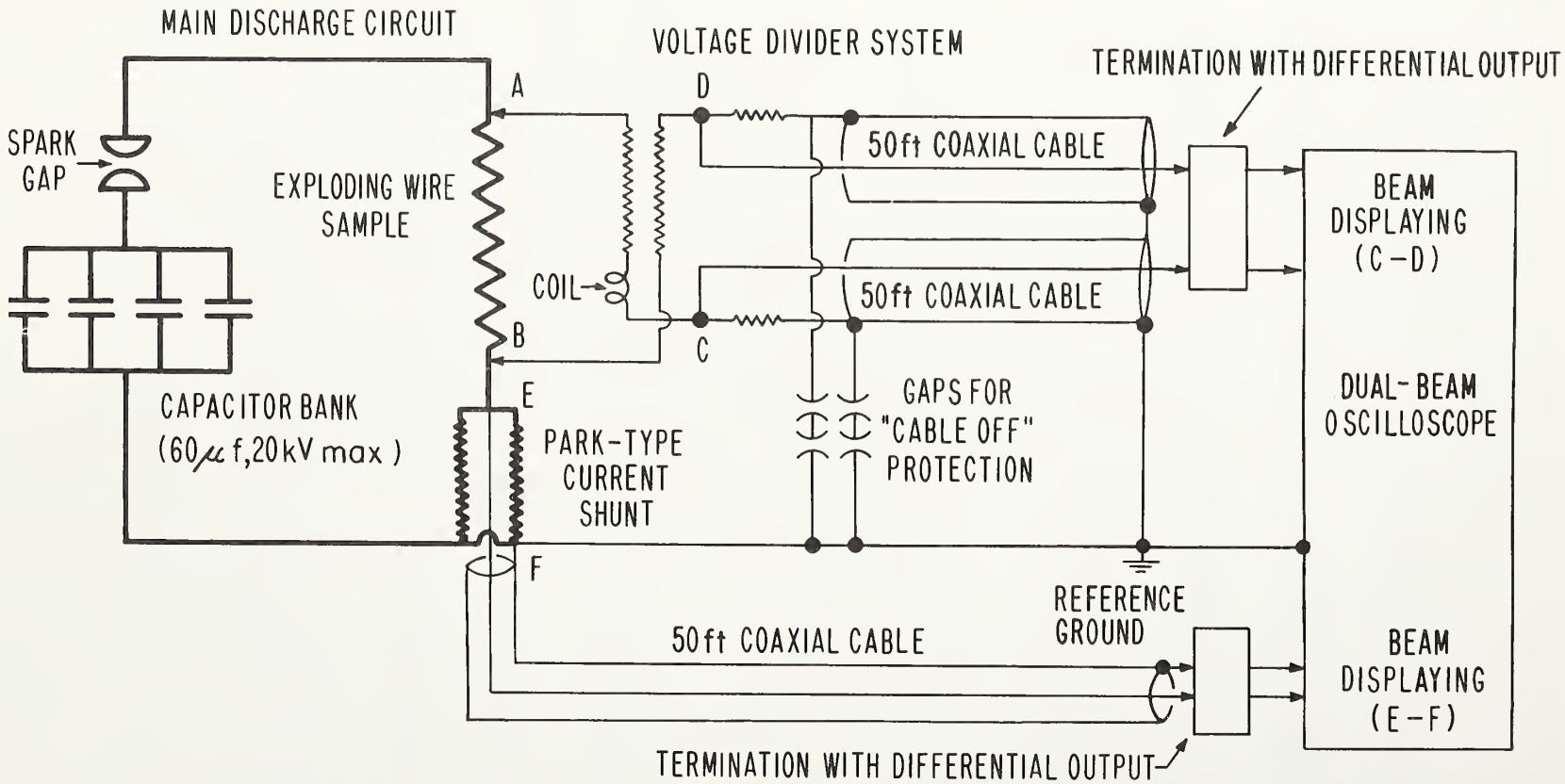

Figure 1. Schematic Diagram of Main Discharge Circuit and Electrical Measurement Circuits

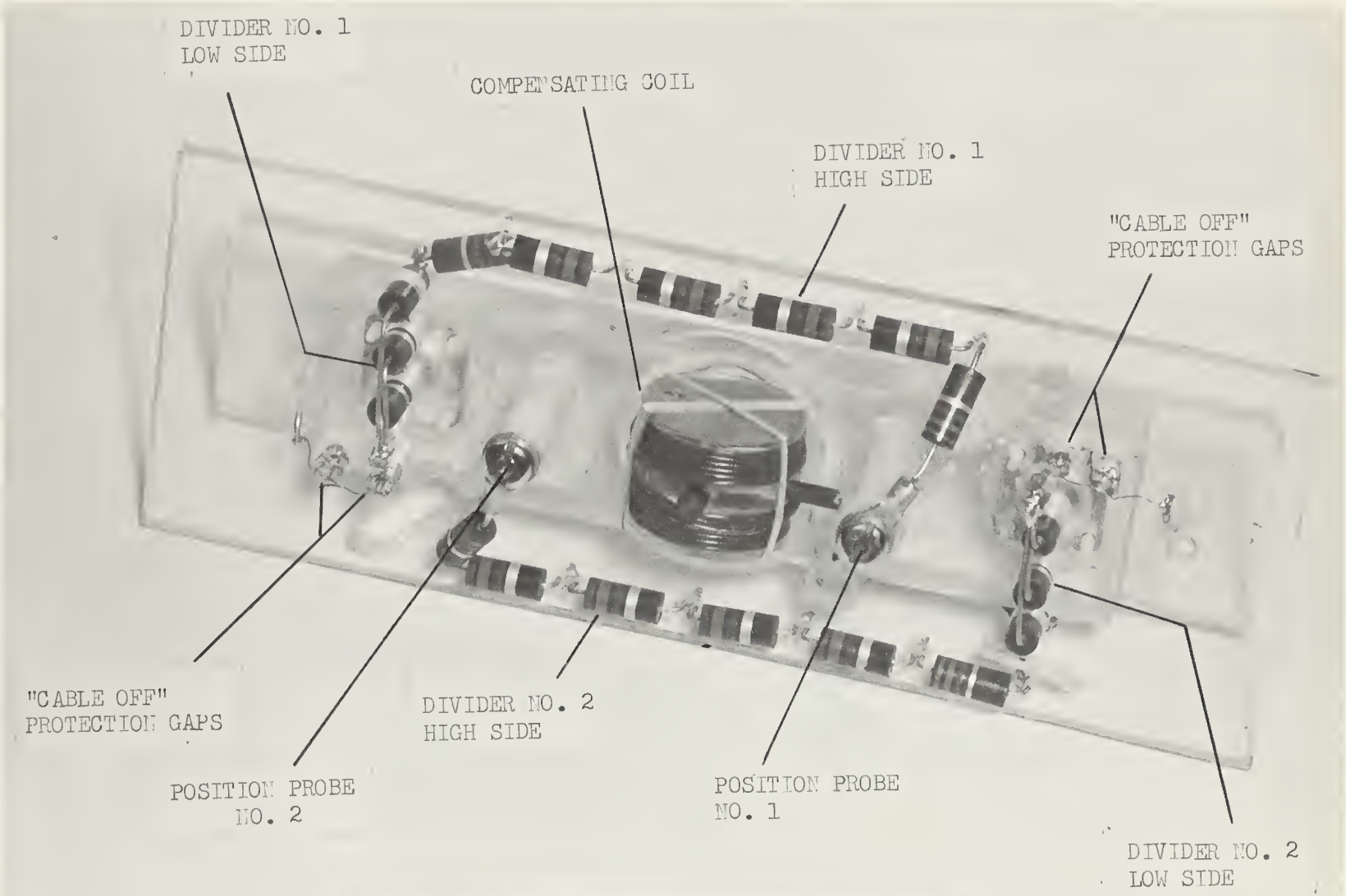

Figure 2. The Voltage Divider System

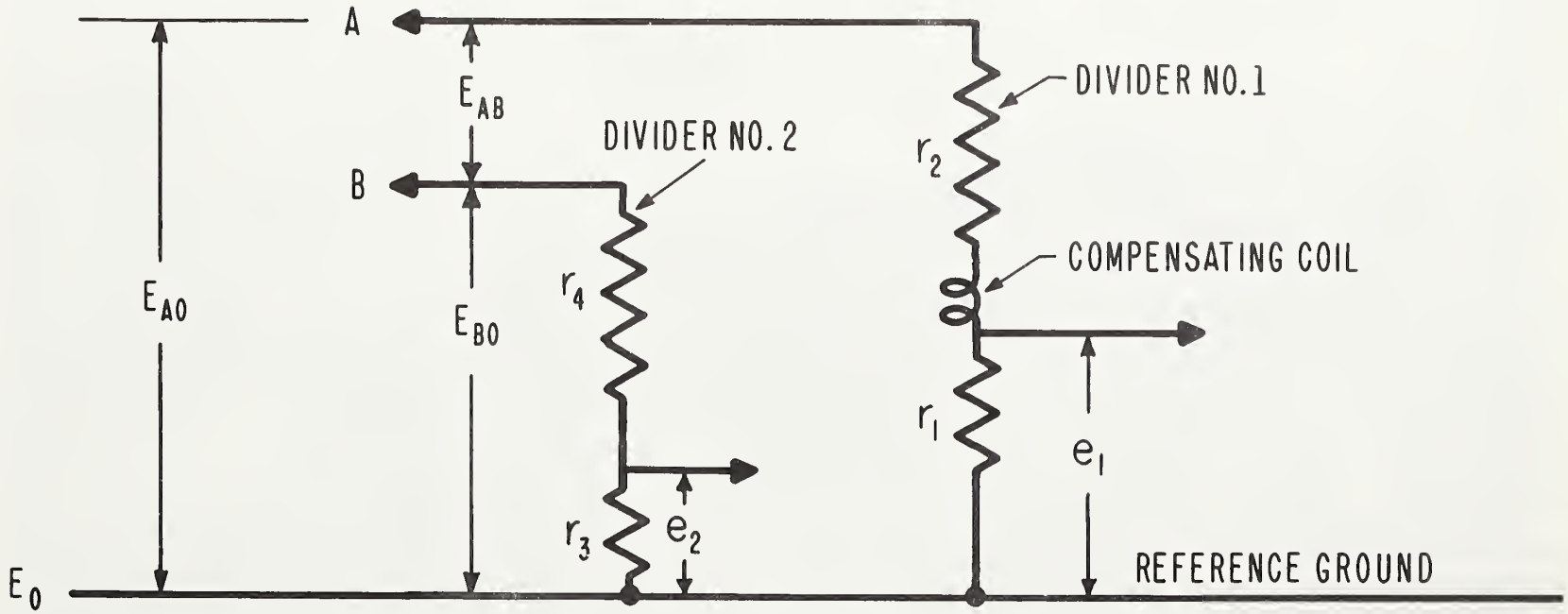

Figure 3. Schematic Diagram Indicating the Potential Levels of Various Points in the Voltage-Measuring System

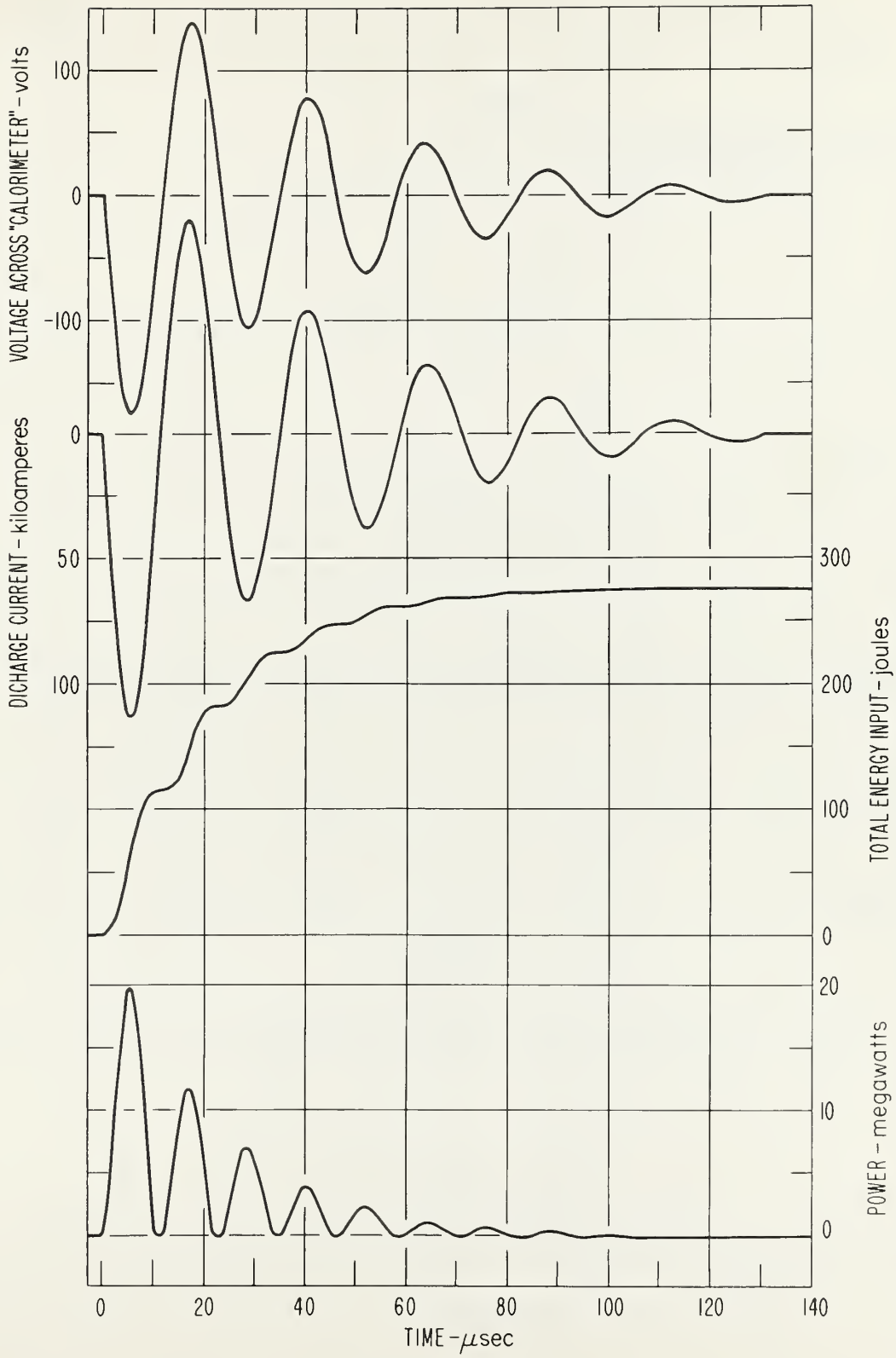

Figure 4. Time-Resolved Voltage, Current, Energy and Power during a calibration experiment. Sample: Inconel "Calorimeter" Tube, 2.5 cm O.D., 0.8 mm wall, 8.8 cm long. Stored energy: 60 μF at 8.2 kV

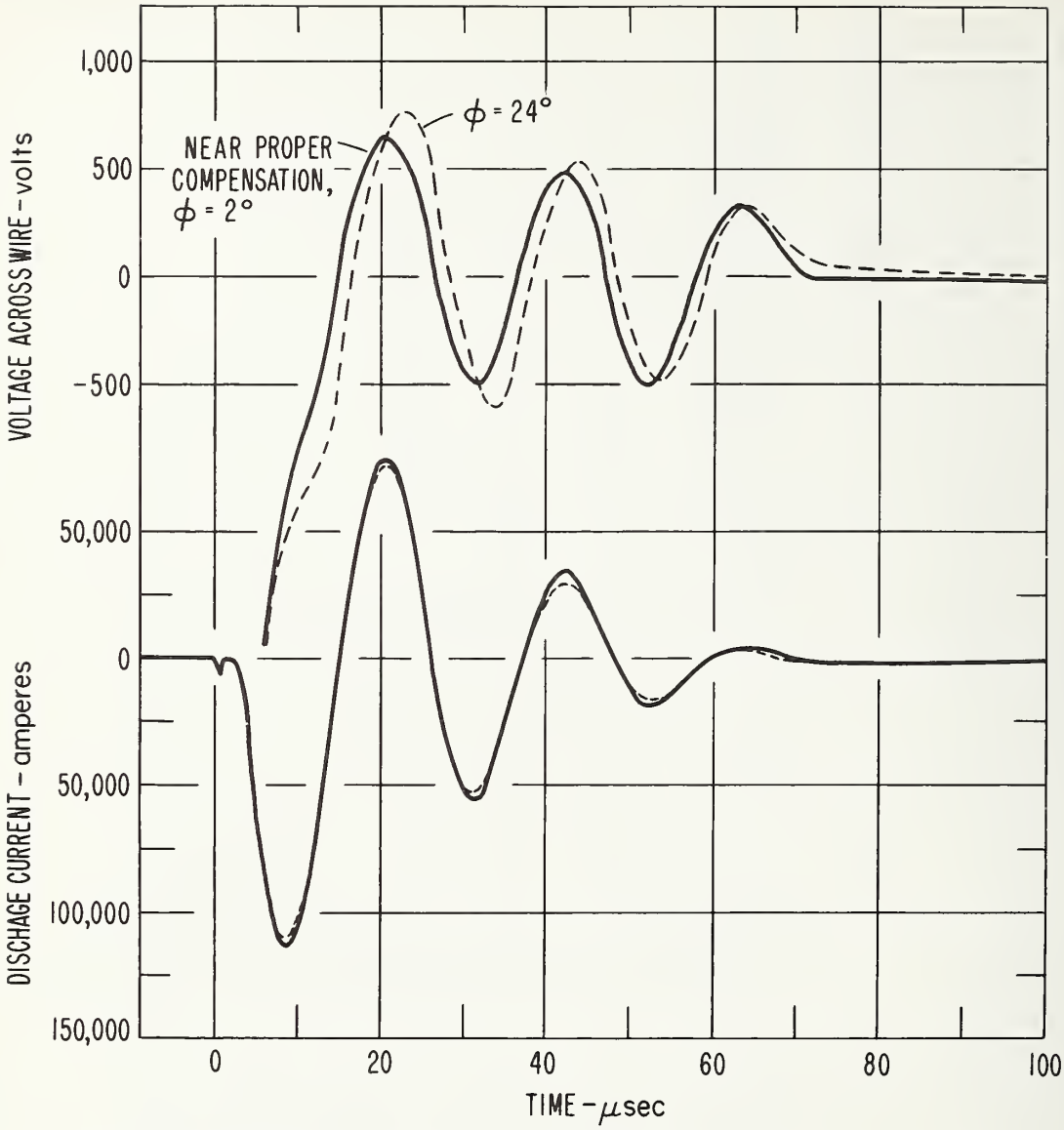

Figure 5. Measured voltage and current from Exploding Wire Experiments with different settings of the compensating coil. Sample: Aluminum Wire, 0.14 mm dia., 6.2 cm long. Stored energy: 60 μF at 9.0 kV (solid curve) and 9.1 kV (dashed curve)

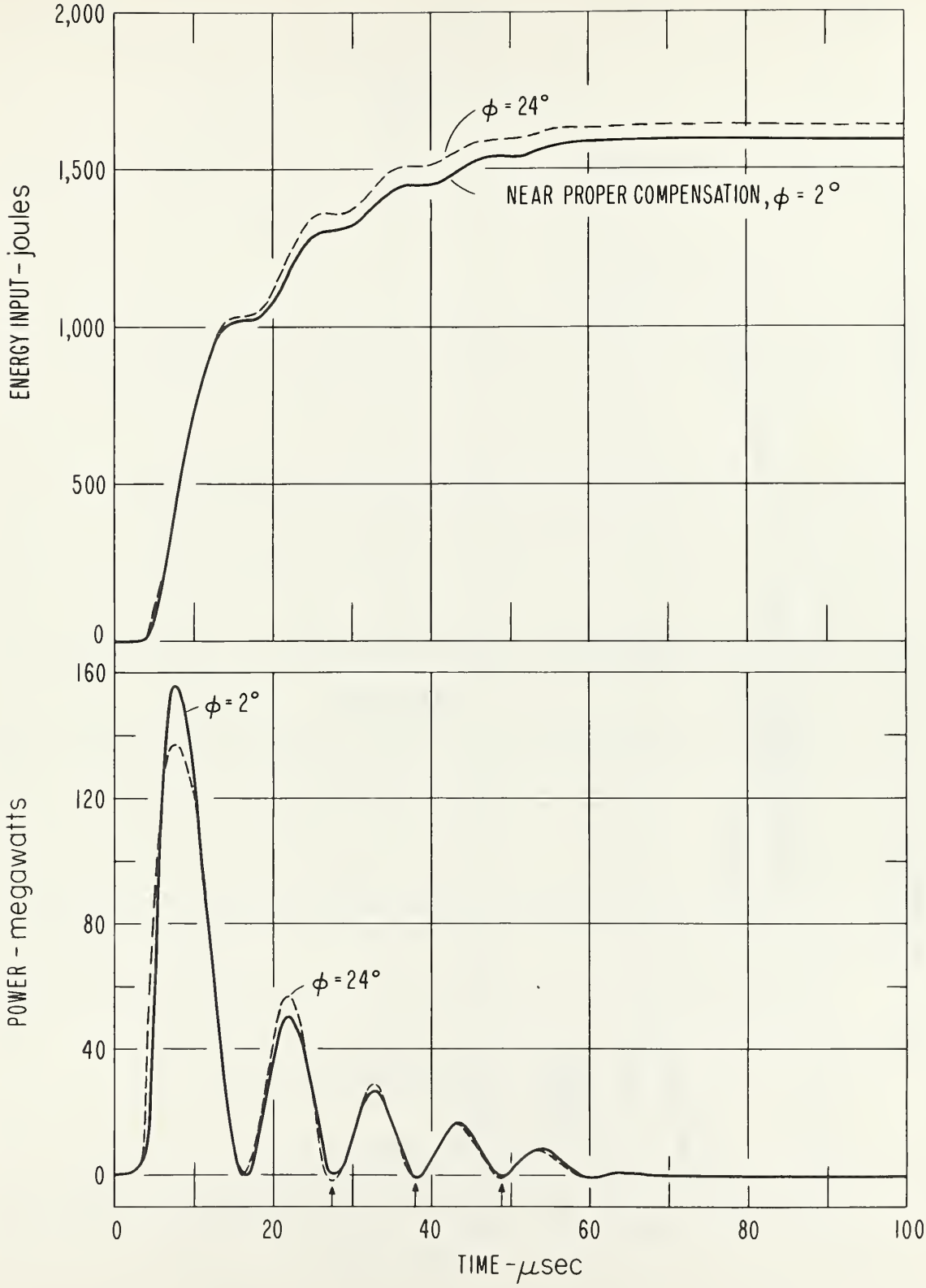

Figure 6. Time-Resolved Energy and Power Dissipation as Determined from the Voltage and Current Measurements in Figure 5.

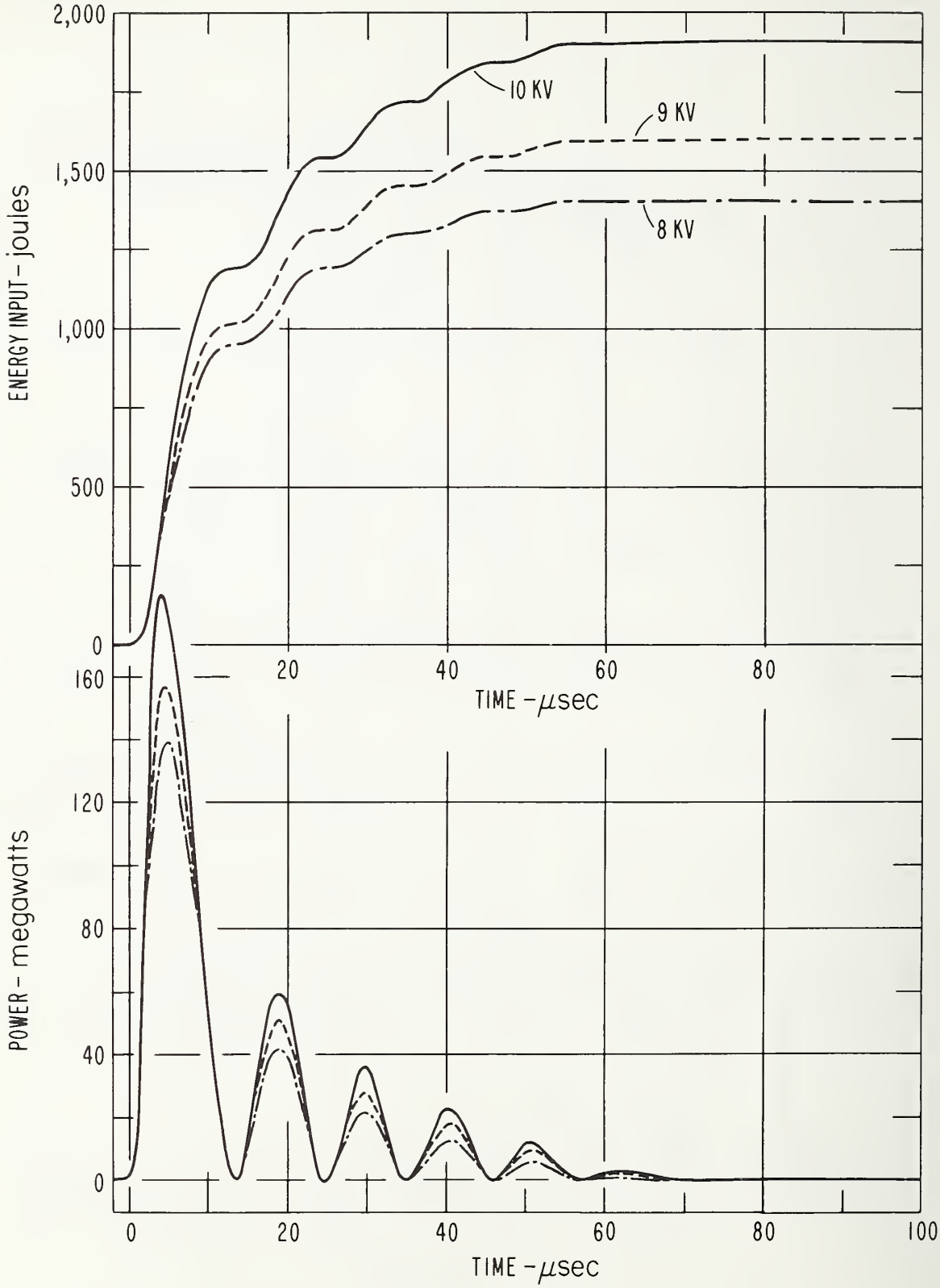

Figure 7. Time-Resolved Energy and Power Determinations in a series of Exploding Wire Experiments. Sample Wire: Aluminum, 0.14 mm dia., 6.2 cm long, Stored energy: 60 μF at 8, 9, and 10 kV

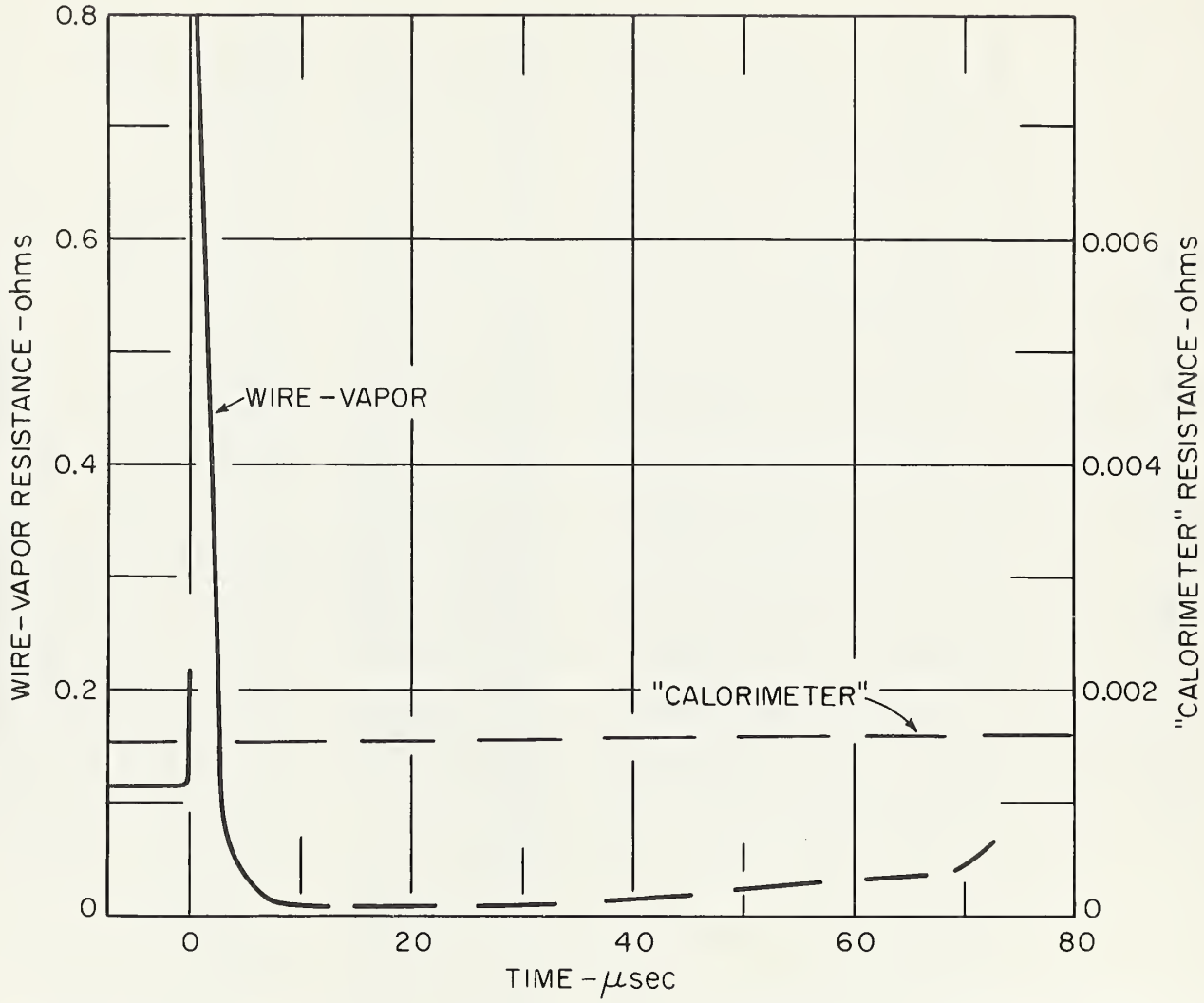

Figure 8. Time-Resolved Determinations of Resistance during High-Current Discharge Experiments: (a) with Inconel "Calorimeter" Sample in Figure 4, Stored energy: 60 μF at 10.0 kV, and (b) with an Exploding Aluminum Wire Sample, 0.14 mm dia. x 6.2 cm long, Stored energy: 60 μF at 8 kV

Chapter B7

ANALYSIS OF HEAT CAPACITY DATA ON SOME SELECTED LIGHT-ELEMENT COMPOUNDS

by George T. Furukawa and Martin L. Reilly

The low-temperature heat-capacity and high-temperature relative-enthalpy data on additional substances of interest to the program were analyzed and tables of thermal functions calculated wherever the data were found adequate. As described in previous reports, high-speed digital computer methods were used in the analysis. Briefly, the computation procedure involved smoothing the effective Debye θ's obtained from the observed data after suitable scaling. Smoothed heat capacities at regularly spaced temperature intervals were then obtained from the smoothed Debye θ's. The lower temperature limit of the heat-capacity data in many instances was about 50°K. For these substances the smoothed Debye θ's were suitably extrapolated to 0°K and the heat capacities obtained. The thermal functions were calculated from the smoothed heat capacities by numerical integration.

The low-temperature heat-capacity data and the high-temperature relative-enthalpy data for many substances could not reasonably be joined because of the large inconsistencies in the data. In some of the cases, e.g. Na_2TiO_3, $Na_2Ti_2O_5$, CaF_2, etc., the two sets of data could not be joined without placing a discontinuity in the heat capacity. In these cases the upper temperature limit of the table of thermal functions was made 300°K.

The substances and references to the data used in the analysis are given in the following section. The substance, chemical formula, and molecular weight are given first, followed by pertinent discussion regarding the substance. Atomic weights of 1961 based on C(12) were used throughout. Where necessary, the conversion of energy units was made based on 1 calorie = 4.1840 joules.

Potassium Nitrate, KNO_3, 101.1069

The low-temperature heat-capacity measurements of:

Southard, J. C. and Nelson, R. A., J. Am. Chem. Soc. 55, 4865-4869 (1933) Range: 16 to 296°K,

were compared with the high-temperature relative-enthalpy equation of:

Kelley, K. K., U. S. Bur. of Mines Bulletin 584, 1960.

Because of large discrepancies in the two sets of data, smooth joining could not be done without excessive adjustments in the data. The table of thermal functions were, therefore, terminated at 300°K for the present report.

Sodium Nitrate, $NaNO_3$, 84.9947

The low-temperature heat-capacity measurements on sodium nitrate, $NaNO_3$, reported by:

Southard, J. C. and Nelson, R. A., J. Am. Chem. Soc. 55, 4865-4869 (1933) Range: 16 to 287°K,

were smoothed and joined with the relative-enthalpy equation given by:

Kelley, K. K., U. S. Bur. of Mines Bulletin 584, 1960.

A table of thermal functions from 0 to 700°K was prepared.

Sodium Aluminum Meta-silicate (Jadeite), $NaAlSi_2O_6$ or $1/2(Na_2O \cdot Al_2O_3 \cdot 4SiO_2)$, 202.1397

Kelley, K. K., Todd, S. S., Orr, R. L., King, E. G., and Bonnickson, K. R., U. S. Bur. of Mines, Rept. Invest. 4955, 1953. Range: heat capacity, 54 to 296°K. relative enthalpy, 298 to 1190°K.

reported heat measurements on jadeite, $Na_2O \cdot Al_2O_3 \cdot 4SiO_2$, covering the two ranges of temperature given above. The two sets of data were smoothed and thermal functions calculated.

Sodium Monotitanate, Na_2TiO_3, 141.8778

Heat capacities at low temperatures of sodium monotitanate, Na_2TiO_3, were determined by:

Shomate, C. H., J. Am. Chem. Soc. 68, 1634-1636 (1946)
Range: 53 to 296°K.

The high-temperature relative enthalpy data reported by:

Naylor, B. F., J. Am. Chem. Soc. 67, 2120-2122 (1945)
Range: 298 to 1584°K,

were found to disagree by about 4 percent at 298°K with the low-temperature data and could not be joined smoothly without excessive

adjustment of the data. The table of thermal functions for Na_2TiO_3 was, therefore, terminated for the present report at 300°K.

Sodium Dititanate, $Na_2Ti_2O_5$, 221.7766

Low-temperature heat-capacity measurements on sodium dititanate, $Na_2Ti_2O_5$, were reported by:

Shomate, C. H., J. Am. Chem. Soc. 68, 1634-1636 (1946)
Range: 53 to 296°K.

The high-temperature relative-enthalpy data of:

Naylor, B. F., J. Am. Chem. Soc. 67, 2120-2122 (1945)
Range: 298 to 1579°K.

were found to be inconsistent with the low-temperature data by about 10 percent. The table of thermal functions of $Na_2Ti_2O_5$ was, therefore, terminated at 300°K for the present report.

Sodium Trititanate, $Na_2Ti_3O_7$, 301.6754

Heat capacities at low temperatures of sodium trititanate, $Na_2Ti_3O_7$, were determined by:

Shomate, C. H., J. Am. Chem. Soc. 68, 1634-1636 (1946)
Range: 53 to 296°K.

These data were smoothed and extrapolated to 0°K. The high-temperature relative-enthalpy data reported by:

Naylor, B. F., J. Am. Chem. Soc. 67, 2120-2122 (1945)
Range: 298 to 1681°K,

were found to disagree considerably (about 10 percent) with the low-temperature data at 298°K. The two data can not be joined smoothly without excessive adjustment of the data. The upper temperature limit of the table of thermal functions for $Na_2Ti_3O_7$ was, therefore, made 300°K.

Cesium Perchlorate, $CsClO_4$, 232.3556

Pitzer, K. S., Smith, W. V., and Latimer, W. M., J. Am. Chem. Soc. 60, 1826-1828 (1938)

investigated cesium perchlorate, $CsClO_4$, from 15 to 292°K. The sample was prepared from "c.p." grade cesium nitrate and iodochloride by addition of dilute perchloric acid solution. Chemical tests showed absence of appreciable amounts of nitrate or iodochloride and spectrochemical tests showed absence of other alkali metals.

Calcium Hydroxide, $Ca(OH)_2$, 74.09474

The heat data on $Ca(OH)_2$ reported by:

Kobayashi, K., Sci. Rept. Tohoku Univ. (1), 34, 153-159 (1950) Range: 314 to 670°K.

and

Hatton, W. E., Hildenbrand, D. L., Sinke, G. C., and Stull, D. R., J. Am. Chem. Soc. 81, 5028-5030 (1959) Range: 19 to 330°K.

were joined smoothly.

Calcium Fluoride, CaF_2, 78.0768

Heat data from the following sources were examined:

Eucken, A. and Schwers, F., Ber. deut. physikal, Gesell. 15, 578-588 (1913) Range: 18 to 86°K.

Todd, S. S., J. Am. Chem. Soc. 71, 4115-4116 (1949) Range: 54 to 296°K.

Krestovnikov, A. N. and Karetnikov, G. A., Legkie Metal. 4, 16-18 (1934) Range: 288 to 1273°K.

Lyashenko, V. S., Metallurg. (USSR) 10, 85-98 (1935) Range: 291 to 1490°K.

Naylor, B. F., J. Am. Chem. Soc. 67, 150-152 (1945) Range: 298 to 1789°K.

Because of the large (about 6 percent) discrepancy of the data in the temperature range (298°K) where the low- and high-temperature measurements meet, the present table of thermal functions was terminated at 300°K.

Strontium Oxide, SrO, 103.6194

Heat data reported by:

Anderson, C. T., J. Am. Chem. Soc. 57, 429-431 (1935)
Range: 58 to 298°K.

were smoothed and extrapolated to 0°K.

Barium Fluoride, BaF_2, 175.3368

Low-temperature heat-capacity measurements on barium fluoride, BaF_2, were reported by:

Pitzer, K. S., Smith, W. V., and Latimer, W. M., J. Am. Chem. Soc. 60, 1826-1828 (1938) Range: 14 to 301°K,

and the high-temperature relative-enthalpy data were obtained by:

Krestovnikov, A. N. and Karetnikov, G. A., Legkie Metal. 3, 29-31 (1934) Range: 288 to 1273°K.

These data were smoothed and a table of thermal functions calculated to 1300°K.

Silicon, Si, 28.086

The precise low-temperature heat-capacity measurements reported by:

Flubacher, P., Leadbetter, A. J., and Morrison, J. A., Phil. Mag. 4, 273-294 (1959) Range: 7.7 to 300°K,

was joined with the heat capacity calculated from the enthalpy equation given by:

Kelley, K. K., U. S. Bur. of Mines Bulletin 584, 1960.

Silicon Carbide, SiC, 40.09715

Both hexagonal (type II) and cubic forms of silicon carbide, SiC, were investigated by:

Humphrey, G. L., Todd, S. S., Coughlin, J. P., and King, E. G., U. S. Bur. of Mines, Rept. Invest. 4888, 1952.

The hexagonal form was investigated from 54 to 1789°K and the cubic form from 54 to 1693°K. The data for the two crystalline forms of SiC were smoothed and thermal functions calculated.

Germanium, Ge, 72.59

Low-temperature heat-capacity measurements have been reported by:

Cristescu, S. and Simon, F., Zeit. phys. chem. 25B, 273-282 (1934)
Range: 10 to 200°K.

Hill, R. W. and Parkinson, D. H., Phil. Mag. 43, 309-316 (1952)
Range: 5 to 160°K.

Estermann, I. and Weertman, J. R., J. Chem. Phys. 20, 972-976 (1952)
Range: 20 to 200°K.

Keesom, P. H. and Pearlman, N., Phys. Rev. 91, 1347-1353 (1953)
Range: 1.5 to 5.0°K.

Flubacher P., Leadbetter, A. J., and Morrison, J. A., Phil. Mag. 4, 273-294 (1959) Range: 7.7 to 300°K.

Piesbergen, U., Zeit. Naturforsch. 18A, 141-147 (1963)
Range: 12 to 273°K.

The heat capacity calculated from the high-temperature enthalpy equation given by:

Kelley, K. K., U. S. Bur. of Mines Bulletin 584, 1960.

was joined with the precise values reported by Flubacher et al.

Lead Ortho-phosphate, $Pb_3(PO_4)_2$, 811.5128

Pitzer, K. S., Smith, W. V., and Latimer, W. M., J. Am. Chem. Soc. 60, 1826-1828 (1938) investigated lead ortho-phosphate, $Pb_3(PO_4)_2$, from 16 to 292°K. The sample was prepared from "c.p." grade lead acetate and Na_2HPO_4 by mixing hot dilute solutions of the two salts with vigorous stirring. The $Pb_3(PO_4)_2$ precipitate was washed thoroughly and dried at 300°C. Lead content of the sample was by electrolytic analysis, within 0.2 percent of the theoretical amount.

Vanadium Monoxide, VO, 66.9414

Vanadium monoxide, VO, was investigated by:

Todd, S. S., and Bonnickson, K. R., J. Am. Chem. Soc. 73, 3894-3895 (1951) Range: 55 to 296°K.

and

Orr, R. L., J. Am. Chem. Soc. 76, 857-858 (1954)
Range: 298 to 1698°K.

The same VO sample was used in the measurements by the above authors. In the preparation of the sample, a mixture of V_2O_3 and vanadium metal was heated in hydrogen atmosphere at 1350°C with intermittent grinding of the material to -325 mesh. The final product was taken to be 98.2 percent VO on the basis of vanadium content. The impurities were Si: 0.92%, Fe_2O_3 + Al_2O_3: 0.10%, and Na_2O: 0.23%. The "hump" observed in the heat capacity in the range 168 to 191°K was attributed to V_2O_3 impurity. No correction was applied for its presence.

Chapter B8

ARC-IMAGE RESEARCH

J. J. Diamond and A. L. Dragoo

Rate of Vaporization of Liquid Alumina in Inert Gases

The bubbling phenomenon when molten Al_2O_3 freezes in the presence of water vapor was described in NBS Report 7587. This phenomenon was not observed when Al_2O_3 froze in the presence of H_2, He, O_2, N_2, Ar, air, or water vapor. The average rate of weight loss of molten Al_2O_3 in atmospheres of Ar and of H_2O (1 atm. ambient pressure) was given in NBS Report 8186. However, there was considerable uncertainty involved in these results due to the small weight losses and to the fact that steam was flowed pass the sample in the water vapor experiments causing possible transpiration.

In order to redetermine whether water vapor might increase the rate of vaporization preliminary experiments were carried out at lower pressures. The results are given in Table I along with the rate of vaporization in vacuum for comparison. A decrease in the pressure of He would probably result in a rate of vaporization near that for vaporization in water vapor. Consequently, it appears that the rate of vaporization depends mainly on the ambient pressure and secondarily, if at all, on whether water vapor is present.

Temperature Measurement

The measurement of the apparent temperature of molten alumina in a solar furnace has been discussed by Diamond and Schneider [1]. The situation of our arc-image furnace is very similar, but complicated by the fact that there is much more stray radiation in the enclosed image chamber. The furnace is fitted with a shutter at the cross-over point which cuts off the energy to the sample chamber 1800 times per minute. Between the specimen and the pyrometer there is a rotating sector disc which can be manually synchronized with the shutter, so that temperature is measured during that portion of the cycle when there is no reflected energy error. Alternatively, the shutters can be de-synchronized, and the apparent temperature measured by sighting on the glare free area of the molten alumina surface as described in reference [1].

The temperature of molten alumina as measured by these two techniques is essentially the same for large, thick drops, but important differences appear for thinner drops. Table II shows the difference in apparent temperature as a function of drop thickness. It is suggested that large drops, whose thicknesses are greater than about 3.5 mm, are sufficiently thick that no radiation reflected from or emitted by the liquid-solid interface can penetrate the liquid to reach the pyrometer; that is, they are "infinitely thick" and essentially opaque to transmitted radiation [2]. Since the specular reflections from the air-liquid interface are substantially eliminated by either technique, the apparent temperatures are essentially the same and equal the true "brightness temperature" of the molten alumina

Molten drops of less than "infinite thickness" permit some stray radiation reflected by the liquid-solid interface to penetrate the liquid to reach the pyrometer. The thinner the drop, therefore, the greater will be the difference between the two temperatures measured. The variation in temperature difference also will be greater with thinner drops because the amount of energy reflected by the liquid-solid interface into the pyrometer will depend on the angle it makes with the line of sight.

To eliminate all reflected-energy errors, therefore, the temperatures of thin drops must be measured using synchronized shutters. The temperatures thus measured, it is evident, will consist of two components: one due to the liquid-solid interface (which is at the melting point of alumina, by definition), whose magnitude varies inversely with the drop thickness, and one due to the molten alumina itself, whose magnitude varies directly with the drop thickness. We do not at present have techniques for separating these two components to arrive at the temperature of the liquid. We suggest that it might be best to measure temperature by viewing from the side, rather than head-on: This will eliminate the liquid-solid interface from the line of sight and present a depth of liquid alumina sufficient to give a true brightness temperature in many cases. Care should be taken to view the liquid at an angle no greater than about 55° with the normal to the surface, since at greater angles the spectral emissivity rapidly decreases.

Gardon [2] has discussed the emissivity of transparent materials in terms of a "dimensionless thickness," $\gamma_\lambda X$, where γ_λ is the absorption coefficient and X is the thickness, and has given 3.5 as the "dimensionless thickness" at which materials can be regarded as "infinitely thick," or opaque. Since we have found that 3.5 mm of molten alumina is "infinitely thick" to light of the pyrometer wavelength, its absorption coefficient at .66μ should be about 1.0 mm^{-1}. Gryvnak and Burch [3] have found the absorption coefficient of solid sapphire just below the melting point to be about 0.02-0.03 mm^{-1} at this wavelength and state that it increases discontinuously by a factor of about 30 or 40 when it melts. This would give a value of about 0.6-1.2 mm^{-1} for molten alumina, consistent with the 1.0 mm^{-1} deduced above.

Given the brightness temperature of liquid alumina one can correct for emissivity to obtain the true black-body temperature. One can calculate the emissivity from the reflectivity of the air-liquid alumina surface, which depends on the index of refraction of the liquid alumina. The index of refraction of molten alumina is not known. Malitson [4] measured it for sapphire at 24°C and found n_o (.65μ) = 1.765, with a positive temperature coefficient of $1.3 \times 10^{-5}\,°C^{-1}$. Jeppesen [5] found n_o = 1.765 and n_e = 1.757, with positive temperature coefficients of 1.36 and $1.47 \times 10^{-5}\,°C^{-1}$, respectively. The average index of the solid

at the melting point is thus 1.79. This leads to a reflectivity of .08 and am emissivity of .92. Gryvnak and Burch estimated that the index of refraction of sapphire increases by .05 (+.01, -.03) from room temperature to 1700°C. This also leads to an emissivity of .92.

Vapor Pressure and Heat of Vaporization of Liquid Alumina

Table III shows some data obtained on the rate of evaporation of molten alumina in vacuum. Only large drops were used and the temperatures were measured using synchronized shutters and are corrected for the attenuation due to sector disk, prism and window, and a spectral emissivity of .92. The samples were weighed before and after heating in order to obtain the mass evaporated. Evaporing areas were measured after solidification and corrected for area expansion on melting on the basis of density data for liquid alumina determined by Kirshenbaum and Cahill [6]. The equation $D = 5.617 - .001144T$ was used, where D is density in g cm^{-3} and T is temperature in °K. This was obtained by a recalculation of their results based on clarification of their procedure for temperature correction [7] and a least-squares analysis of the adjusted data.

The vapor pressures shown in Table IV were calculated from the measured rates of vaporization assuming that the molten alumina evaporated to $2Al(g) + 3O(g)$ with a vaporization coefficient of one. The third law method was used to calculate the heats of vaporization, using the free energy functions given in the JANAF Thermochemical Tables [8]. The heat of vaporization calculated from the thermodynamic data published in the same tables is 708.0 kcal mol^{-1}.

References

[1] J. J. Diamond and S. J. Schneider, J. Am. Ceram. Soc. 43 [1], 1-3 (1960).

[2] R. Gardon, J. Am. Ceram. Soc. 39, [8], 278-87 (1956).

[3] D. A. Gryvnak and D. E. Burch, J. Opt. Soc. Am. 55 [6], 625-29 (1965).

[4] I. H. Malitson, J. Opt. Soc. Am. 52 [12], 1377-79 (1962).

[5] H. A. Jeppesen, J. Opt. Soc. Am. 48 [9], 629-32 (1958).

[6] A. D. Kirshenbaum and J. A. Cahill, J. Inorg. Nucl. Chem. 14 [3,4], 283-87 (1960).

[7] J. A. Cahill, private communication.

[8] JANAF Thermochemical Tables, Dow Chemical Co., 1960.

Table I

Rate of Vaporization of Molten Alumina as a Function of Ambient Pressure

GAS	TEMP. (°K)	AMBIENT GAS PRESSURE (atm.)	RATE OF VAPORIZATION ($\mu g\ cm^{-2} sec^{-1}$)
Vacuum	2550	0.000	75.
H_2O	2407	0.024	2.4
H_2O	2455	0.024	6.1
H_2O	2467	0.025	6.2
He	2476	0.049	3.8
He	2433	0.076	2.5
Ar	2460	1.000	0.04

TABLE II

Apparent Temperatures of Molten Alumina in Air in an Arc-Image Furnace

Shutters Synchronized °C	Shutters not Synchronized °C	Difference °C	Thickness of molten drop mm
2135	2137	2	4.6
2146	2148	2	3.5
2130	2141	11	2.8
2162	2.75	13	3.2
2148	2166	18	2.9
2146	2164	18	2.7
2130	2157	27	2.9
2095	2125	30	2.4
2097	2137	40	2.3
2100	2141	41	2.2
2114	2164	50	1.5
2056	2169	113	1.3

TABLE III

Rate of Vaporization of Molten Alumina in Vacuum

Temp. °K	Heating Time sec.	Mass Evaporated mg	Evaporating Area cm^2	Rate of Evaporation $g\ cm^{-2} sec^{-1} \times 10^5$
2606	397	34.580	0.82	10.673
2554	380	28.926	1.37	5.538
2535	431	25.737	1.25	4.773
2575	375	29.838	1.02	7.818
2559	390	25.595	1.18	5.554
2493	400	14.629	1.40	2.608
2559	360	30.821	1.10	7.756
2579	380	35.089	1.37	6.733
2577	350	22.788	0.82	7.919
2546	355	19.566	1.01	5.461

TABLE IV

Vapor Pressure and Heat of Vaporization of Molten Alumina

Temp. °K	Pressure (Al) Atm. × 10^6	Pressure (O) Atm. × 10^6	log Equilibrium Constant	Heat of Vaporization $\Delta H_v^\circ(298°)$ kcal mol^{-1}
2606	12.52	14.47	-24.32	727.8
2554	6.43	7.43	-25.77	730.4
2535	5.52	6.38	-26.10	729.0
2575	9.12	10.53	-25.01	727.3
2559	6.46	7.46	-25.76	731.6
2493	2.99	3.46	-27.43	732.2
2559	9.02	10.42	-25.04	723.3
2579	7.86	9.08	-25.34	732.4
2577	9.24	10.67	-24.98	727.5
2546	6.33	7.32	-25.80	728.6

Mean $\Delta H_v^\circ(298°)$ = 729.0 kcal mol^{-1}

Standard Deviation = 2.8 kcal mol^{-1}

Standard Error = 0.9 kcal mol^{-1}

Chapter B9

USE OF THE ROTATING BOMB CALORIMETER FOR THE REACTION OF A METAL WITH ACID, A CONTRIBUTION TO THE THERMOCHEMISTRY OF BERYLLIUM

by George T. Armstrong and Charles F. Coyle

1. Introduction

The rotating bomb calorimeter was specifically designed [1] for combustion reactions in which is formed a liquid phase which must be made homogeneous in order to establish a well defined thermodynamic state for the products of reaction. In principle, there is no reason the rotating bomb calorimeter could not be used equally well for other solution processes in which a liquid phase must be made homogeneous. Nor is there any reason that the results should not be as accurate as are given by the bomb combustion process provided the solution process is as carefully analyzed as the combustion process has been, and appropriate corrections made for deviations of the actual process from the standard state reaction. In practice, a severe limitation is readily recognized: that the energy equivalent of the bomb calorimeter is very large (typically of the order of 15 kJ deg^{-1}), while the energies of many reactions of substances leading to solutions in quantities small enough for the bomb are only a few kilojoules, or a fraction of a kilojoule. Thus the precision of which the calorimeter is capable is lost because of the loss of relative accuracy in measuring the temperature rise.

The solution of a metal in an acid is a reaction potentially suitable for the rotating bomb. In some cases at least, the amount of heat liberated is appropriate to operate the calorimeter in its normal temperature interval. Also, the bomb provides a suitable closed space in which the hydrogen liberated from the acid can be retained, so that it and the solution formed are in well defined thermodynamic states at the conclusion of the reaction. The hydrogen formed as a result of the reaction is available for analysis as a verification of the amount of reaction.

There has been under way in our laboratory a study of the heat of formation of beryllium fluoride by direct combination of the elements, which is reported elsewhere in this report [2]. The dissolution of the metal in acid appeared to be a relatively simple way to provide confirmatory evidence, independent of the heat of formation of BeO, upon which other acid solution calorimetery of BeF_2O depends [3,4]. The study of the solution method, as thus far carried out in the rotating bomb calorimeter and described in this report, while not definitive in its treatment of beryllium fluoride because of certain incompletely resolved features of the experiment, provides ample justification for the belief that the procedure can be made applicable to many substances for which an appropriate solvent can be found.

Of special interest in the thermodynamics of refractory materials and other high temperature substances is its potential applicability to alloys and to intermetallic compounds. When applied in a carefully designed study of the separate metals and the alloy or intermetallic compound, the precision of the bomb calorimetric technique should allow distinction of the generally small heat involved in the interaction of the metals.

The heat of solution of beryllium in aqueous hydrofluoric acid was studied in the experiments which are described here. A series of test measurements were carried out to establish the validity of the measurements. The resulting data were combined with the heat of solution of BeF_2 determined by Kolesov et al. [3] to calculate the heat of formation of $BeF_2(c)$, for comparison with the heat of formation of BeF_2 as determined by direct combination of the elements in this laboratory [2].

2. Calorimetric Instruments

The measurements were made with a rotating-bomb calorimeter, designated RBC-1, and a platinum-lined rotating bomb, designated RB-2. These instruments were made in the National Bureau of Standards (NBS) shops following generally the Argonne National Laboratory designs [5] with some minor modifications. This calorimeter is described in somewhat more detail in Part A of this report in the section entitled "Combustion and Reaction Calorimetry of Fluorine and its Compounds" [65]. The jacket temperature was maintained constant within a few thousandths of a degree by a mercury-contact regulator. The sensitivity of the regulator was increased by a tapping device which markedly reduced the range between make- and break-contact.

Temperatures of jacket and calorimeter were measured with a G-2 Mueller bridge (NBS 19742) and a fast-response platinum-resistance thermometer (Serial No. 283) having a single-coil resistance element with a nominal ice-point resistance of 25.5 ohms.

The individual heat measurements were carried out following a prescribed program, timed by NBS standard second signals which are converted to an audible signal, and by a printing timer which operates on the NBS standard 60 Hz signal. Resistance measurements in the initial and final drift periods were made at one-minute intervals as indicated by the odd second of the standard second signals. Times at which the resistance reached prescribed values during the rapid temperature rise were recorded to 0.0001 minute. The two timing devices were synchronized during the experiment.

For the calibration experiments the calorimeter and bomb were used in their normal configurations for oxygen-combustion experiments. Several minor changes were made for the reaction experiments involving the metal and acid. Because the reactions were initiated with the bomb upright rather than in its normal inverted position, an extension of the fuse connection external to the bomb in the calorimeter was required. This consisted of a small copper wire weighing 0.1564 grams and a plastic tape weighing 0.0445 grams. The connecting device for the platinum fuse inside the bomb was slightly modified and the crucible gimbal was removed for the reaction measurements. Different crucibles were used for calibration and reaction measurements. The crucible for the reaction measurements was somewhat deper and had a small gold button soldered to the edge of the bottom. It was closed by a loose fitting Teflon stopper. The interior arrangement of the bomb for the reaction measurements is illustrated in Figure 1. Corrections were made to the energy equivalent for the differences in the calorimeter as used for calibration and reaction measurements.

In the calibration experiments the reaction was initiated by a fuse and cotton thread arrangement. For the reaction experiments, platinum wire 0.003 inches in diameter, fastened to the upper rim of the crucible, was used to support the crucible against the gimbal holder and was fastened at one end to the fuse lead. Passage of an electric current through the platinum wire (I, Figure 1.) fused it dropping the crucible, E, into the solution, A. Another platinum wire, K, connected to the crucible support was wound around the gold button on the crucible base. It served as a snubber, and tipped the falling crucible over, thus spilling out the Teflon stopper, F, and the contents of the crucible. This mechanism for initiating reaction required few changes in the bomb and its fittings, and was found to work without fail.

3. Preliminary Experiments and Tests of Procedures

A. Initiation of reaction should not be by rotation.

An obvious application of the rotating feature and the falling crucible feature of the rotating bomb calorimeter to the dissolution of metal in acid is to use them to initiate the reaction. Two experiments were sufficient to indicate that this is not a satisfactory procedure.

For these experiments the crucible was loaded with one gram of beryllium. To initiate reaction the bomb was rotated, dropping the crucible from its gimbal into 50 grams of aqueous acid solution on the first revolution. Reaction occurred and proceeded rapidly; however, it did not terminate sharply. In the first experiment, ten minutes

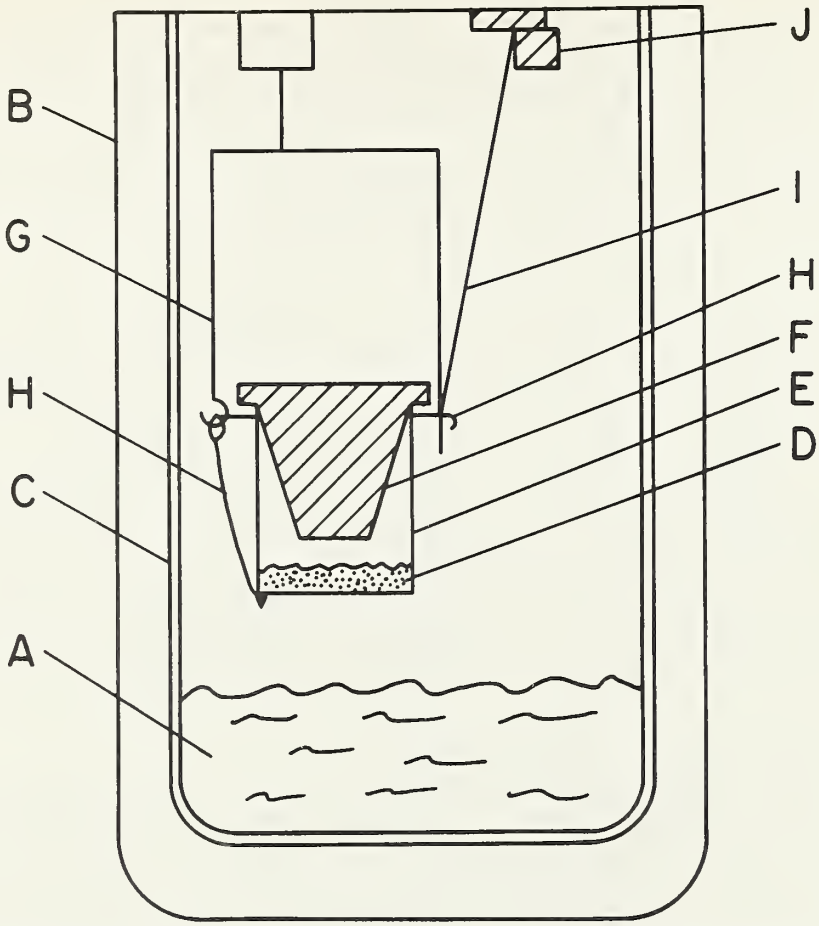

Figure 1. Preliminary Crucible and Fuse Arrangement for Heats of Reaction of Metal in Aqueous HF in Rotating Bomb

A, aqueous HF solution; B, bomb wall; C, platinum liner; D, metal powder; E, platinum crucible, F, Teflon stopper; G, gimbal holder; H, platinum wire gimbal; I, platinum wire fuse; J, platinum fuse holder; K, platinum snubbing wire.

after reaction the temperature drift rate was higher than normal by about 7×10^{-5} ohms min^{-1} and after 40 minutes was still changing. In the second experiment the drift rate was about 25×10^{-5} ohms min^{-1} higher than normal ten minutes after initiation of reaction, and continued to decline for an hour. In contrast with this behavior, the drift rate reached its final steady state by ten minutes after ignition, when the procedure was modified to initiate reaction by fuse, without immediate rotation, as described in Section 2.

The cause of the anomalous behavior when the reaction was initiated by rotation was not definitely established. We suggest the following plausible explanation. On rotation of the bomb, the solid powder falls ultimately on the lid which contains crevices around the edge, around the electrode supports, and in the valve openings. Powder falling into these crevices may be expected to deplete the nearby acid or, by formation of bubbles, be separated from the body of liquid. Thenceforth its reaction could be quite slow. It was this line of reasoning which led to the successful arrangement. This consisted of dropping the crucible, without rotation of the bomb, on the smooth bomb floor, where it was allowed a reasonable time for complete reaction before rotation was begun.

B. Air must be purged from the bomb.

Two heat measurements, not listed in the tables of experimental results, were carried out in which beryllium was dissolved in acid in a bomb still containing the air that was in it at the time it was closed. These two experiments gave hydrogen yields low by 8.0 and 5.3 percent, respectively. Apparently under the conditions of the reaction of the metal, the hydrogen formed may react with free oxygen to the extent that it is present. A calculation of the amount of oxygen in the bomb showed that the smaller deficiency of hydrogen could largely be accounted for in this way. For later combustion experiments, therefore, the air in the bomb was displaced by helium after closing the bomb. The immediate effect of this procedure was to increase the recovery of hydrogen to over 99 percent as shown in table 1. Purging time of the bomb was 20 to 25 minutes and the rate of flow of helium used was about 400 cc min^{-1}.

C. Metal powder must be protected from HF vapors in the bomb.

Prior to initiation of the principal reaction, if the metal is exposed to the gases in the bomb, the small amount of acid in the vapor phase reacts with the metal. This fact was demonstrated by carrying out blank experiments in which the bomb was loaded, and purged of air, and the amount of hydrogen formed was measured, without carrying out a solution reaction. In purging the bomb,

Table 1

Recovery of Water in the Hydrogen Analysis Train

Source of H_2O	Recovery (%)	Note	Source of H_2O	Recovery (%)	Note
Water introduced	99.372		Reaction HF-Be(4)	99.348	B
	99.946		(5)	99.659	B
	99.942		(7)	96.781	
			(8)	98.662	
Pre Reaction	.14	B	(9)	99.034	
	.12	B	(10)	99.220	
	.054		(11)	99.390	
Reaction, HF-Aℓ	96.863		(12)	98.208	C
	98.651		(13)	99.098	
	99.422		(14)	99.446	
	99.421		(15)	99.917	
	99.721		(16)	98.885	
	99.224		(17)	88.539	C
Reaction HF-Be(1)	91.95	A,B			
(2)	94.66	A,B			

Note A: Bomb was not purged of air.

Note B: No lid on crucible.

Note C: Loss of hydrogen observed.

Within each group the order is chronological, however the groups are not chronologically arranged. Also some experiments in which gross errors occurred are not listed.

helium passed through it at a rate of about 400 cc min^{-1} for one hour during which the gases passed through a hydrogen collection train. Thereafter, the bomb was closed, and the train was flushed with helium overnight following the usual procedure for collecting hydrogen. Besides the evolution of hydrogen, the formation of a crust on the beryllium powder gave evidence of pre-ignition reaction. The blank measurements of hydrogen were used later as a quantitative measure of pre-ignition reaction for estimating a correction to the observed heat of reaction. In the blank experiments, the amount of hydrogen recovered as water was 0.12 and 0.14 percent of the total hydrogen equivalent of the sample when the crucible was left uncovered. Covering the crucible reduced the amount of hydrogen to 0.054 percent. These measurements of pre-ignition reaction are listed in table 1.

D. Collection of water as a measure of the amount of reaction has not yet been made quantitative.

As a result of the tests so far carried out, the collection of hydrogen is not quite complete, based on the weight and composition of the beryllium sample. In addition to the preliminary tests and the heat measurements using beryllium, further tests on collection of hydrogen were made using pure hydrogen gas and others using aluminum metal. These tests are described in more detail in Section 7. In the case of hydrogen gas the effect of impurities was too large, because of the difference in molecular weights, to allow an accurate calculation of the weight of hydrogen corresponding to a given amount of water collected. In the case of aluminum, the hydrogen collected was low by an amount comparable to that in the beryllium experiments. The deficiencies observed with the metals apparently represent inadequate control of some factor in the hydrogen analysis scheme; though the possibility of an unknown side-reaction has not been entirely ruled out.

E. Heat of rotation is not seriously complicated by the solutions in the bomb.

Temperature drift rates of the calorimeter were studied under several conditions associated with the experiment, in order to establish whether any anomalous behavior was associated with the comparatively large amounts of liquid in the bomb, and whether evidence of reaction in the solutions or between solutions and bomb could be observed. These tests were negative. The heat-leak modulus a of the calorimeter has an average value near 235 x 10^{-5} min^{-1} with a standard deviation of 1 or 2 x 10^{-5} min^{-1}. The effect of rotation of the empty bomb during the final drift but not during the initial drift is to reduce the value of a calculated from the initial and final drift rates 2 x 10^{-5} min^{-1} below that with the bomb not rotating during either

interval. With the aqueous HF solution (50 grams) in the bomb the constant calculated in the same manner, with the bomb rotating in the final period, was reduced 3×10^{-5} min^{-1} below that for the empty stationary bomb. These changes, while apparently real are not very significant in view of the normal fluctuations in a. The calorimeter showed similar values of a in calibration and in measurements of the heat of solution of beryllium. The constant a had the mean value 236.3×10^{-5} min^{-1} and a standard deviation of 2.0×10^{-5} min^{-1} in 4 calibration experiments. Excluding one experiment (No. 7) in which an unusually high final drift rate was observed, the constant a had a mean value of 234.3×10^{-5} min^{-1} and a standard deviation of 2.1×10^{-5} min^{-1} in 12 measurements with beryllium and acid in the bomb. Except in experiment No. 7, no unusual drift rates of the calorimeter were observed. The calorimetric process thus appears to be without complications of unexplained side reactions or incomplete reactions.

4. Materials for the reaction.

Beryllium.

Beryllium metal in powder form was obtained from two commercial sources, and both samples were used in the experiments. The samples were the same as those used by Churney and Armstrong [2] for combustion in fluorine, and are described in more detail in the reference cited. The largest quantity of material was that labelled Sample BB which was the less pure and more finely divided of the two. Sample BB was used for the preliminary experiments and the first series of measurements. Sample NM was used for a final short series of measurements. The analyses of the samples are shown in Table 2, in which the reactive impurities are indicated in the forms in which they were presumed to be present.

Safety precautions used in handling beryllium.

Because of the extreme toxicity of beryllium [7] the metal powder and the aqueous solutions resulting from reaction were handled with great care. Prior to the experiments the beryllium metal powder had previously been portioned in samples of about one gram into small polyethylene vials having snap-on caps. This process was carried out in a dust box.

To transfer beryllium from the vial to a crucible for the reaction experiments, the crucible and vial were manipulated in a plastic bag to prevent accidental dispersal of dust. Both the crucible and vial were weighed before and after the transfer in order to have knowledge of possible losses as well as to weigh the sample. Mass balance errors

Table 2

Composition of Beryllium Samples

Sample BB					
Constituent	Contribution per gram of sample				
	Wt, g	HF, equiv.	H_2O, moles	H_2, moles	ΔH, J
Be	0.988579	0.219387	-	0.1096935	Q
BeO	.007252	.000580	.000290	-	-29.0
Be_2C	.002000	.000266	-	.0001330	-54.4
Be_3N_2	.000393	.000043	-	.0000215	- 5.0
Metals[a]	.001776	.000133	-	.0000665	-14.7
Totals	1.000000	0.220409	.000290	0.1099145	-103.1

Sample NM					
Constituent	Contribution per gram of sample				
	Wt, g	HF, equiv.	H_2O, moles	H_2, moles	ΔH, J
Be	0.997372	0.2213382		0.1106691	Q
BeO	.001302	.0001041	.0000521	-	- 5.21
Be_2C	.001252	.0001667	-	.0000833	-34.05
Be_3N_2	.000008	.0000008	-	.0000004	- .10
Metals[b]	.000068	.0000071	-	.0000036	- .65
Totals	1.000002	0.2216169	.0000521	0.1107564	-40.01

a. Other metals are (micrograms per gram): Mg(100), Aℓ(436), Si(83), Ca(50), Mn(56), Fe(795), Cu(50), Ni(90), Pb(5), Mo(10), Cr(90), Others (11).

b. Other metals are (micrograms per gram): Aℓ(16), Si(17), Mn(8), Fe(13), Cu(8), Ni(5), Cr(1).

ranged from 0.09 to 0.49 mg. In the unlikely event that the mass unaccounted for had escaped into the room, the average concentration would not have exceeded 2.5×10^{-6} gm^{-3}.

After an experiment the solution remaining in the bomb when the hydrogen had been purged out was poured into a polyethylene bottle in a laboratory sink by an operator wearing rubber gloves. The bomb was rinsed two or three times and the rinsings were added to the bottle. The solution in the bottle was neutralized with sodium hydroxide solution, and packaged for later disposal by the NBS safety office.

Hydrofluoric acid.

The hydrofluoric acid solution used as a solvent was prepared from Reagent Grade aqueous stock solution labelled as assaying 48.0-51.0 percent HF. The acid was diluted to about 25 percent (12.5 meq HF/g solution). Two batches of HF solution were used in the experiments, respectively containing 25.15 and 25.72 percent HF by weight.

Solutions used in the experiments were standardized by titrating with a direct-reading, continuous-indicating pH meter having a range 0-14 pH and a sensitivity of 0.01 pH, using a glass electrode to determine the end point.

The hydrofluoric acid solutions were stored in polyethylene bottles and standardized in polyethylene beakers. For standardization, a sample of about one gram was weighed accurately from a polyethylene weighing bottle and diluted to 50 cc. This was titrated against standardized NaOH solution using methyl red indicator to determine an approximate end point (about pH 6), at which point the glass electrode of the pH meter was introduced for determining the final end point. This concentration of HF is too low to attack the glass electrode.

Sodium hydroxide solutions for titration of the HF were standardized against potassium acid phthalate, NBS Standard Sample 84g, which had been previously dried and weighed. Two NaOH solutions of concentrations 0.26217 N and 0.3855N, respectively, were used.

5. Calibration of the Calorimeter.

The calorimeter was calibrated by combustion in oxygen of benzoic acid, NBS Standard Sample 39i, for which the energy released in the standard bomb process, $-\Delta U_B^o$, is 26434 J g^{-1}. The four experiments used to determine the energy equivalent of the calorimeter are

summarized in Table 3. The experiment number; corrected temperature rise, ΔR_c; mass of benzoic acid, m_s; fuse energy, q_f; correction of the heating value of benzoic acid to the conditions of the experiment, $\Delta U_B - \Delta U_B^o$; correction of the calorimeter energy equivalent to the standard calorimeter, $\Delta\varepsilon_S$; and the calculated energy equivalent of the standard calorimeter, ε_S, are given in Table 3. For these experiments the standard calorimeter was taken to be the calorimeter can with its stirrer, rotation shaft, heater, and water sufficient to make a total of 4930 g, the calorimeter cover, the thermometer partially immersed, the fuse connector, and the bomb with its standard contents and rotating mechanism.

For the benzoic acid experiments, in addition to its standard contents, the bomb contained the combustion sample, approximately 30 atm. oxygen, one gram of water, a platinum fuse connector, a stainless steel fuse connector, and a platinum crucible and gimbal. Auxiliary data used in making the corrections are listed in Table 4.

6. Experimental Procedures for Beryllium-Acid Reactions.

Other sections of this report outline or allude to many details of the procedure. In this section we give a general description of the procedure with references to other relevant sections.

Prior to an experiment the hydrofluoric acid solution was weighed and placed in the bomb. The sample of about one gram of beryllium metal was weighed into its crucible, using a safety technique described in Section 4. The bomb head and crucible were arranged as described in Section 2, and as illustrated in Figure 2. The bomb was closed, connected to a helium source, and purged for 20-30 minutes, using about 400 cm^3 min^{-1} of helium. It was then placed in the weighed calorimeter for the heat measurement.

The heat measurement followed a normal pattern of initial drift period, fuse ignition, rapid temperature rise, initiation of rotation, and final drift period. The resistance bridge was used in the N-only mode for most of the drift measurements and the rapid temperature rise. A check of the N-R difference was made at one point in each drift period, and any change observed was used to calculate a correction to the temperature rise for the change of the thermometer leads during an experiment.

After ignition of the fuse the temperature rose rapidly, T_m for the experiment coming approximately the same length of time after ignition as in a combustion experiment. Rotation was initiated two minutes after initiation of reaction. The delay in initiating rotation was made to allow reasonably complete reaction while the powder rested on the smooth bottom of the bomb. Final drift measurements were begun nineteen minutes after fuse ignition, and lasted fifteen minutes.

Table 3

Calibration of Calorimeter

Expt. No.	ΔR_c ohm	m_s g	q_f J	$\Delta U_B - \Delta U_B^o$ J g^{-1}	$\Delta\varepsilon_S$ J ohm^{-1}	ε_S J ohm^{-1}
4	0.301821	1.739608	22.9	5.3	-192.1	152211.1
5	0.300673	1.733058	21.0	5.3	-192.3	152210.8
6	0.304372	1.754657	19.7	5.1	-192.7	152230.7
7	0.301184	1.735368	21.5	5.0	-193.0	152157.4
Mean						152202.5
Standard deviation of the mean						15.7 (.010%)

Table 4

Auxiliary Data used in Calculating Volume of Bomb and Energy Equivalent of Calorimeter

Substance	C_p J ohm^{-1}	C_v J ohm^{-1}	ρ g cm^{-3}	Ref.
He		207.86 $mole^{-1}$		[11]
H_2		205.5 $mole^{-1}$		[12]
O_2		209.6 $mole^{-1}$		[10]
Be	178.24 $mole^{-1}$		1.816	[11]
Benzoic Acid	12.1 g^{-1}		1.320	[10]
$H_2O(\ell)$	41.795 g^{-1}		0.997	[10]
HF(aq)(25.15%)	34.68 g^{-1}		1.092	[13]
(25.72%)	34.54 g^{-1}		1.092	[13]
Pt	1.36 g^{-1}		21.45	[10]
Stainless Steel	4.392 g^{-1} (a)		7.8	[11]
Teflon	11.7 g^{-1}		2.23	[14]

(a) Calculated from composition.

At the conclusion of the heat measurement, the bomb was removed from the calorimeter and fitted with needle valves sealed to the bomb by Swagelok fittings. With the needle valves closed, the bomb valves were opened. The bomb was then attached to the hydrogen collection train (Figure 2). At this point the bomb contained hydrogen at a pressure of about seven atmospheres, plus helium at one atm. The procedure for determination of hydrogen is described in some detail in Section 7.

When all hydrogen had been purged from the bomb, the bomb was disconnected from the hydrogen analysis train, and was opened in the hood. The contents of the bomb were examined visually for undissolved metal sample but none was ever found. The solution was always clear, water white. It was disposed of as described in Section 4.

7. Determination of Hydrogen.

Hydrogen formed in the reaction was converted to water and the water was weighed in order to determine the amount of hydrogen formed. This technique was not entirely perfected at the time of writing this report, there being generally an unexplained deficiency of hydrogen in all tests of the method and in the experiments on beryllium. The deficiency was of the order of 0.5 percent in the beryllium experiments and puts an upper limit on the uncertainty of the amount of reaction that occurred. In view of the consistency with the experiments in the collection of hydrogen from reaction of aluminum, it is unlikely that an uncertainty greater than 0.2 percent in the amount of reaction exists on this account.

The apparatus used for the hydrogen determination is shown schematically in Figure 2. The flow train for gases consists of a helium tank, which is a source of gas for purging hydrogen from the system and transporting water vapor through the system; a connecting position for the reaction bomb, equipped with suitable valves to allow the bomb to be emptied, purged, or bypassed; drying tubes to dry the effluent gases; a control weighing tube; a flowmeter; a furnace tube packed with copper oxide; two H_2O weighing tubes; a protective drying tube, and a bubbler for the exit gases. These components are identified more closely in the caption to Figure 2.

The flow system from the helium cylinder to position T is all metal, and joints are made with Swagelok connectors 1/4 inch in diameter. From T to the outlet end the system is glass. In this region connections are made by O-ring connectors with Buna-N O-rings, or by standard-taper greased joints, except for the Tygon covering the joint from the protective drying tube, I, to the bubbler, J.

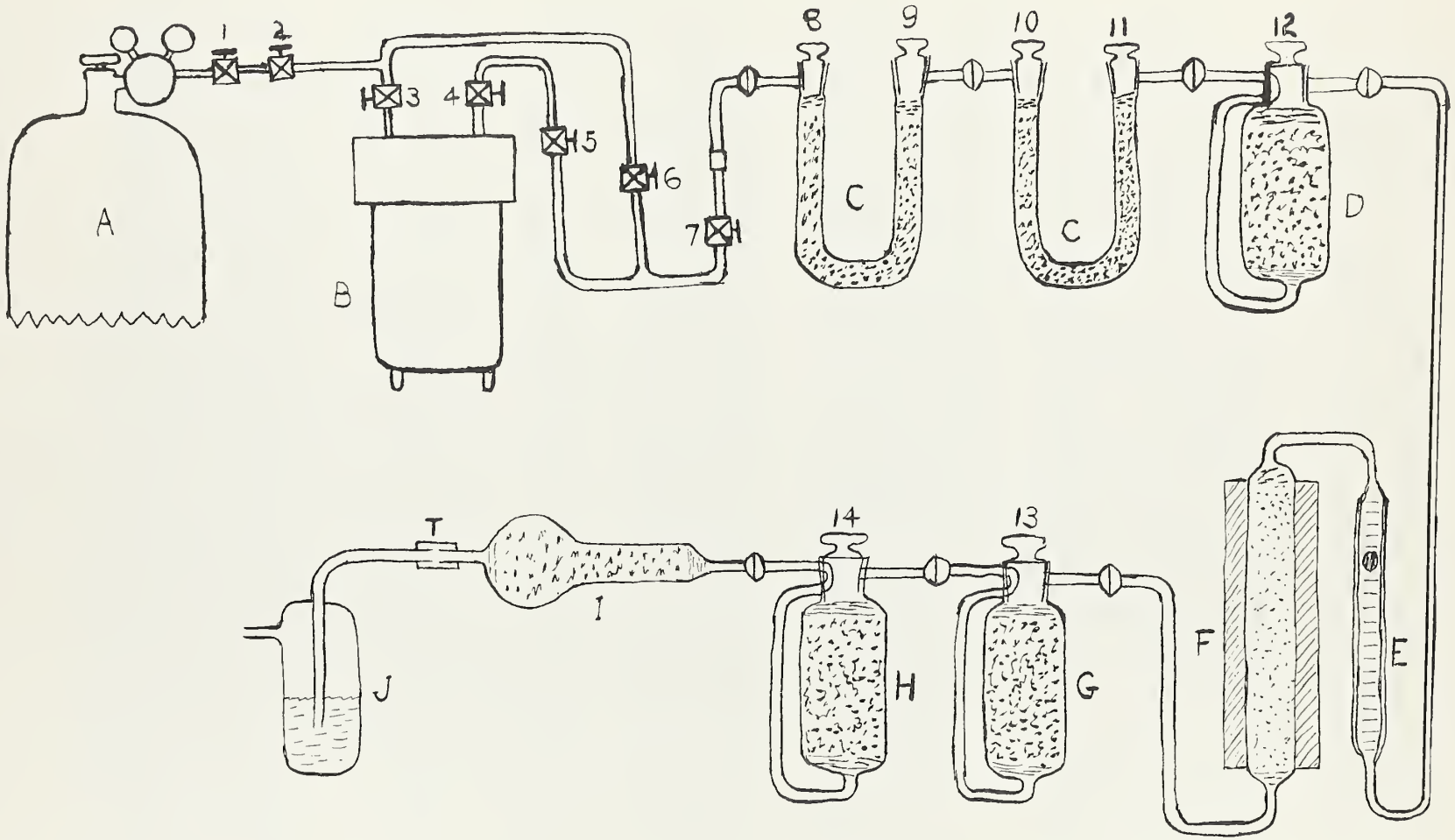

Figure 2. Flow train for determination of hydrogen.

A, Helium cylinder; B, combustion bomb; C, drying tubes; D, control weighing bulb; E, flowmeter; F, furnace; G, H, water collecting bulbs; I, protective drying tube; J, bubbler; T, metal-glass joint. Metal valves 1,2,3,4,5,6,7; Glass valves 8,9,10,11,12,13,14.

The drying tubes, C, are necessary to remove water and HF from the gases emerging from the bomb. They are U-tubes with greased ground glass stoppers at entrance and exit. Each tube contains a magnesium perchlorate packing held in place with asbestos fiber.

The bulbs used for weighing absorbed water, were commercial Nesbitt absorption bulbs modified slightly to conform to the configuration described by Rossini [8], and fitted with O-ring connectors. The bulbs were packed with anhydrous magnesium perchlorate, bounded by layers of shredded asbestos, as described by Rossini. The control weighing bulb, B, is used to determine a blank for the experiment. The small changes in weight of this bulb appear to be related to loss of powdered packing material when gases are passed through. Bulb H is a backup absorber to confirm that all water has been absorbed in bulb G.

The oxidizer tube in the furnace, F, consists of a Vycor tube 30 mm inside diameter and 38 cm long, packed with CuO wire fragments. The furnace surrounding it was kept at a temperature between 400 and 500°C. We expected that in this temperature range conversion of H_2 to H_2O would be complete. The CuO in the Vycor tube is reduced to Cu by the reaction. It can be restored to an oxidized state by passing oxygen through the system.

The flowmeter is a commercial floating-ball flow indicator in a tapered glass tube having a range of helium flow rates from 110 to 1100 cm^3 min^{-1}. The indication of the flowmeter loses sensitivity at very low flow rates. In this region the bubbler, J, gives a positive indication of flow. The bubbler is filled with butyl phthalate.

The final weighing bulb, H, is protected from CO_2 and H_2O entering the system at the exit by tube I which contains magnesium perchlorate and ascarite.

For analysis of hydrogen in the bomb, the bomb was attached to the train and as a first step the excess pressure of gas was relieved by releasing the gas into the train. For this step, the valves leading to the helium tank (Valves 1, 2 and 3) and the by-pass valve (Valve 6) were closed and all other valves opened. When the gas pressure in the bomb had almost reached line pressure, and the outflow as observed in the bubbler had become slow, the valves from the helium tank were opened. The bomb was purged with helium for one hour at a rate of 400 cm^3 min^{-1}. Most of the water formed in the process up to this point condensed in the glass tube at the bottom of the furnace. After the bomb had been purged, the valve by-passing the bomb was opened and the bomb valves were closed. The purging then continued overnight to transport all the water formed into the weighing bulbs. The purging time was 16 to 18 hours.

Bulbs D, G, and H were weighed along with a similar tare bulb before and after the absorption of water. The tare bulb was used to eliminate the principal part of the buoyancy correction. The weight of bulb D was used as a control in the weight measurements on bulb G.

When the bulbs were being weighed they contained helium, which was brought to atmospheric pressure by opening a stopper momentarily at the time of weighing. A buoyancy correction for displacement of helium caused by absorption of water in the magnesium perchlorate was applied by using the factor 0.99996 suggested by Rossini [8].

Tests made to demonstrate the adequacy of the technique included studies of weight changes during blank runs, the collection of water introduced into the system, and the collection of water from hydrogen introduced as a weighed sample or as a product of reaction of acid with a weighed amount of aluminum.

In blank runs changes in weight of bulbs D and G amounting to 3 mg or less were observed. The changes in weight of bulb D and bulb G in any blank experiment were the same within 0.3 mg. Losses of weight observed in bulb D were, therefore, applied as corrections added to the weight of water collected in bulb G.

Completeness of collection of water introduced into the system was verified with much better completeness than was achieved with water formed from hydrogen. A weighed bulb similar in design to bulb D and containing water was introduced between bulb D and flowmeter E. The water was transported into bulb G by a stream of helium flowing overnight. The furnace was at its operating temperature during this procedure. The average amount of water recovered in two measurements was 99.94 percent, with a range of 0.004 percent.

Collection of water from weighed amounts of hydrogen was unsatisfactory because of the small weight of gas compared to the weight of the sample bulb, and because of the large relative uncertainty introduced by impurities in the hydrogen. For example, an uncertainty of 0.05 mole percent in nitrogen impurity introduces an uncertainty of 0.70 percent in the weight of hydrogen.

When weighed amounts of finely divided aluminum of known purity were dissolved in acid in the bomb, the amount of water collected in four experiments was about 99.45 percent of that expected, with a standard deviation of an experiment of 0.20 percent. In making the calculation the amount of oxide in the sample was taken into account. The aluminum was the same as that used by Domalski and Armstrong [9]. A new analysis indicated the presence of 0.70 percent $A\ell_2O_3$.

The collection of hydrogen in the train is summarized in Table 1.

Factors which should be examined in refinement of the technique of hydrogen collection and weighing include: sources of the blank corrections of the weighing bulbs; the possibility that hydrogen reacts and is absorbed somewhere in the system, such as by absorption in grease; and the possibility that some hydrogen passes through the furnace without being converted to water.

8. Experimental Measurements

Thirteen heat measurements were made on the reaction of beryllium with hydrofluoric acid solution in the bomb. The experimental data for the measurements and the results of the calculations are given in Tables 5-7.

All the experiments listed led to heat measurements from which an energy of reaction could be determined. Experiment 7, which was the first in which the Teflon stopper was used, had an anomalously low calorimeter heat transfer coefficient a. We suspect that a side reaction continuing after the main period caused the anomalous final drift rate that was observed for this experiment and the high energy observed for the reaction. This experiment was not used in the final averages.

In Table 5 we list from left to right the experiment number; two adjustments to the energy equivalent of the calorimeter, $\Delta\varepsilon_i$(HF) and $\Delta\varepsilon_i$ (other); the corrected temperature rise, ΔR_c; the observed total energy, $\varepsilon_i \Delta R_c$; the final reaction temperature, T_f; and the calorimeter heat transfer coefficient, a.

The term $\Delta\varepsilon_i$(HF) is the adjustment for the heat capacity of aqueous HF which is by far the largest adjustment to the calorimeter. The specific heat data of Thorvaldson and Bailey [13] were used in this calculation. Auxiliary data for calculation of the two corrections are listed in Table 4. By combining these corrections with the calibration data from Table 3 and the corrected temperature rise, ΔR_c, one can calculate the total energy observed, $\varepsilon_i \Delta R_c$.

In Table 6 we list the reaction quantities placed in the bomb and the calculated products of reaction. The mass of sample m_s is the initial mass placed in the bomb. In the calculation of the number of moles of Be, an adjustment for the small amount of pre-ignition reaction was made. The hydrofluoric acid was weighed into the bomb to obtain m (HF, aq), and from m(HF,aq) the number of moles of H_2O and HF, $n_i(H_2O)$, and n_i(HF) respectively, initially in the bomb were calculated by means of the analytical data on the solution.

Table 5

Calorimetric Data on Beryllium-Hydrofluoric Acid Reactions

Expt No.	$\Delta\varepsilon_i$(HF) J ohm^{-1}	$\Delta\varepsilon_i$(other) J ohm^{-1}	ΔR_c ohms	$\varepsilon_i \Delta R_c$ J	T_f deg C	a min^{-1}
4	1911.9	41.9[b]	0.292052	45021.7	31.814	0.00235
5	1928.8	41.6[b]	.287153	44271.2	31.780	.00237
7	1981.1	155.1	.294299	45421.7	31.894	.00218
8	1894.7	157.5	.319284	49251.1	31.915	.00238
9	1821.1	155.9	.296785	45758.2	31.868	.00230
10	1749.2	157.3	.314782	48498.4	31.752	.00234
11	2051.3	155.3	.288163	44495.0	31.721	.00232
12	1874.5	157.4	.319476	49274.2	31.870	.00233
13	1865.6	155.1	.286794	44233.2	31.741	.00233
14	1803.1	155.6	.292612	45109.4	31.747	.00233
15[c]	1872.4	156.4	.302732	46690.7	31.732	.00234
16[c]	1874.8	155.5	.291037	44887.5	31.710	.00234
17[c]	1845.9	159.7	.345222	53236.0	32.112	.00236

[b] No Teflon stopper used in the crucible.

[c] NM sample was used in experiments 15, 16, 17.

Table 6

Reaction Quantities of Beryllium-Hydrofluoric Acid Reactions

Expt. No.	m_s g	m(HF,aq) g	n_i(Be) moles	$n_i H_2O$ moles	$n_i HF$ moles	$n_f BeF_2$ moles	$n_f H_2O$ moles	$n_f HF$ moles	$n_f H_2$[d] moles
4	.976878	55.1250	0.107015[a]	2.290696	0.692358	0.107658	2.290979	0.477331	0.107230
5	.960465	55.6121	.105217[a]	2.310934	.698483	.105849	2.311212	.487070	.105429
7	.981989	57.1213	.107660[b]	2.373647	.717611	.108221	2.373932	.501289	.107877
8	1.069056	54.8506	.117142[c]	2.262298	.704245	.117816	2.262608	.468869	.117378
9	.993219	52.7193	.108891[b]	2.174389	.677008	.109459	2.174677	.458211	.109110
10	1.053146	50.6393	.115461[b]	2.088601	.650285	.116062	2.088906	.418287	.115693
11	.963348	59.3834	.105616[b]	2.449250	.762605	.106166	2.449529	.550389	.105829
12	1.069675	54.2660	.117273[b]	2.238185	.696865	.117884	2.238495	.461224	.117509
13	.958483	54.0068	.105082[b]	2.227494	.693548	.105630	2.227772	.482408	.105294
14	.979561	52.1989	.107393[b]	2.152929	.670326	.107953	2.153213	.454538	.107610
15	1.003986	54.2056	.111050[b]	2.235693	.696097	.111250	2.235745	.473718	.111138
16	.964552	54.2731	.106688[b]	2.238479	.696968	.106880	2.238529	.483324	.106773
17	1.148068	53.4391	.126987[b]	2.204081	.686234	.127216	2.204141	.431942	.127087

[a] A correction of 0.133 percent pre reaction has been made.

[b] A correction of 0.054 percent pre reaction has been made.

[c] A correction of 0.108 percent pre reaction has been made.

[d] Percent recovery of hydrogen is listed in Table 1.

Table 7

Thermal Results of Beryllium-Hydrofluoric Acid Reactions

	$-\Delta E$(corr) J	$-\Delta E_T^\circ$ kJ mole^{-1} Be	$-\Delta E^\circ$ Imp kcal/mole Be	$-\Delta H^\circ_{305.15}$ kcal mole^{-1} Be
4	1.85	420.7219	-0.2356	99.7129
5	1.87	420.7787	- .2356	99.7265
7	1.84	421.9166	- .2292	100.0049
8	1.74	420.4541	- .2336	99.6509
9	1.83	420.2370	- .2292	99.6035
10	1.76	420.0566	- .2292	99.5603
11	1.86	421.3079	- .2292	99.8594
12	1.74	420.1815	- .2292	99.5902
13	1.87	420.9576	- .2292	99.7757
14	1.85	420.0576	- .2292	99.5606
15	1.80	420.4638	- .0911	99.7958
16	1.85	420.7535	- .0911	99.8650
17	1.62	419.2367	- .0911	99.5025
Mean				99.6836
Uncertainty			$2\bar{s}$	±.1016

The final numbers of moles of beryllium fluoride, $n_f(BeF_2)$; water, $n_f(H_2O)$; hydrofluoric acid, $n_f(HF)$ and hydrogen, $n_f(H_2)$, in the bomb at the conclusion of the reaction include small contributions to each from the reactions of impurities in the beryllium sample. The percentage collection of hydrogen shown in Table 1 is the percentage of the anticipated value, $n_f(H_2)$ in Table 6. In a few experiments, as indicated in Table 1, some observed loss of hydrogen occurred in making the analysis. This did not invalidate the heat measurement, but makes it impossible to calculate the affected experiments on the basis of hydrogen.

Table 7 lists the calculated thermodynamic quantities found for the reactions. The material in Table 7 will be discussed further in Section 9. Heats of formation used as auxiliary data in making the calculations are listed in Table 8.

9. Adjustment of the Observations to a Standard Reference State

The starting materials of the reaction in the bomb consist of a solid reactant, a liquid mixture and a gaseous mixture. The solid reactant is n_i^{Be} moles of beryllium metal containing as impurities $n_i^{BeF_2}$ moles of BeF_2, n_i^{BeO} moles of BeO and n_i^{Me} gram equivalent weights of metallic impurities Me.

The liquid phase is a mixture of $n_i^{HF\ell}$ moles of HF and $n_i^{H_2O\ell}$ moles of water, under a pressure of one atmosphere, and saturated with helium at that pressure.

The gaseous phase consists of n_i^{He} moles of helium at about one atmosphere pressure, saturated with n_i^{HFg} moles of gaseous HF and $n_i^{H_2Og}$ moles of gaseous H_2O in equilibrium with the liquid phase. The contents of the bomb are all at the initial temperature, T_i.

The contents of the bomb at the conclusion of the experiment consist of a homogeneous final liquid phase and a homogeneous final gaseous phase.

The final liquid phase consists of a mixture of $n_f^{BeF_2}$ moles of BeF_2 in which for convenience we include the n_i^{Me} gram equivalent weights of metal fluorides on the basis that one equivalent weight behaves as one half mole of BeF_2, $n_f^{HF\ell}$ moles of HF, and $n_f^{H_2O\ell}$ moles of water under a pressure, P_f, of about ten atmospheres of hydrogen and about one atmosphere of helium and saturated with each gas at its respective pressure.

Table 8

Auxiliary Heats of Formation Used in the Calculations

Substance	ΔH^{o}_{f298} kcal mole^{-1}	Reference
Be_2C	-22.2	[19]
BeO	-143.1	[18]
Be_3N_2	-137.8	[19]
Metallic Fluorides		[11]
HF x 3.2 H_2O	-76.010	[17]
HF x 3.8 H_2O	-76.080	[17]
HF x 4.8 H_2O	-76.157	[17]
HF x n H_2O	by interpolation	[17]

The final gaseous phase consists of $n_f^{H_2}$ moles of hydrogen mixed with n_f^{He} moles of helium, and saturated with $n_f^{H_2Og}$ moles of gaseous H_2O and n_f^{HFg} moles of gaseous HF in equilibrium with the liquid phase. For the purpose of this discussion, a small amount of CH_4, which may be present as a product of reaction of the beryllium carbide impurity in the sample, is treated as hydrogen, and the carbide itself is treated as a metal in the equation of the reaction.

In carrying out the calculation, we ignore certain factors which would have to be included in a rigorous treatment. The helium present in the bomb is not considered to be involved in any process. We feel that the energ changes involving helium are small. The amount of hydrogen dissolved and its heat of solution in the final aqueous phase, the energies of compression of the initial solid and liquid phases and the final liquid phase, and the energies of mixing of the gaseous phases are all considered to be negligible.

Equations for the reactions carried out and those used in calculating adjustments to a reference process are shown in Table 9. Reaction (1) represents the process actually carried out in the bomb. The actual bomb process was adjusted to reaction (2). In making the adjustment, processes represented by reactions (3), (4), (7), and (9) were presumed to be carried out. Equations (5), (6) and (8) represent intermediate stages of the calculations. Equation (3a) represents the condensation of $n_f^{H_2Og}$ and n_f^{HFg} moles of gaseous H_2O and HF respectively into the bomb solution; and equation (3b) represents the evaporation of n_i^{HFg} moles of HF and $n_i^{H_2Og}$ moles of H_2O from the initial solution. The vapor pressure data of Brosheer, Lenfesty, and Elmore [15] were used in the calculations. Equation (4) represents the adjustment of hydrogen from its final pressure to the ideal gas state. Data on the internal energy of hydrogen were taken from Hilsenrath, et al. [12]. The corrections resulting from reactions (3) and (4) are listed in Table 7 under the heading $-\Delta E$(corr). Equation (5) is the sum of equations (1), (3a), (3b), and (4). Equation (6) is the same as equation (5) converted to the basis of one mole of elemental beryllium in the starting material. Equation (7) represents the process of adjusting the concentrations of H_2O and HF in such a way that the final process will be represented by equation (2). Equation (7) is rewritten as equation (7') in order to show more clearly the proportions of H_2O, HF, and BeF_2 in the solutions, and to ease the process of calculating the energy changes. Because no information is available on the energy of dilution of BeF_2 solutions in aqueous HF, we make the

approximation here that an equivalent weight of BeF_2 in solution has the same thermal effect as a mole of HF. The effect of this assumption is that zero energy change is found for reaction (7). Equation (8) is the sum of equations (6) and (7). The energy found for equation (8) is listed in Table 7 as $-\Delta E_T^o$. Equation (9) represents the reactions of impurities, and is used to calculate the energy contributed by them. The energy found for this reaction is listed in Table 7 as $-\Delta E^o$(imp). Equation (2) is the sum of equations (8) and (9).

The enthalpy change of reaction (2) is found by adding the PV term for hydrogen in the ideal gas state, and is listed as $-\Delta H^o_{305.15}$ in Table 7.

Atomic weights used are from the 1961 atomic weight scale based on the atomic mass of $^{12}C = 12$ [16]. The calorie is taken as 4.1840 J.

In Table 10 are listed the energy relations for the reactions in Table 9. Table 11 gives the relationships between coefficients in the various reactions of Table 9.

The data obtained as a result of the experiments show an undesirable lack of internal precision. The reasons for this are not entirely clear. However, attempts to correlate the values found for $\Delta H^o_{305.15°K}$ with parameters of the experiments show suggestive trends. There is a concentration effect which has not yet been adequately accounted for in our treatment of the data thus far. The heat of reaction shows a pronounced dependence upon the ratious HF/Be and H_2O/HF. Treatment of the data in such a way as to remove one dependence removes the other also. If one ignores the presence of BeF_2 in the HF solutions and considers the heat of formation of HF to be that for the mixture of H_2O and HF alone a correction is introduced which reduces the observed trend by about 25 percent. A much larger factor is still unaccounted for. It is probably an interaction energy between the BeF_2 and HF. Qualitative evidence of such as interaction energy is given by Sengupta [22] who performed a thermometric titration of aqueous HF by BeF_2 solution, in which he observed an exothermic heat effect which he associated the formation of H_2BeF_4 in solution. The heat effect of mixing aqueous HF and aqueous BeF_2 solutions roughly estimated from Sengupta's data is greater than two kcal (mole $BeF_2)^{-1}$.

10. Heat of Formation of BeF_2(c)

The data obtained from our measurements are inadequate to allow a firm statement to be made about the heat of formation of BeF_2(c). However, some information is available. The heat of solution of

Table 9

Equations for the Bomb Process and Adjustments

(1) $n_i^{Be}Be(c) + n_i^{BeF_2}\ BeF_2 \quad n_i^{BeO}\ BeO + n_i^{Me}Me + [n_i^{HF\ell}HF + n_i^{H_2O\ell}H_2O](\ell) + n_i^{HFg}HF(g) + n_i^{H_2Og}H_2O(g) =$

$[n_f^{BeF_2}BeF_2 + n_f^{HF\ell}HF + n_f^{H_2O\ell}H_2O](\ell) + n_f^{HFg}HF(g) + n_f^{H_2Og}H_2O(g) + n_f^{H_2}H_2(g,\ p = p_f)$

(2) $Be(c) + 6(HF \times 3.2\ H_2O)(\ell) = [BeF_2 + 4\ (HF \times 4.8\ H_2O)](\ell) + H_2(g,\ p = 0)$

(3a) $n_f^{H_2Og}H_2O(g) + n_f^{HFg}HF(g) + [n_f^{BeF_2}BeF_2 + n_f^{HF\ell}HF + n_f^{H_2O\ell}H_2O](\ell) = [n_f^{BeF_2}BeF_2 + n_f^{HF}HF + n_f^{H_2O}H_2O](\ell)$

(3b) $[n_i^{HF}HF + n_i^{H_2O}H_2O] = n_i^{HFg}HF(g) + n_i^{H_2Og}H_2O(g) + [n_i^{HF\ell}HF + n_i^{H_2O\ell}H_2O](\ell)$

(4) $n_f^{H_2}H_2(g,\ p=p_f) = n_f^{H_2}H_2(g,\ p=0)$

(5) $n_i^{Be}Be + n_i^{BeF_2}BeF_2 + n_i^{BeO}BeO + n_i^{Me}Me + [n_i^{HF}HF + n_i^{H_2O}H_2O](\ell) = [n_f^{BeF_2}BeF_2 + n_f^{HF}HF + n_f^{H_2O}H_2O](\ell)$
$+ n_f^{H_2}H_2(g,\ p=0)$

(6) $Be + r_1BeF_2 + r_2BeO + r_3Me + [r_4HF + r_5H_2O](\ell) = [r_6BeF_2 + r_7HF + r_8H_2O](\ell) + r_9H_2(g,\ p=0)$

(7) $[6HF + 19.2\ H_2O](\ell) + [(r_6BeF_2 + r_7HF + r_8H_2O](\ell) =$
$[r_4HF + r_5H_2O](\ell) + [r_6BeF_2 + (4 - 2r_2 - r_3)\ HF + (19.2 + r_2)\ H_2O](\ell)$

(7') $6[HF \times 3.2\ H_2O](\ell) + 2r_6 + r_7)\ [(HF + BeF_2/2) \times r_8/(2r_6 + r_7)\ H_2O](\ell) =$
$r_4[HF \times (r_5/r_4)\ H_2O](\ell) + (4 + 2r_6 - 2r_2 - r_3)[(HF + BeF_{2/2}) \times (19.2 + r_2)/(4+2r_6-2r_2-r_3)\ H_2O](\ell)$

(8) $Be(c) + r_1BeF_2 + r_2BeO + r_3Me + [6HF + 19.2\ H_2O](\ell) =$
$[(1 + r_1 + r_2 + \frac{r_3}{2})BeF_2 + (4-2r_2-r_3)HF + (19.2+r_2)\ H_2O](\ell) + (1 + r_{3/2})H_2(g)$

(9) $[(1 + r_1 + r_2 + \frac{r_3}{2})\ BeF_2 + (4-2r_2-r_3)HF + (19.2 + r_2)\ H_2O](\ell) + r_{3/2})\ H_2(g) =$
$r_1BeF_2 + r_2BeO + r_3Me + [BeF_2 + 4HF + 19.2\ H_2O](\ell)$

Table 10

Energy Relations in Table 9

$\Delta E(1) = \Delta E$ obs.

$\Delta E(2) = \Delta E$ adjusted $= \Delta E(8) + \Delta E(9)$

$\Delta E(3a) = n_f^{H_2Og} (-\Delta E \text{ vap } [H_2O]) + n_f^{HFg} (-\Delta E \text{ vap } [HF])$

$\Delta E(3b) = n_i^{H_2Og} (\Delta E \text{ vap } [H_2O]) + n_i^{HFg} (\Delta E \text{ vap } [HF])$

$\Delta E(4) = (E_t^o - E_t^p) [H_2(g)]$

$\Delta E(5) = \Delta E(1) + \Delta E(3a) + \Delta E(3b) + \Delta E(4)$

$\Delta E(6) = \Delta E(5) / n_i^{Be}$

$\Delta E(7) = \Delta E(7') = \Delta E$ diln of $HF-H_2O$ and BeF_2-HF-H_2O solutions

$\Delta E(8) = \Delta E(6) + \Delta E(7)$

$$\Delta E(9) = -\left(\frac{n_i^{BeF_2}}{n_i^{Be}}\right) \Delta E_R(BeF_2) - \left(\frac{n_i^{BeO}}{n_i^{Be}}\right) \Delta E_R(BeO) - \left(\frac{n_i^{Me}}{n_i^{Be}}\right) \Delta E_R(Me)$$

Table 11

Relations between Coefficients of Table 9

$r_1 = n_i^{BeF_2} / n_i^{Be}$

$r_2 = n_i^{BeO} / n_i^{Be}$

$r_3 = n_i^{Me} / n_i^{Be}$

$r_4 = n_i^{HF} / n_i^{Be}$

$r_5 = n_i^{H_2O} / n_i^{Be}$

$r_6 = n_f^{BeF_2} / n_i^{Be}$

$r_7 = n_f^{HF} / n_i^{Be}$

$r_8 = n_f^{H_2O} / n_i^{Be}$

$r_9 = n_f^{H_2} / n_i^{Be}$

$n_i^{H_2O} = n_i^{H_2Og} + n_i^{H_2O\ell}$

$n_f^{H_2O} = n_f^{H_2Og} + n_f^{H_2O\ell}$

$n_i^{HF} = n_i^{HFg} + n_i^{HF\ell}$

$n_f^{HF} = n_f^{HFg} + n_f^{HF\ell}$

$n_f^{BeF_2} = n_i^{Be} + n_i^{BeF_2} + n_i^{BeO} + n_i^{Me}/2$

$n_f^{HF} = n_i^{HF} - 2n_i^{BeO} - n_i^{Me} - 2n_i^{Be}$

$n_f^{H_2O} = n_i^{H_2O} + n_i^{BeO}$

$n_f^{H_2} = n_i^{Be}/2 + n_i^{Me}$

$BeF_2(c)$ in aqueous HF was reported by Kolesov, Popov, and Skuratov [3]. Their experiments were carried out with solutions having a molar ratio of $H_2O/HF = 3.8$, which is in the range between the initial and final concentrations that we used. However, their experiments involved solutions much more dilute in BeF_2 than ours. We have devised a series of possible reactions which could be carried out, or data obtained from the literature, to make possible the adjustment from one concentration to the other, and additional reactions from which the data can be used to calculate the heat of formation of $BeF_2(c)$. These reactions are listed in Table 12 as equations (A-H). Reaction (2), Table 7, becomes reaction D of this series. The measurement by Kolesov, et al. is reaction E. Reaction (A) is of primary interest because it contains only quantities for which thermodynamic information is readily available, besides BeF_2, and can be used to calculate $\Delta H_f(BeF_2)(c)$. The relationships between the reactions are as follows:

$$\Delta H(A) = \Delta H(D) - \Delta H(B) - \Delta H(C)$$

$$\Delta H(C) = \Delta H(E) + \Delta H(F) + \Delta H(G) + \Delta H(H)$$

The value obtained for ΔH is listed in the column at the right of Table 12. For other reactions than D and E, the assumption is made as before that BeF_2 in solution can be replaced by an equivalent amount of HF and the data for HF(aq) be used in calculating the heat of reaction. This approximation is subject to the same error that has been mentioned before; and there is evidence in the experimental work that the approximation is not valid, but in fact causes a greater error.

While a value of -242.38 kcal $mole^{-1}$ can be calculated from the above data, the uncertainties listed above preclude any further conclusion to be drawn than that the heat of formation does not differ from this by more than a few kcal $mole^{-1}$.

A further uncertainty is introduced by possible continuing uncertainty in the heat of formation of HF(aq). Cox and Harrop [21] report ΔH_f of $HF + 20H_2O$ to be -77.396 kcal $mole^{-1}$. This is 1.116 kcal $mole^{-1}$ more negative than values listed by Evans [17]. Making a change this great in the heat of formation of HF in $(HF + 3.2\ H_2O)$ we obtain for $\Delta H_f[BeF_2(c)]$ the value -244.61 kcal $mole^{-1}$. While this is closer to the value reported by Churney and Armstrong [2], and could thus be cited as evidence for a more negative heat of formation of HF(aq), we must recognize that the dilution problems mentioned before still exist.

Table 12

Equations from which $\Delta H_f[BeF_2(c)]$ can be calculated

		ΔH° kcal mole^{-1}
A.	$Be + 2(HF \times 3.2\ H_2O)(\ell) = BeF_2(c) + 6.4\ H_2O(\ell) + H_2(g)$	- 90.36
B.	$6.4\ H_2O + 4(HF \times 3.2\ H_2O)(\ell) = 4.0\ (HF \times 4.8\ H_2O)(\ell)$	- 0.588
C.	$BeF_2(c) + 4.0\ (HF \times 4.8\ H_2O)(\ell) = [BeF_2 + 4.0\ (HF \times 4.8\ H_2O)](\ell)$	- 8.732
D.	$Be + 6(HF \times 3.2\ H_2O)(\ell) = [BeF_2 + 4.0(HF \times 4.8\ H_2O)](\ell) + H_2(g)$	- 99.68
E.	$BeF_2(c) + 340(HF \times 3.8\ H_2O)(\ell) = [BeF_2 + 340(HF \times 3.8\ H_2O)](\ell)$	- 8.04
F.	$4.0(HF \times 4.8\ H_2O)(\ell) + 336(HF \times 3.8\ H_2O)(\ell) = 340(HF \times 3.8\ H_2O)(\ell) + 4H_2O(\ell)$	+ 0.308
G.	$[BeF_2 + 340(HF \times 3.8)](\ell) = BeF_2 + 4(HF \times 3.8\ H_2O)](\ell) + 336(HF \times 3.8\ H_2O)(\ell)$	- 0.340
H.	$[BeF_2 + 4(HF \times 3.8\ H_2O)](\ell) + 4H_2O(\ell) = [BeF_2 + 4(HF \times 4.8\ H_2O)](\ell)$	- 0.660

11. References

[1] Hubbard, W. N., Katz, C., and Waddington, G., J. Phys. Chem. 58, 142 (1954).

[2] Churney, K. L., and Armstrong, G. T., This Report, Chapter B-10.

[3] Kolesov, V. P., Popov, M. M., and Skuratov, S. M., Zh. Neorg. Khim. 4, 557-8 (1959).

[4] Churney, K. L., NBS Report 8033, 1 July 1963, pp. 43-54.

[5] Argonne National Laboratory Drawings CE 3986, 28 June 1957.

[6] Armstrong, G. T., "Combustion and Reaction Calorimetry on Fluorine and Its Compounds", This Report, Part A.

[7] Tepper, L. B., Hardy H. L., and Chamberlain, R. I., "Toxicity of Beryllium Compounds (Elsevier Publishing Company, Amsterdam, 1961).

[8] Rossini, F. D., Calibration of Calorimeters for Reactions in a Flame at Constant Pressure, Chapter 4, in "Experimental Thermochemistry", F. D. Rossini, editor, (Interscience Publishers, New York, 1956) pp.59-74.

[9] Domalski, E. S., and Armstrong, G. T., J. Research Natl. Bur. Standards 69A, 137-147 (1965).

[10] Coops, J., Jessup, R. S., and van Nes, K., "Calibration of Calorimeters for Reactions in a Bomb at Constant Volume", Chapter 3 in "Experimental Thermochemistry", F. D. Rossini, editor (Interscience Publishers, New York, 1956) pp. 27-58.

[11] Rossini, F. D., Wagman, D. D., Evans, W. H., Levine S., and Jaffe, I., Natl. Bur. Standards Circular 500 (U. S. Government Printing Office, Washington, D. C., 1952).

[12] Hilsenrath, J., Beckett, C. W., Benedict, W. S., Fano, Lilla, Hoge, H. J., Masi, J. S., Nuttall, R. S., Touloukian, Y. S., and Woolley, H. G., Natl. Bur. Standards Circular 564 (U. S. Government Printing Office, Washington, D. C., 1955).

[13] Thorvaldson, T., and Bailey, E. C., Can. J. Research 24B, 51-56 (1946).

[14] Furukawa, G. T., McCoskey, R. E., and King, G. J., J. Research Natl. Bur. Standards 49, 273-8 (1952).

[15] Brosheer, J. C., Lenfesty, F. A., and Elmore, K. L., Ind. Eng. Chem. 39, 423 (1947).

[16] Cameron, A. E., and Wichers, E., J. Am. Chem. Soc., 84, 4175 (1962).

[17] Evans, W. H., NBS Report 8504, 1 July, 1964, pp. 164-184.

[18] Cosgrove, L. A., and Snyder, P. E., J. Am. Chem. Soc. 75, 3102 (1953).

[19] Armstrong, G. T., and Krieger, L. A., Chapter A2, NBS Report 6645, 1 January 1960, pp. 2-9.

[20] Stull, et al. JANAF Thermochemical Tables, March 31, 1963, (Dow Chemical Co., Midland, Michigan).

[21] Cox, J. D., and Harrop, D., Trans. Faraday Soc. 61, 1328-37 (1965).

[22] Sengupta, A. K., J. Indian Chem. Soc. 37, 291-4 (1960).

Chapter B10

THE HEAT OF FORMATION OF AMORPHOUS BERYLLIUM FLUORIDE

by K. L. Churney and G. T. Armstrong

1. Introduction

No direct determination of the heat of formation of beryllium fluoride by combustion of beryllium in fluorine has been published. Unpublished measurements [1], based on a 50 to 60 percent conversion of beryllium foil to partially glassy beryllium fluoride, give values of ΔH°_{F298} for $BeF_2(c)$ of -258.3, -256.8, and -255.9 kcal mole^{-1}.

Three types of indirect determinations of the heat of formation of $BeF_2(c)$ have been made:

1. Combination of the measurements of ΔH°_{F298} of BeO(c) [2,3,4,5,6] and the heats of solution of BeO(c) [7,8,9,10,11], $BeF_2(c)$ [7], and Be(c) [8,12] in aqueous HF.

2. Combination of the measurements of ΔH°_{F298} of BeO(c) [3], the heat of sublimation of $BeF_2(c)$, [13,14,15,16], and ΔH°_{R298} for the reaction [17]:

$$BeO(c) + 2HF(g) \rightarrow BeF_2(g) + H_2O(g)$$

3. Combination of the measurements of ΔH°_{F298} of $PbF_2(c)$, [18,19] and ΔH°_{F298} for the reaction [20]:

$$Be(c) + PbF_2(c) \rightarrow BeF_2(c) + Pb(c)$$

An evaluation of the data involved in the first type of determination [21] gives a value for ΔH°_{F298} of $BeF_2(c)$ of -242.27 kcal mole^{-1} with a precision of ±0.59 kcal mole^{-1}. A systematic error of 0 to -3.4 kcal mole^{-1} was assigned primarily on the basis that ΔH°_{F298} of BeO(c) [2] might be more negative by 3.0 kcal mole^{-1}.

Inconsistencies in the data necessary to calculate ΔH°_{F298} of BeF_2 by the second method [21,22,23] have been to a large extent resolved [24] by the acquisition and analysis of new experimental data (see 14,24,25,26,27,28). A calculation using the new thermal data for $BeF_2(g)$ [27] and $BeF_2(c,\ell)$ [14] gives a value for ΔH°_{F298} of $BeF_2(c)$ of -246.6 kcal mole^{-1} with an uncertainty interval that is of the order of +3.4 to -6.4 kcal mole^{-1} or more.

Although the work on fluorination of Be(c) with PbF_2(c) apparently has not been completed, an analysis [19] of the preliminary results [20] gives a value for ΔH^{o}_{F298} of BeF_2(c) of -244.0 kcal $mole^{-1}$.

Even though the data necessary for the last two indirect determinations became available after our experimental work was started, a more accurate value for the heat of formation of BeF_2(c) is still needed. Direct combustion of beryllium in fluorine was undertaken because of the inherently lower uncertainty of a value obtained by this method in comparison to indirect methods. In contrast to efforts of other workers (see the next section), we were able to obtain better than 99 percent conversion of beryllium to the fluoride by the device of burning a mixture of beryllium and Teflon in fluorine. However, 65 to 70 percent of the heat liberated by the combustion of the mixture is necessarily due to Teflon. This magnifies the effect of any uncertainty in the corrections to the remaining energy to obtain that liberated by combustion of beryllium to BeF_2. Further, analysis of the solid combustion products showed that appreciable quantities of Be_2C and a residue of high carbon content were present as well as BeF_2 that was amorphous rather than crystalline. Failure to correct for the formation of Be_2C or the presence of this residue would lead to an error of the order of 0.1 and 1 percent, respectively, in the heat of formation of BeF_2. Consequently, development of an accurate method for determination of the amounts of Be_2C and the residue as well as unburned beryllium metal constituted an important part of the experimental work. In spite of these problems, our final results appear to have a reasonably small uncertainty and confirm our suspicion that the heat of formation of BeF_2 is more negative than -242 kcal $mole^{-1}$.

2. Preliminary Experiments

Attempts by other workers to burn beryllium rod [29], foil [1], or powder [29] to completion in fluorine have been notably unsuccessful (in general less than 50 percent burned). Similar difficulties encountered with aluminum were overcome by burning a mixture of aluminum and Teflon powders in fluorine [30]. The possibility of using this method for combustion of beryllium was tested by burning pellets of compacted mixtures of 100 mesh beryllium powder and Teflon powder in 20 atmospheres of fluorine. It was found that pellets of compositions varying from 1:2 to 1:20 in weight of beryllium to Teflon gave approximately the same percent combustion of beryllium - from 75 to 90 percent. However, spattering of beryllium metal on the combustion walls, formation of glassy BeF_2, and corrosion of the holder were minimal when 0.1 grams of metal was mixed with 1.7 grams of powder. Combustion of 200 mesh beryllium powder of lower purity in pellets of the latter composition was nearly complete - 99 to 100 percent. Tests of various sample supports showed only nickel resisted

corrosion. Stainless steel and monel reacted with the pellet to varying degrees while calcium fluoride discs tended to crack or melt.

The decision to burn the higher purity beryllium powder required the development of a method of determining the amount of unburned beryllium accurate to 0.1%. Preliminary estimates of the completion of combustion, based upon weight changes of the entire combustion bomb were found to have a probable error of 1 percent. Analyses based upon the reaction of beryllium metal with concentrated KOH to give hydrogen fulfilled this accuracy requirement; a summary of the development of this method is given in the appendix.

3. Starting Materials

Two different beryllium samples were used: type NM of 100 mesh or finer particle size and 99.7 percent purity and type BB of 200 mesh particle size and 98.9 percent purity. The amount and assumed state of combination of these impurities is given in Table 1 The amount of the major impurities given in the batch analyses supplied with the samples were checked and, in general, confirmed by nuclear activation techniques (done commercially). Carbon was determined (as CO_2) by the NBS Analysis and Purification Section. The uncertainty in the amount of the impurity are those given in the check analyses where performed; the remainder are our estimates of the uncertainty in the supplier's analyses. An approximate check on the oxide impurity was obtained from the measurement of the moles of hydrogen evolved upon dissolving the powders in aqueous HF in conjunction with other work performed in this laboratory [31]. The results, summarized below,

Sample	Moles H_2/gm sample Observed	Predicted
BB	0.10916 ±0.00018	0.10989 ±0.00005
NM	0.11067 ±0.00084	0.11076 ±0.00003

tend to confirm the assigned oxide content since the observed deficiency of hydrogen was similar to that found for a pure aluminum sample [31]. The uncertainties of the observed values are twice the standard deviation of the mean for seven experiments for sample BB and the uncertainty for the single experiment with sample NM is estimated from the uncertainty in sample BB.

Table 1. Impurities in Beryllium Samples

Sample BB

Impurity[a]	Amount (Weight %)	Estimated Uncertainty	Assumed Products	Assumed ΔH_R^o (kcal mole^{-1})	Ref.
Li	0.0001	0.00005	$LiF(c)$	-147.1	(19)
B	0.00004	0.00002	$BF_3(g)$	-269.9	(53)
Be_2C	0.20 [b]	0.025	----	----	
Be_3N_2	0.0393	0.0197	$BeF_2(c)$, $N_2(g)$	-597 [e]	
BeO	0.7252 [c]	0.0445	$BeF_2(c)$, $O_2(g)$	-100 [e]	
Mg	0.01	0.01	$MgF_2(c)$	-268.7	(54)
Al	0.0436 [c]	0.0004	$AlF_3(c)$	-360.4	(30)
Si	0.00831 [c]	0.00126	$SiF_4(g)$	-360.0	(55)
Ca	0.005	0.005	$CaF_2(c)$	-290.3	(18)
Mn	0.0056 [c]	0.0004	$MnF_3(c)$	-238	(18)
Fe	0.0795 [c]	0.0108	$FeF_3(c)$	-235	(18)
Cu	0.005	0.0025	$CuF_2(c)$	-126.9	(18)
Ag	0.0005	0.00025	$AgF(c)$	-48.5	(18)
Cd	0.00007	0.00004	$CdF_2(c)$	-167.39	(56)
Ni	0.009	0.004	$NiF_2(c)$	-159.5	(18)
Pb	0.0005	0.0005	$PbF_2(c)$	-158.9	(18)
Mo	0.001	0.0005	$MoF_6(g)$	-372.35	(57)
Co	0.0004	0.0002	$CoF_3(c)$	-187	(18)
Cr	0.009	0.004	$CrF_5(c)$	-350	(18)
	1.14212				
Be	98.85788	±0.057 [e]			

Sample NM

Be_2C	0.125 [b]	0.0250	----		
Be_3N_2	0.0008	0.0004	$BeF_2(c)$, $N_2(g)$	-597 [e]	
BeO	0.1302 [c]	0.0169	$BeF_2(c)$, $O_2(g)$	-100 [e]	
Al	0.0016 [d]	0.0004	$AlF_3(c)$	-360.4	
Si	0.0017 [d]	0.0004	$SiF_4(g)$	-359.98	
Mn	0.0008	0.0004	$MnF_3(c)$	-238	
Fe	0.0013 [d]	0.0003	$FeF_3(c)$	-235	
Cu	0.0008	0.0004	$CuF_2(c)$	-126.9	
Ni	0.0005	0.0003	$NiF_2(c)$	-159.5	
Cr	0.0001	0.0001	$CrF_5(c)$	-350	
	0.2628				
	99.7372	±0.030 [e]			

a C,N,O assumed combined as Be_2C, Be_3N_2, BeO
b determined by NBS (as CO_2)
c determined by nuclear activation
d determined by supplier for our sample
e $\Delta H_F^o{}_{298}$ $BeF_2(c)$, $Be_3N_2(c)$, $BeO(c)$ -243, -132, -143(19)

Teflon powder was obtained as a commercial preparation designated as TFE Fluorocarbon Resin "Teflon 7". It was composed of irregularly shaped particles with an average size of 35 microns. Teflon film, designated FEP Fluorocarbon Resin, of 0.001 inch thickness was used to enclose the beryllium-Teflon mixtures. Neither the film or the powder was modified or specially treated before use.

Fluorine gas was periodically analyzed by absorbing the fluorine in mercury and observing the residual pressure of the unreacted gases [32]; the residual gas composition was analyzed in a mass spectrometer. The analyses appear in Table 2. The estimated uncertainties of the impurities include both uncertainty in our measurement of the total mole percent as well as those in composition from estimates supplied by the mass spectrometrist. In the case of the "pure fluorine" we can give no simple explanation for the variation in oxygen content, which gives rise to differing total impurities. Data obtained during composition analysis definitely suggests the major portion and variability of SiF_4 is due to the reaction of fluorine with the glass walls of the sample bulb.

4. Calorimetric Apparatus

An isothermal-jacket, stirred-water calorimeter which is a modification of the Dickinson design [33] by Prosen and coworkers [34] was used in the heat measurements. The jacket and calorimeter vessel stirrers were coupled by rubber O-ring pulleys to individual motors mounted on an insulated bracket on the jacket wall to minimize heat transfer between the motors and calorimeter. The jacket water temperature was held constant to ±0.002°C near a value of 31°C. The connections for the electrical leads between the calorimeter vessel and jacket were designed to insure good thermal contact with the calorimeter jacket.

Timing and temperature measurement equipment and procedures for making the heat measurements are adequately described elsewhere [35,36].

The combustion reactions were carried out in a commercially available combustion bomb identical to that described elsewhere [30]. The only significant difference in the internal bomb arrangement, shown in figure 1 for a beryllium-Teflon combustion, is the presence of a filter, Q, to prevent the loss of $BeF_2(c)$ when fluorine is removed from the bomb. The filter element, a monel fritted disc, is held by lead O-rings in a stainless steel holder that screws into one inlet port of the bomb head. Combustions of Teflon powder and film alone were carried out on a monel holder similar to that described by Domalski [30] after removal of the plate, P, cup, O, and filter, Q.

The standard initial calorimeter for the fluorine experiments consisted of the combustion bomb with the internal arrangement shown in figure 1, 6 cm of 0.002 inch diameter tungsten fuse wire, the calorimeter vessel electrical heater (see [30] for a description of the heating element), a platinum resistance thermometer and the calorimeter vessel with a weighed quantity of water.

Table 2. Analysis of Fluorine

No.	1		2		3		4		5	
Type of fluorine	Impure		Pure		Pure		Pure		Pure	
Impurities, mole %	Value	Uncert.	Value	Uncert.	Value	Uncert.	Value	Uncert.	Value	Uncert.
N_2 x 10	1.03	± 0.05	0.54	± 0.03	0.51	± 0.04	0.57	± 0.04	0.50	± 0.03
O_2 x 1	1.50	0.1	0.25	0.01	0.43	0.03	0.42	0.03	0.27	0.01
Ar x 10^3	2.8	1.0	1.1	0.3	0.7	0.3	1.7	0.3	n.d.	----
CO x 10^2	7.0	0.4	1.80	0.08	5.9	0.4	6.8	0.5	1.48	0.07
CF_4 x 10^2	2.7	0.2	2.9	0.03	0.60	0.05	0.55	0.5	0.23	0.02
SO_2F_2 x 10^3	5.4	0.9	1.1	0.1	1.2	0.2	1.8	0.3	1.5	0.2
SiF_4 x 10^3	3.8	0.5	0.050	0.07	1.01	0.15	0.47	0.07	0.15	0.02
C_2F_4 x 10^3	2.8	0.3	↑	↑	1.1	0.2	1.1	0.2	0.50	0.06
C_2F_6 x 10^3	1.2	0.4			0.31	0.06	0.37	0.06	0.18	0.06
C_3F_8 x 10^3	0.5	0.2	1.1	0.8	0.10	0.05	0.10	0.05	0.5	0.2
C_4F_8 x 10^3	0.3	0.15	↓	↓	n.d.	----	0.11	0.05	n.d.	----
SF_6 x 10^3	1.0	0.3	1.1	0.8	n.d.	----	0.09	0.03	0.9	0.3
Total impurities, mole %	2.09	± 0.08	0.36	± 0.04	0.702	± 0.05	0.633	± 0.05	0.352	± 0.04

n. d. = none detected

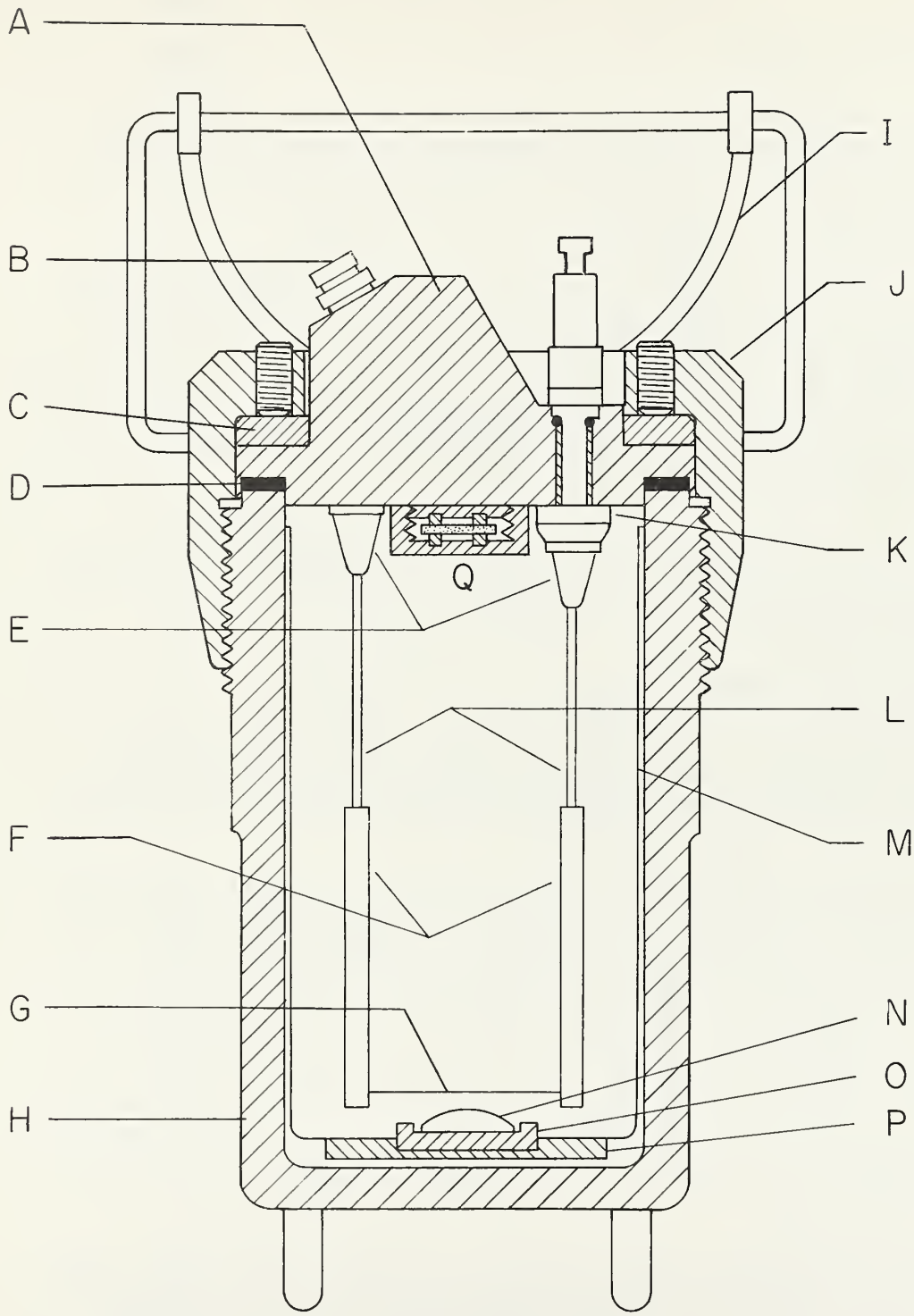

FIG. I FLUORINE COMBUSTION BOMB

A, nickel bomb head; B, needle valve; C, monel pressure plate; D, Teflon gasket; E, monel lock nut; F, aluminum electrode; G, tungsten fuse; H, bomb body; I, handle; J, screw cap; K, alumina washer; L, type 304 stainless steel rod; M, type 304 stainless steel liner; N, pellet; O, pellet cup; P, nickel base plate; Q, filter.

5. Fluorine Manifold

The manifold for filling and emptying the combustion bomb with fluorine and obtaining samples of fluorine and volatile products of combustion is shown in figure 2. The main features and operation of the system are nearly identical to another in our laboratory [30]. Two differences are noteworthy:

1. In the first series (series I) of fluorine combustions, the bomb was evacuated prior to loading with fluorine via filter Z and the fluorine manifold with only vacuum pump (1) until the pressure was less than 10^{-2} mm Hg (on gauge U_2). In the final series (series II) of fluorine combustions, the bomb was evacuated by both vacuum pump (1) (filter Z was removed) and vacuum pump (2) until the pressure in the bomb (gauge U_1) and manifold (gauge U_2) were less than 10^{-3} mm Hg and 10^{-2} mm Hg respectively.

2. Ballast tank W was installed in the manifold to allow the reduction of the pressure of the entire gaseous contents of the bomb after combustion to one atmosphere prior to sampling for mass spectrometer analysis.

6. Beryllium Manipulation

On the basis of consultation of the literature [37,38,39,40] and the experience of others who handled beryllium [41,1], special procedures and certain equipment modifications were deemed necessary for the safe handling of beryllium.

All manipulations involving the transfer or fluorine combustion of beryllium powder were carried out in a high exhaust velocity hood which could be decontaminated regularly by washing with dilute hydrochloric acid and water. The fluorine manifold and calorimeter in the hood were protected from contamination by enclosing the former in a water-tight lucite box and the latter in a polyethylene bag with a removable top. The manifold valves were operated by extension rods passing through Teflon O-ring seals in the box. The calorimeter controls were mounted outside the exhaust hood. A monel fritted disc filter was mounted in the fluorine port of the combustion bomb to prevent the escape of BeF_2 into the manifold while fluorine and volatile combustion products were being removed.

After transfers of solid combustion products were carried out in a dry box, all working surfaces of the box, the combustion bomb, and contaminated equipment were washed with water. The atmosphere of the box and dry box entry chamber was filtered and dried prior to removal of any equipment.

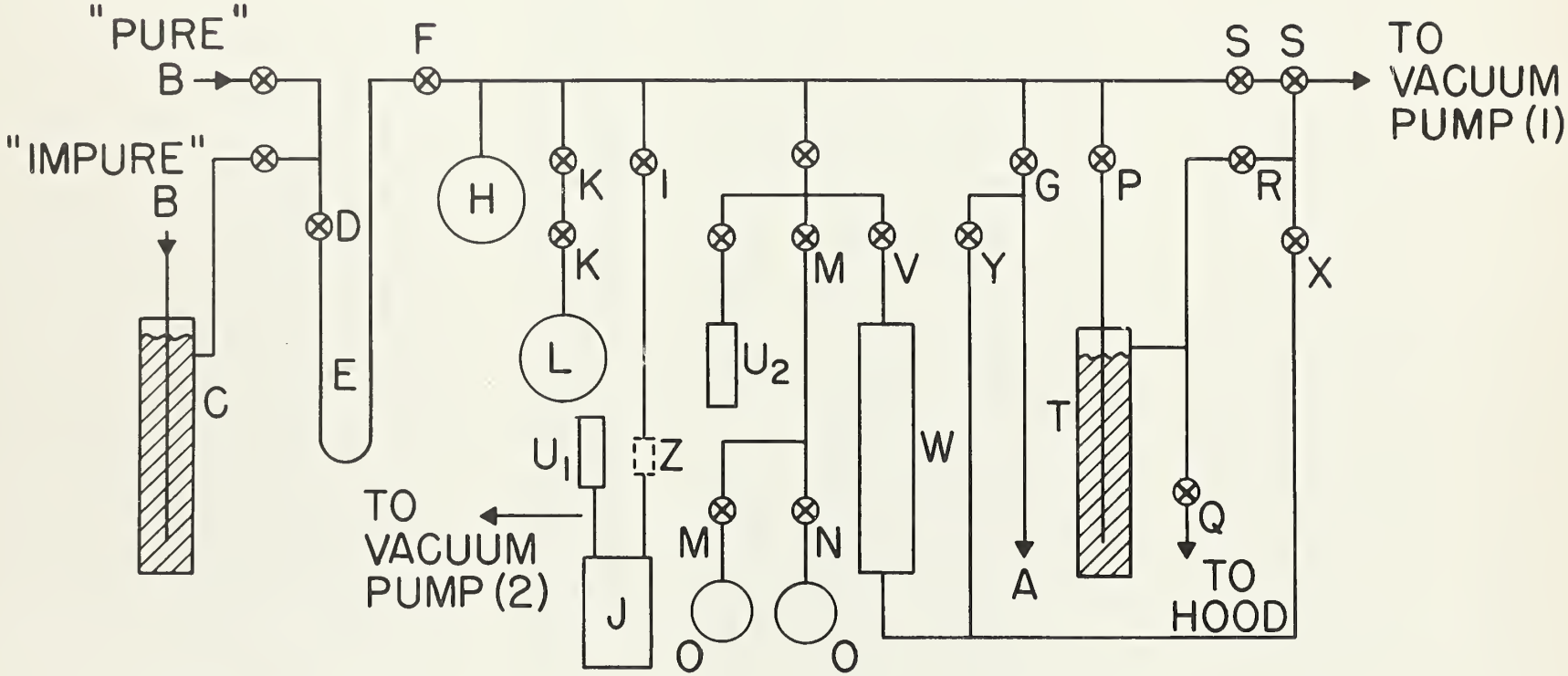

FIGURE 2 SCHEMATIC DIAGRAM OF FLUORINE MANIFOLD

A, helium; B, fluorine; C, hydrogen fluoride trap; D, fluorine valve; E, liquid nitrogen trap for fluorine; F, fluorine valve to manifold; G, helium valve to manifold; H, pressure gauge (0-35 atm); I, valve to combustion bomb; J, combustion bomb; K, valves to vacuum gauge; L, vacuum gauge (0-1 atm); M, N, valves to gas-sample collector bulbs; O, gas-sample collector bulbs; P, valve to fluorine absorption tower; Q, vent valve to fume hood; R, valve to vacuum via absorption tower; S, valves to vacuum; T, fluorine absorption tower; U, thermocouple gauges; V, valve to ballast tank; W, ballast tank; X, valve to vacuum via ballast tank; Y, valve to helium via ballast tank; Z, fritted disc filter.

7. Combustion Experiments

7.1 Calibration

The calorimeter was calibrated by burning benzoic acid (standard sample 39h) in high purity (99.996%) oxygen at 30 atmospheres. The internal bomb arrangement differed from that given in figure 1 as follows: (1) absence of the filter, Q, and pellet holder, O; (2) a monel instead of type 304 stainless plate, P; (3) platinum electrodes, F; (4) a platinum crucible sample support; and (5) a 2 cm piece of chromel C fuse wire (0.16 mm diameter) supported over the sample by platinum wire, and (6) 1 ml. distilled H_2O.

7.2 Pellet Preparation

Beryllium-Teflon mixtures were prepared in Teflon bags to avoid transfer and pelleting losses found in earlier mixing techniques [30]. The film was sealed by sandwiching a fold in the film layers between two strips of aluminum and gently heating the exposed crease in an open flame. Pellets were prepared by transferring about 1.7 grams of Teflon and 0.1 grams of beryllium to the weighed bag and weighing after each addition. The bag contents were mixed by moving the enclosed bubble of air through the mixture. The bag was then punctured, placed in a pellet die piece, slowly compressed into a pellet, and stored in a desiccator.

Weight changes for a number of pellets prepared during this research are summarized in Table 3. The method of pellet preparation in series II was different from that used in series I in the following ways:

1. The beryllium powder was added to the bag before the Teflon powder in series II. This reduces the possibility that any weight loss on sealing the bag, item (1), is due to loss of beryllium rather than Teflon. In all cases, the weight loss was assumed to be loss of Teflon bag.

2. A larger puncture hole was made in the bags and pressure was applied more slowly to the die pieces in forming pellets in series II (30 minutes rather than 2 minutes). This resulted in better agreement between the pellet weight just before it was burned and the weight of the sealed bag plus contents just prior to pelleting, see item (3). Although the weight of all newly formed pellets (except sample 4, series I) was greater than the weight before pelleting, see item (2), the weights of the pellets in series II approached a constant weight in a shorter period of time than series I.

Table 3. Weight Changes (micrograms) in Pellet Preparation

Series	I						II				
Sample	1	2	4	5	6	7	2	3	4	5	6
(1) Wt. loss on sealing	72	18	29	246	278	88	36	39	115	15	24
(2) Wt. gain on pelleting	201	198	125	282	-23	259	151	207	218	168	215
(3) Wt., Final, minus wt., before pelleting	51	46	-15	-23	-45	-19	-26	-14	22	2	-1
Elapsed time *(days)	12	18	54	56	60	61	15	16	17	18	3

* between wt. before pelleting and final wt.

3. More closely fitting die pieces were used in the preparation of the pellets of series II. As a consequence, no Teflon was found on the die pieces and no correction was necessary for loss of Teflon as in series I.

The weights of pellets of Teflon formed by rapid compression of powder decreased rapidly with time (as much as 400 micrograms in 20 hours). Consequently, Teflon pellets were weighed after being stored in the balance case for one month and pellets of both powder and film were formed by slow compression in the die pieces.

7.3 Analysis of Combustion Products

After a beryllium combustion experiment, the bomb was dried by evacuation in the dry box entry chamber. After disposing of volatile combustion products, the bomb was filled with one atmosphere of helium and placed in the dry box. The dry box atmosphere was dried until the dew point was -78°C. The solid combustion products in the bomb were stored in vials or petri dishes in a desiccator. In the case of Teflon combustions the solid products were examined in the room.

The inner surfaces of the bomb were covered with a fine white hygroscopic powder after a beryllium-Teflon combustion. The larger part of this powder covered a mixture of black particles confined to the nickel pellet cup. Analysis of the beryllium content (as BeO) of a known weight of the white powder showed it to be BeF_2; the Xray pattern was similar to that observed for vitreous BeF_2 [42].

The contents of the pellet cup were analyzed by reaction with hot concentrated KOH (see appendix) for the amount of unburned beryllium (as H_2 gas) and beryllium carbide (as CH_4 gas). The black residue remaining in the KOH solution was filtered, washed, dried, and weighed. Its appearance suggested a mixture of unburned Teflon and a fine black powder; carbon analysis (as CO_2) of one residue (see combustion experiment 6, I, Table 7) gave 87.8% carbon by weight.

After a Teflon combustion, the area of a sample holder formerly in contact with the pellet was covered with a thin black film. This residue was weighed by difference by wiping off the film and was assumed to be unburned Teflon.

Samples of the volatile combustion products were analyzed with a mass spectrometer after absorption of the fluorine in mercury. Results of these analyses are present in Table 4 in terms of the differences in millimoles of the amount of impurity present after a combustion minus that present prior to a combustion. The uncertainties include those of the fluorine analyses as well as the volatile combustion production analyses.

Table 4. Volatile Product Analysis
Increase in Constituents on Combustion[a]

No.	1		2		3				4		5	
Type of Combustion	Be(NM)[b]-Teflon Teflon, 0.0510 moles		Be(NM)-Teflon Teflon, 0.0551		Be(NM)-Teflon Teflon, 0.0492				Teflon Teflon, 0.0874		Teflon Teflon, 0.0585	
Fluorine (moles)	Impure, 0.287 Analysis No. 1		Pure, 0.258 Analysis No. 2		Pure, 0.270 Analyses				Pure, 0.276 Analysis No. 5		Pure, 0.274 Analysis No. 5	
					No. 3	No. 4	No. 3	No. 4				
Impurity, millimoles	Increase	Uncert.	Increase	Uncert.	Increase		Uncert.		Increase	Uncert.	Increase	Uncert.
N_2 x 1	0.54	0.04	0.21	0.03	0.06	0.04	0.02	0.02	0.27	0.03	2.56	0.3
O_2 x 1	7.4	0.4	1.24	0.06	0.17	0.19	0.07	0.05	1.19	0.03	0.85	0.3
Ar x 10	0.8	0.1	0.3	0.2	4.0	4.0	0.6	0.6	0.8	0.4	0.7	0.4
CO_2 x 10	-0.3	0.1	1.9	0.1	-0.03	-0.3	0.1	0.1	1.6	0.1	0.9	0.1
CF_4	----	---	----		-----	----	---	---	----	---	----	---
SO_2F_2 x 10^3	5.0	6.0	(203.)	(115)	7.0	5.1	3.4	3.6	-4.1	0.5	-4.1	0.5
SiF_4	----	---	----	----	-----	----	---	---	----	---	----	---
C_2F_6 x 10^3	-4.0	3.0	↑		12.3	12.8	5.4	5.4	2.6	2.2	2.5	1.2
C_3F_8 x 10^3	-3.4	1.0	8.3	29.0	-0.8	-0.9	0.2	0.1	-0.5	0.2	-0.5	0.2
C_4F_8 x 10^3	-1.3	0.5			+3.4	+3.1	1.0	1.3	-1.3	0.6	-1.3	0.2
C_2F_4 x 10^3	-0.9	0.5	↓		-0.3	-0.3	0.15	0.1	----	0.0	0.0	---
SF_6 x 10^3	-0.1	2.0	-25.0	4.0	0.0	-0.2	---	0.05	-2.5	0.8	0.0	---

Estimated Increases in Higher Fluorocarbons

Impurity millimoles	Impure F_2 Be-Teflon		Pure F_2 Be-Teflon		Pure F_2 Teflon	
C_2F_4 x 10^3	-4.0	±3.0	12	±5	2.6	±1.7
C_3F_8 x 10^3	-3.4	1.0	-0.8	0.2	-0.5	0.2
C_4F_8 x 10^3	-1.3	0.5	3.0	1.0	-1.3	0.4
C_2F_4 x 10^3	-0.9	0.5	0.3	0.15	0.0	

[a] See table 2 for the appropriate fluorine analysis
[b] Be(NM) is type NM beryllium sample

8.1 Treatment of Combustion Data

The energy equivalent of the oxygen calorimeter, calculated using standard procedures [35,36] was 14,621.0 J $°C^{-1}$ with a standard deviation of the mean for seven experiments of ±1.1 J $°C^{-1}$. The energy equivalent of the standard fluorine calorimeter is 14,656.68 J $°C^{-1}$. The notation of the tables and method of standard state corrections are explained in detail elsewhere [43,44]. The numbered entries in tables 5, 6, and 7 are: (1) the mass (in vacuo) of Teflon, tables 5 and 6, and beryllium, table 7, reacted; (2) the initial pressure of fluorine; (3) corrections to be added to the standard calorimeter (fluorine) energy equivalent for fluorine, combustion sample, and variations in internal bomb arrangement; (4) the observed increase in calorimeter temperature corrected for heat exchanged between the calorimeter and its surroundings; (5) the energy equivalent of the actual calorimeter multiplied by the corrected temperature rise; (6) the net correction due to the hypothetical compression and decompression of bomb gases; (7) correction for fuse energy; (8) correction for the change in higher gaseous fluorocarbons (than CF_4) as estimated in Table 4; (9) and (10) correction for the energy contributed by the Teflon powder and film assuming complete combustion; (11) and (12) correction for the formation of Be_2C and carbon-Teflon residue of the beryllium-Teflon combustion; (13) correction for combustion of the impurities in the Be sample excluding Be_2C; (14) the standard state energy change at 31°C per gram of Teflon film, Table 5, or powder, Table 6, for the reaction:

$$[CF_2] + F_2(g) \rightarrow CF_4(g)$$

and (15) the standard state enthalpy change at 25°C per mole of beryllium for the reaction:

$$Be(c) + F_2(g) \rightarrow BeF_2 \text{ (c, amorphous)}$$

In item (1) the Teflon "residue" of tables 5 and 6 is treated as unburned Teflon. Also, the beryllium, item (1), Table 7, is corrected for impurities, unburned beryllium, and beryllium consumed in the formation of Be_2C as summarized at the top of Table 7. In item (5) the ignition energy was assumed to be zero and a small correction is applied to the calorimeter heat capacity in cases where the mean temperature of the experiment differed from that of the benzoic acid calibrations. Items (9) and (10) are based on the mass of Teflon film and powder before the pellet was formed. The loss in weight occurring on sealing the bag was assumed to be loss of Teflon film. No correction was applied to the film weight due to loss during pelleting unless film was found on the pellet die pieces. Item (12) assumes a composition of each residue of 16.1 percent Teflon and 83.9 percent carbon as obtained by analysis on sample 6, I. The temperature of the hypothetical isothermal process to which each of items (2) through (13) refers is the final temperature of the calorimeter for each experiment if no heat had been exchanged with the surroundings.

Table 5. Teflon Powder Combustions[a]

Experiment	1	2	3	4	5	6	7	8
wt. pellet, g	4.287787	4.297522	3.796061	4.349297	4.368609	2.926029	4.318171	2.860629
wt. residue, g	0.000	0.00060	0.000756	0.000361	0.000142	0.000233	0.000299	0.000364
1. m', Teflon reacted, g	4.287787	4.296922	3.795305	4.348936	4.368467	2.925796	4.317872	2.860265
2. $P^i(F_2)$, atm	18.58	18.57	20.26	20.18	20.40	20.25	20.62	20.09
3. $E^i(\text{cont})$, $J\,°C^{-1}$	-19.96	-19.97	-19.83	-19.14	-18.93	-20.11	-19.08	-20.24
4. Δt_c, °C	3.04130	3.04877	2.69334	3.08567	3.09823	2.07538	3.06222	2.02860
5. ΔE_{IBP}[b], J	-44,514.66	-44,623.96	-39,422.01	-45,166.62	-44,531.16	-30,376.44	-44,823.31	-29,691.48
6. $\Delta E(\text{gas})$[c], J	18.68	18.72	17.26	20.07	20.48	13.13	19.70	12.57
7. $-n\Delta E°(\text{fuse})$, J	17.71	18.75	18.49	18.64	17.49	21.87	20.74	20.93
8. $-n\Delta E(\text{IMP Gas})$, J				0.25				
14. $\Delta E°_C(31°C)/M$, Jg^{-1}	-10,373.3	-10,376.4	-10,377.9	-10,376.8	-10,372.8	-10,370.3	-10,371.6	-10,369.0

Av. $\Delta E°_C(31°C)/M = -10{,}373.5\ Jg^{-1}$ std. dev. of mean = $\pm 1.2\ Jg^{-1}$

a Symbols employed are explained in ref. [44]

b $\Delta E_{IBP} = [E(\text{calor}) + E^i(\text{cont})]\,(-\Delta t_c)$

c $\Delta E(\text{gas}) = \Delta E^i(\text{gas})]_{P^i(\text{gas})} + \Delta E^f(\text{gas})]_{P^f(\text{gas})}$

Table 6. Teflon Film Combustions[a]

Experiment	1	2	3
wt. pellet, g	3.106874	3.097896	3.074705
wt. residue, g	0.000483	0.000837	0.000685
1. m', Teflon reacted, g	3.106391	3.097059	3.074020
2. $P^i(F_2)$, atm	20.22	20.26	19.59
3. E^i(cont), $J°C^{-1}$	-19.98	-19.98	0.97
4. Δt_C, °C	2.20895	2.20266	2.18224
5. ΔE_{IBP}, J	-32,331.74	-32,239.67	-31,986.51
6. ΔE(gas), J	13.92	13.84	12.48
7. $-n\Delta E°$(Fuse), J	22.63	20.74	22.63
8. $-n\Delta E°$(Imp, Gas), J	0.25	0.25	0.25
14. ΔE_C^o (31°C)/M, Jg^{-1}	-10,396.4	-10,398.6	-10,394.0

Av. ΔE_C^o(31°C)/M -10,396.3 Jg^{-1} std. dev. of mean ±1.3 Jg^{-1}

[a] see bottom of table 5

Table 7. Beryllium-Teflon Combustions[a]

Sample No., Series, type of Be	1,I,NM	3,I,BB	6,I,NM	2,II,BB	3,II,BB	4,II,BB	5,II,BB
wt. Teflon powder, g	2.031374	2.159857	2.187286	1.983933	2.479838	2.005580	2.082622
wt. Teflon film, g	0.528567	0.494459	0.537886	0.462695	0.473074	0.436645	0.464008
wt. Be sample, g	0.100614	0.089802	0.104813	0.089153	0.080249	0.113741	0.091545
wt. Be in sample, g	0.100350	0.088776	0.104538	0.088135	0.079332	0.112442	0.090499
wt. Be in products, g	0.018536	0.000148	0.017832	0.000144	0.000184	0.000098	0.000091
wt. Be_2C in products, g	0.005442	0.000213	0.006578	0.000279	0.000195	0.000405	0.000285
wt. Be_2C formed, g	0.005376	0.000033	0.006447	0.000101	0.000035	0.000227	0.000102
wt. Be in Be_2C formed, g	0.003190	0.000020	0.003869	0.000060	0.000021	0.000107	0.000061
wt. residue, g	0.001683	0.001706	0.002131	0.0020	0.002011	0.001916	0.001670
1. m′, Be burned to BeF_2, g	0.078624	0.088608	0.082837	0.087931	0.079127	0.112237	0.090347
2. $P^i(F_2)$, atm	19.99	20.08	20.35	18.87	18.73	18.90	18.84
3. E^i(cont), $J°C^{-1}$	-85.06	8.92	-32.09	9.20	9.90	9.56	9.47
4. Δt, °C	2.42047	2.55480	2.55497	2.40858	2.69866	2.59427	2.49879
5. ΔE_{IBP}, J	-35,270.17	-37,467.67	-37,365.39	-35,323.95	-39,580.11	-38,048.19	-36,647.63
6. ΔE(gas), J	8.30	8.54	9.62	7.10	9.60	6.35	7.50
7. $-n\Delta E°$(Fuse), J	22.61	22.61	22.69	20.79	18.89	20.75	22.63
8. $-n\Delta E°$(imp, gas), J	9.00	-11.88	-11.88	-11.88	-11.88	-11.88	-11.88
9. $-n\Delta E°$(Tef. powd.), J	21,071.64	22,404.41	22,689.16	20,579.99	25,724.35	20,804.68	21,603.87
10. $-n\Delta E°$(Tef. film), J	5,494.92	5,140.35	5,591.86	4,810.22	4,918.17	4,539.45	4,823.92
11. $-n\Delta E°$(Be_2C formed), J	-146.77	-0.91	-178.00	-2.79	-0.96	-2.96	-1.68
12. $-n\Delta E°$(residue), J	-111.21	-112.73	-140.82	-132.16	-132.89	-126.60	-110.35
13. $-n\Delta E°$(imp, solid), J	2.45	17.76	2.55	17.63	15.87	22.50	18.11
15. $\Delta H°$(25°C) kJ $mole^{-1}$	-1,024.70	-1,018.38	-1,022.59	-1,030.85	-1,031.83	-1,029.79	-1,029.31

Av. Series II -1,030.5 kJ $mole^{-1}$ (-246.28 kcal $mole^{-1}$) std. dev. mean ±0.6 kj $mole^{-1}$ (±0.13 kcal $mole^{-1}$)

Av. Series I -1,021.9 kJ $mole^{-1}$ (-244.24 kcal $mole^{-1}$) std. dev. mean ±1.9 kj $mole^{-1}$ (±0.22 kcal $mole^{-1}$)

[a] See bottom of table 5

The results for the two series of beryllium combustions were treated separately because of a significant difference in the two sets of experiments. This was the better evacuation of the combustion bomb in series II brought about by the change in the method of pumping indicated in section 5. During series I, premature ignition of two beryllium-Teflon pellets (samples 4 and 7 in terms of the sequence of experiments listed in Table 7) and a Teflon pellet (sample 8 of the series) occurred. The subsequent discovery of severe corrosion of the fritted disc filter in the fluorine manifold connection to the bomb suggested the trouble was due to poor evacuation. No difficulty had been encountered prior to series I and no premature ignitions occurred in the 17 experiments performed in series II (all but two of the Teflon combustions and five beryllium-Teflon combustions). Since poor evacuation of the combustion bomb would lead to "prereaction" of the beryllium and this would be more severe for beryllium powder of smaller particle size, there is reason to expect not only the results of series I to be less negative than those of series II but also that the value of sample 3,I would be the least negative.

8.2 Auxiliary Data

Buoyancy corrections for the masses of beryllium, Teflon powder, and Teflon film were calculated using densities of 1.84, 2.15, and 2.21 g cm^{-3}, respectively.

A heat of formation of $WF_6(g)$ of -416 kcal $mole^{-1}$ [45] was used to compute the fuse energy (22.61 J for 6 cm of wire).

Data for the net heat correction for the hypothetical compression and decompression of bomb gases is based on the parameters of the Lennard-Jones 6-12 potential function determined for fluorine [46] and CF_4 [47]. The values used for C_V (20 atm, 304.15°K) and C_V^o(298.15°K) for fluorine and C_V^o (298.15°K) for CF_4 were 5.54, 5.499 [48], and 12.607 [49] cal deg^{-1} $mole^{-1}$, respectively. Values of C_p in cal deg^{-1} g^{-1} for beryllium, Teflon, and $BeF_2(c)$ were taken to be 3.932 [50], 0.280 [51], 0.2640 [52], respectively.

The heats of formation used in the calculation of heat corrections for impurities in the beryllium samples, the formation of Be_2C, and the beryllium-Teflon residues are those given in Table 1 and a heat of formation of -221 [55] kcal deg^{-1} $mole^{-1}$ for $CF_4(g)$.

The heats of formation of $C_2F_4(g)$, $C_2F_6(g)$, $C_3F_6(g)$, $C_3F_8(g)$ and $C_4F_8(g)$ used to calculate the heat correction for the change in higher fluorocarbon content of the gases in a fluorine combustion were -152, -315, -259, -409, and -352 [64] kcal $mole^{-1}$, respectively.

Atomic weights used in the calculations were taken from the 1961 Table of Atomic Weights based on $C^{12} = 12$ [59]. The unit of energy is the Joule with one calorie equal to 4.184 Joules.

8.3 Uncertainty and Summary of Results

Table 8 is a summary of our results and preliminary estimates of uncertainties. The precision is the 95 percent confidence limits given by the Student t distribution. The precision of the measurements are calculated from the standard deviation of the means of the measurements. The overall precision includes the scatter due to the calibration experiments, item (1), and, in the case of the heat of formation of BeF_2, item (4), also the scatter due to the Teflon combustion.

The next five items of Table 8 are estimates of the systematic error in the heat of formation due to uncertainties in the following: (5) solid combustion product gas analysis and beryllium sample composition; (6) heat capacity differences in the internal bomb arrangement in the calibration and fluorine combustion experiments; (7) collection of all unburned tungsten fuse; (8) analysis of beryllium-Teflon combustion residue composition assuming all residues have the same composition (indefinite sign); and (9) the change in higher fluorocarbon (than CF_4) content of the bomb gases for a beryllium-Teflon combustion. The error of +0.13% appearing in item (8) is an estimate of the upper limit of the change in the heat of formation of BeF_2 when the composition of all of the beryllium-Teflon combustion residues are known. Items (1) and (11) are the changes in the heat of formation of BeF_2 if the residues from the Teflon combustions are pure carbon rather than the assumed unburned Teflon and the carbon in the beryllium sample is present as free carbon rather than Be_2C, respectively. Neither of these errors are considered to be very likely but cannot be excluded at the present time. No estimates of the systematic error due to the method of pellet preparation have been made.

Although the 95% confidence intervals, due to precision, of the heats of formation of BeF_2 of the two series of measurements overlap, evidence cited in section 8.1 clearly suggests that the two series do not involve the same statistical population and the results of series I, item (12), are unreliable. Accordingly, we find for the standard state enthalpy change at 25°C for the reaction:

$$Be(c) + F_2(g) = BeF_2 \text{ (c, amorphous)}$$

a value of -1,030.5 kJ $mole^{-1}$ (-246.28 kcal $mole^{-1}$) with a standard error, based on the 95% confidence limits of the student t distribution, of ±1.9 kJ $mole^{-1}$ (±0.45 kcal $mole^{-1}$). The systematic error is tentatively estimated to be from + 0.9 to -7.5 kJ $mole^{-1}$ (+ 0.2 to - 1.8 kcal $mole^{-1}$).

Table 8. Summary of Results and Uncertainties

A. Precision

Precision	Value	Precision of Measurements	Overall Precision
(1) Standard initial F_2 calorimeter, $J°C^{-1}$	-14,656.68	±2.7	±2.7
(2) Teflon powder, $\Delta E_c^o(31°C)/M$, Jgm^{-1}	-10,373.5	±2.8	±3.4
(3) Teflon film, $\Delta E_c^o(31°C)/M$, Jgm^{-1}	-10,396.5	±5.6	±5.9
(4) BeF_2, Series I ΔH_f^o, kJ $mole^{-1}$	-1,021.9	±8.2	±8.2
, Series II ΔH_f^o, kJ $mole^{-1}$	-1,030.5	±1.8	±1.9

B. Systematic errors in ΔH_f^o of BeF_2 (Percent of ΔH_f^o of BeF_2)

	Error in results as calculated		
		Series II	Series I
(5) m'	±0.07		
$n\Delta E°(Be_2C$ formed)			
$n\Delta E°$(Imp, solid)			
(6) E^i(cont)	±0.02		
(7) $n\Delta E°$(Fuse)	-----	+0.04	+0.04
(8) $n\Delta E°$(residue)	±0.04	+0.13	+0.07
(9) $n\Delta E°$(Imp, gas)	±0.02		
	±0.09	±0.11	

	Error in results if assumptions are invalid	
(10) Assume residue of Teflon combustion is carbon and not unburned Teflon	+0.20	+0.21
(11) Assume carbon in Be sample is present as carbon and not Be_2C	+0.26	+0.19
	+0.63	+0.51

C. Summary of results

	Value	Overall Precision	Systematic Error
(12) BeF_2, series I, ΔH_f^o, kJ $mole^{-1}$	-1021.9	±8.2	+1.1, -6.2
kcal $mole^{-1}$	-244.2	±2.0	+0.3, -1.5
(13) BeF_2, series II, ΔH_f^o, kJ $mole^{-1}$	-1030.5	±1.9	+0.9, -7.5
kcal $mole^{-1}$	-246.28	±0.45	+0.2, -1.8

9. Appendix, Solid Combustion Product Gas Analysis

9.1 Introduction

Addition of aqueous concentrated KOH to the combustion products remaining in a nickel sample holder gave a mixture of hydrogen gas from unburned beryllium, and methane gas from beryllium carbide. Depending upon whether 100 or 200 mesh beryllium powder was burned, from 10^{-3} to 10^{-5} moles, respectively, of this gas mixture had to be analyzed and separated from water with an accuracy of 0.1 to 10%, respectively. We felt this requirement excluded methods of analysis based upon the weight of adsorbed carbon dioxide and water after reaction of the gas mixture with oxygen or complete reliance on mass spectrometer analysis of gas composition. However, the accuracy of the method of gas separation finally adopted does require nearly complete absence of oxygen, i.e., no air leak in the container where the KOH reaction is carried out. The following two sections summarize the development of a satisfactory reaction chamber and the method of gas analysis.

9.2 Reaction Chamber

Design of a leak free reaction chamber was complicated by the necessity of being able to admit concentrated KOH to the reaction chamber, heat the base to about 100°C* without "bumping", and open the chamber to load it with a 1 1/4 inch diameter nickel sample holder. These problems were solved in the reaction chamber sketched in figure 3 by the use of inert Kel-F grease on all joints exposed to base (stopcock B and joint D) and a ground glass joint, D, large enough to pass the nickel cup, that could be water-cooled while the base was being heated. "Bumping" of the base was prevented by the large vapor-liquid interface of the base, E, when it was in the reaction flask, G, and rotation of the nickel cup, H, with a magnetic stirrer.

The reaction of the combustion products with KOH was carried out as follows. The reaction chamber head (A, B, C, D of figure 3) was connected in an inverted position to a vacuum system via joint D (see connection O of figure 7). 25 cc of 50 weight percent KOH in bulb A was degassed by evacuation of the bulb after each of three successive freezings of the base in a dry ice-methylene chloride bath. After clamping stopcock B in the closed position with springs attached to wings, F, the reaction chamber head and flask, G, were placed in a dry box, the box atmosphere was dried, and the nickel cup and its contents were placed in the flask. The dry atmosphere

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*To insure completion of the reaction of beryllium metal with base.

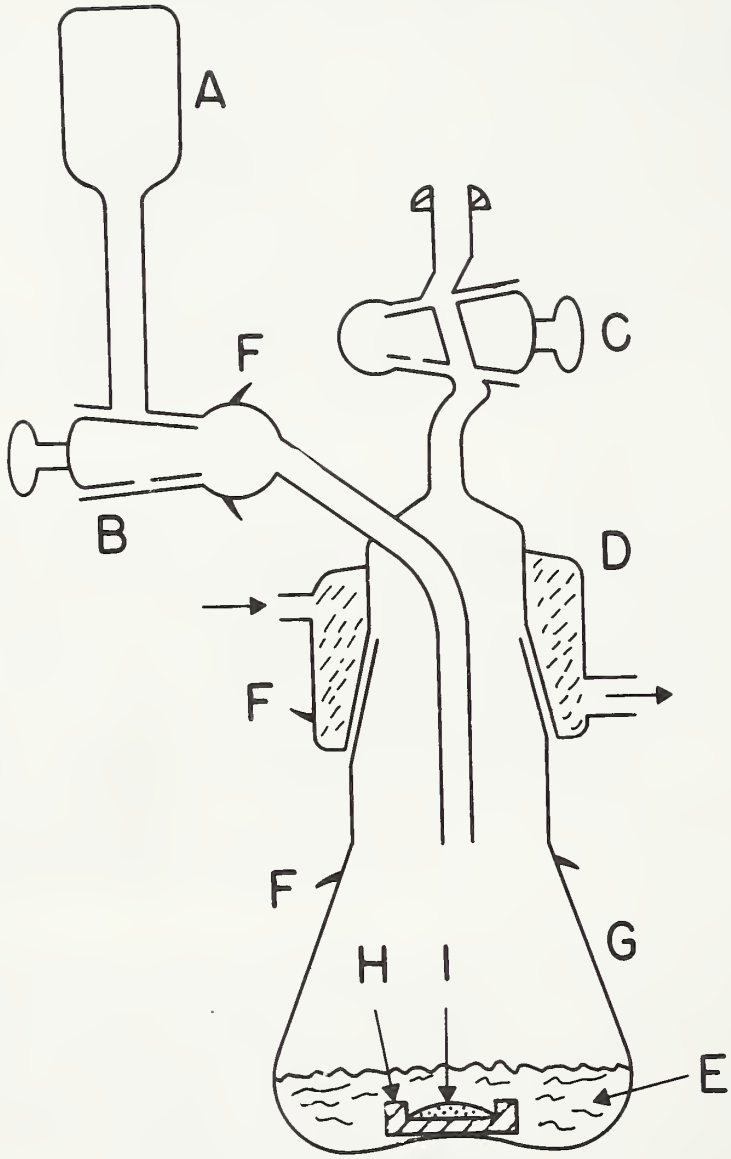

FIGURE 3 SKETCH OF REACTION CHAMBER

A, bulb, 50 cm^{-3}, containing degassed base; B, stopcock to admit degassed base into reaction chamber; C, stopcock to gas analysis system; D, water cooled ground glass joint; E, base (conc. KOH); F, "wings" to secure spring clamps; G, reaction chamber flask; H, nickel pellet cup from combustion bomb; I, solid combustion products.

was necessary since unburned beryllium, present in the cup along with Be_2C and some BeF_2 powder, reacts slowly with moisture to give hydrogen. Loss of cup contents or contamination of the glass joint on the reaction flask with BeF_2 powder by electrostatic attraction* was eliminated by covering the flask with Saran wrap during the loading. After removing the Saran wrap, the reaction chamber was assembled, decontaminated with water, removed from the dry box, and evacuated via stopcock, C, to a pressure of less than 10^{-3} mm of mercury. After closure of stopcock C, base was slowly admitted to the reaction chamber and the stopcock, B, was spring-clamped in the open position. The reaction of the combustion products with base was completed by placing the chamber in an oil bath whose temperature is slowly raised and held at 80-100°C for ten to twelve hours.

It was found that the reaction chamber consistently leaked less than 2×10^{-8} moles of air during this procedure.

9.3 Gas Analysis

Initially, we attempted to develop a method of analysis based upon separation of hydrogen from methane by passing the mixture through a palladium filter, selectively permeable to hydrogen, and measurement of the quantity of each gas by collection in a gas burette. The actual filter, a copy of a design by Rudzitis [60] is given in figure 4. Gas flows into the glass mantle, D, enclosing a palladium thimble, A, that is heated by a nichrome heater, E, to a temperature of 500°C measured by a thermocouple in well F. Hydrogen is sucked through the palladium via the Kovar tube, D, connected to a glass tube at C leading to a Toepler pump. Experiments testing this filter were made by connecting the filter inlet to a bulb containing gas of known quantity and composition and the filter outlet to a Toepler pump via a U-tube trap immersed in liquid nitrogen.† Since hot palladium is an excellent catalyst for the reactions

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

the presence of air in the gas mixtures leads to total or partial loss of the gas sample. Even in the absence of oxygen some sample is lost, as indicated by the tests summarized in Table 9. This may be caused by oxides present on the Kovar tube or nichrome heater even after prolonged exposure to hydrogen.

*Due to charge buildup during drying of the atmosphere of the dry box.

†To protect the palladium from the mercury in the Toepler pump.

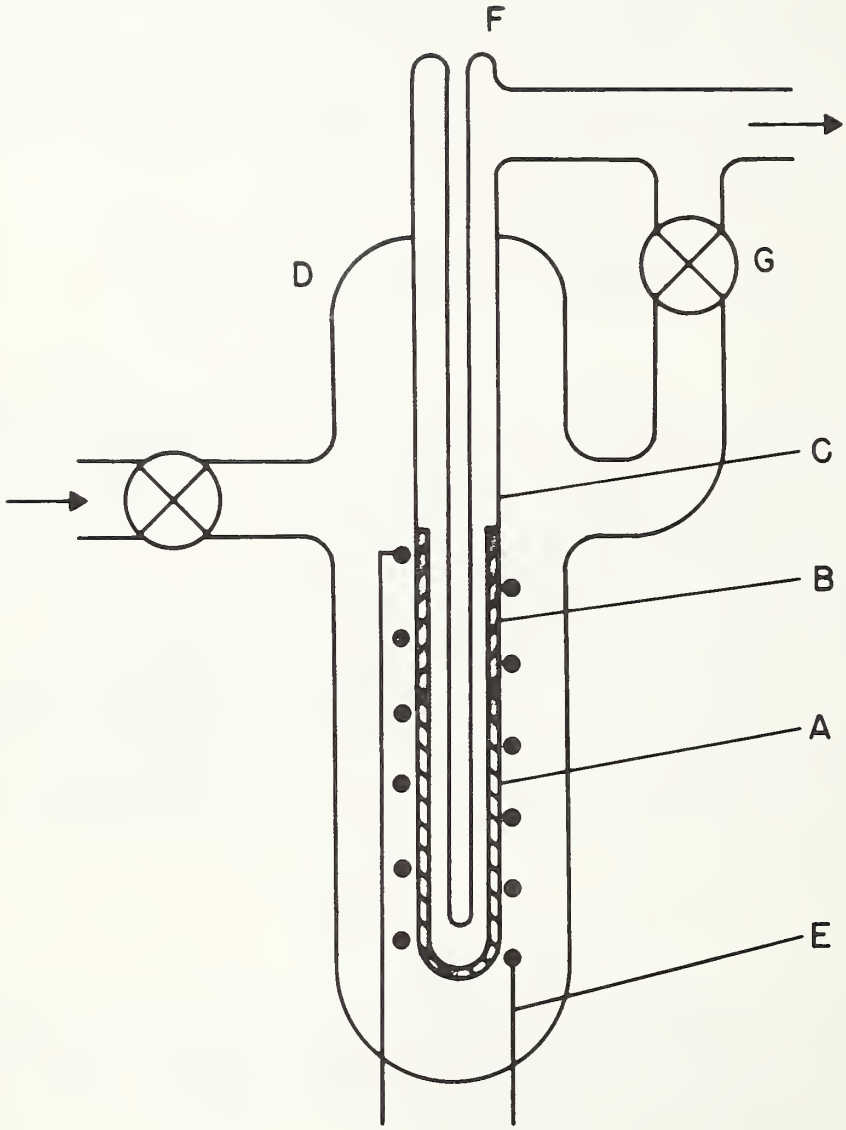

FIGURE 4 SKETCH OF PALLADIUM FILTER

A, palladium thimble; B, Kovar tube; C, Kovar to glass seal; D, glass mantle; E, heater leads; F, glass thermocouple well; G, bypass stopcock.

A method of gas separation that would avoid loss of the gas sample was suggested by the successful separation and purification of gases by preferential adsorption and desorption on molecular sieves [61,62,63]. The possibility of using molecular sieves was investigated by measuring equilibrium pressures (with either a thermocouple gauge or mercury manometer) as a function of sieve temperature (with a thermocouple) where approximately 2 x 10^{-4} moles of methane, nitrogen, or oxygen were placed in contact with 30 grams of type 5A molecular sieve. Since hydrogen is scarcely adsorbed at all at -190°C [63], this data, summarized in figure 6, suggested that hydrogen might be separated from oxygen from -170 to -180°C, oxygen from methane from -130 to -140°C, and certainly hydrogen from methane at -130 to -140°C.

Separation experiments were carried out with a sieve separator essentially identical to the final model shown in figure 5. The gas sample was completely adsorbed on the molecular sieve, A, by cooling well B to about -215°C as measured by the thermocouples, E. This temperature was produced by preliminary cooling of the jacket, D, in liquid nitrogen and then by filling the jacket with liquid nitrogen via tube, I, and pumping on the liquid via stopcock, L. After closing stopcock C, the well was warmed to -195°C, the liquid nitrogen was blown out of the jacket via tube J by applying nitrogen pressure at tube I. Stopcock C was slowly opened and then the sieve was slowly warmed to and held at the "separation" temperature for one hour to reduce contamination of the less strongly adsorbed gas by the more tightly bound constituents. Because of the low pumping rate of our Toepler pump, 250 cm^{-3} per minute, another sieve trap similar to that in figure 5 was used to adsorb the "volatile gas" from the separator by maintaining the trap at -215°C. Subsequent warming of this sieve released the separated gas to be transferred to the gas burette with the Toepler pump.

Experiments with this apparatus, see Table 10, showed that hydrogen can be separated from methane at a sieve temperature of -130°C. However, separation of a mixture of hydrogen, oxygen, and methane with an accuracy of 0.1% proved beyond the capability of our apparatus.

A diagram of the gas analysis system is shown in figure 7. After completion of the reaction of the combustion products with KOH and freezing out the base by immersing the chamber flask (see G, figure 3) in a dry ice-methylene chloride bath, the mixture of hydrogen and methane gas was removed from the reaction chamber via cold trap D (held near -78°C). Large quantities of the gas mixture (greater than 10^{-3} moles) had to be adsorbed into the sieve separator, E, and separated into hydrogen and methane in successive batches. Small

Table 9. Tests of Palladium Filter

Gas to be analyzed	H_2		H_2, CH_4	
Composition H_2, %	100.00		77.5 ± 3	
(mass spect.) CH_4, %	0.00		22.5 ± 3	
other, %	0.00		0.00	
Experimental arrangement	see text		see text	
	Amt.	Uncert.	Amt.	Uncert.
Initial sample, moles x 10^4	1.103 ±	0.001	1.293 ±	0.001
Amt. passing filter, moles x 10^4	1.089	0.001	0.923	0.001
Amt. behind filter, moles x 10^4	0.004	0.001	0.344	0.001
Sample lost, moles x 10^4	0.010	0.002	0.026	0.002
Obsv. composition H_2, %	99.6	0.2	72.8	0.2
(sample collected) CH_4, %			27.2	0.2
other, %	0.4	0.2		

Table 10 Tests of Molecular Sieve Separator

Gas to be analyzed	H_2, CH_4		H_2, CH_4	
Initial composition	Amt.	Uncert.	Amt.	Uncert.
H_2, moles x 10^4	3.367 ±	0.004	1.474 ±	0.002
CH_4, moles x 10^4	2.031	0.003	>2.0	
Total, moles x 10^4	5.398	0.005	-----	
"Separation" temperature	-144°C.		-130°C.	
Analyzed composition				
H_2, moles x 10^4	3.354 ±	0.004	1.478 ±	0.002
CH_4, moles x 10^4	2.049	0.003	>2.0	
Total, moles x 10^4	5.403	0.005		

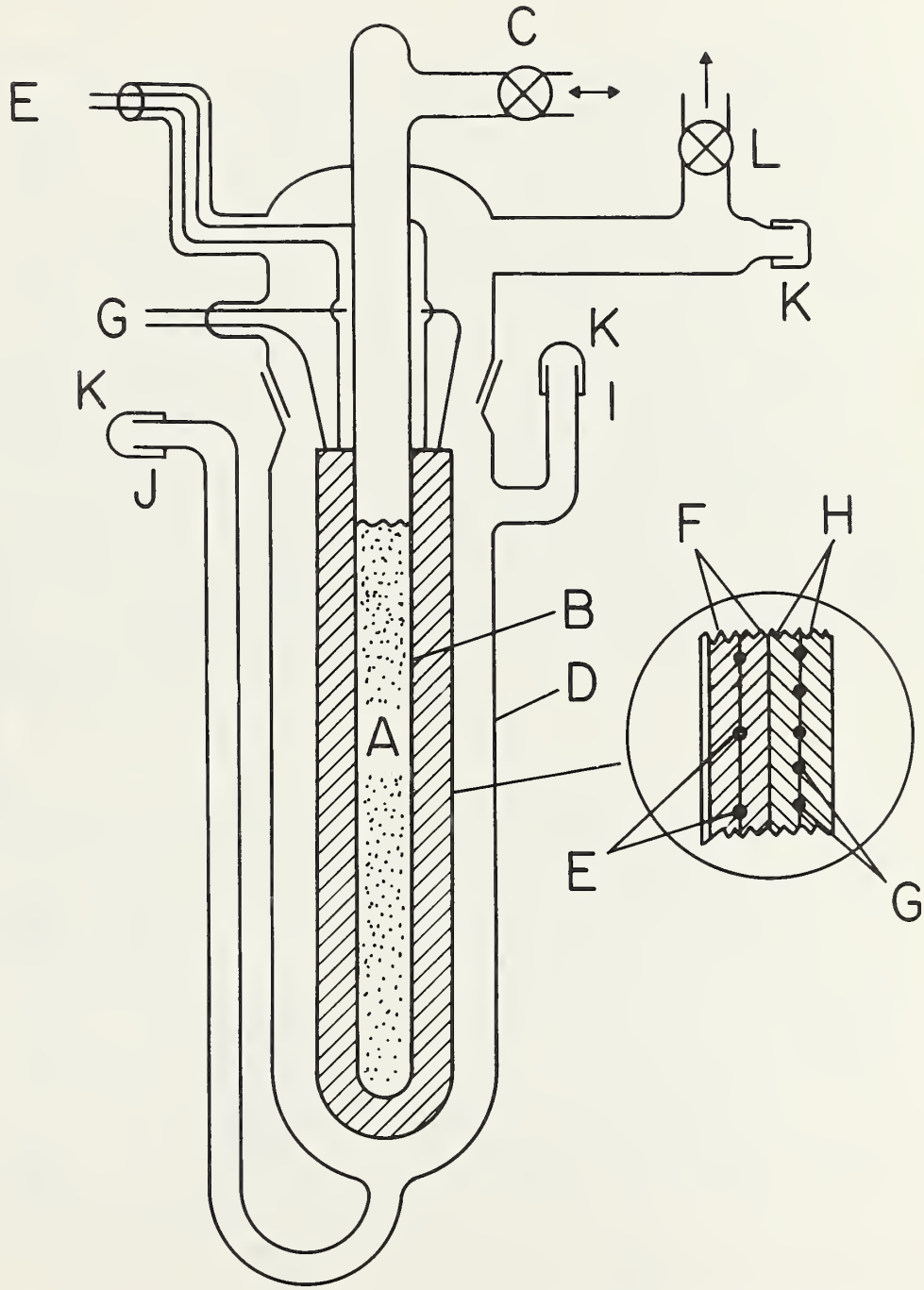

FIGURE 5 SKETCH OF SIEVE SEPARATOR

A, type 5A molecular sieve; B, sieve well; C, stopcock to gas analysis system; D, jacket; E, thermocouples; F, aluminum foil; G, heater wire; H, asbestos tape; I, liquid nitrogen entry port; J, flushing port; K, removable rubber caps; L, stopcock to rough vacuum.

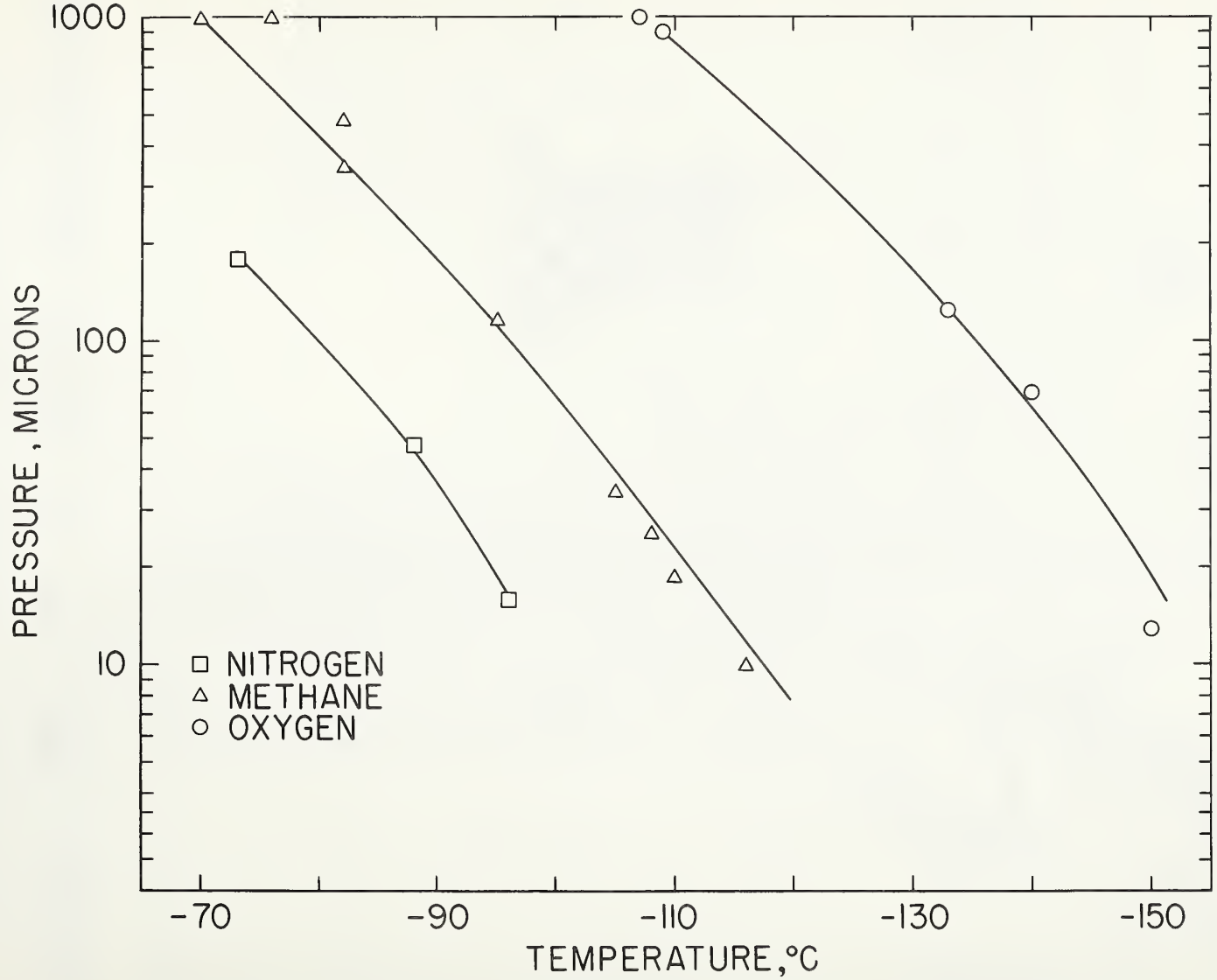

FIGURE 6 GAS PRESSURE VS SIEVE TEMPERATURE

quantities of gas (2×10^{-5} moles) were usually collected in the gas burette for measurement of the total moles of gas prior to analysis by molecular sieve or the mass spectrometer (see results in section 9.4).

The gas burette, I of figure 7, consists of a U-tube mercury manometer with arms of equal internal diameter (about 1.4 cm) connected to a mercury reservoir. The left arm is the actual gas burette (100 cm^{-3}); the space over the mercury in the right arm is kept evacuated. Variation of the air pressure above the mercury in the reservoir permits variation of the mercury levels in the two arms so that the pressure-volume product of the collected gas may be measured with the best possible precision. The temperature of the water jacket surrounding the left arm varies slowly enough with time to allow estimation of the temperature of the gas in the burette to 0.1°C, after appropriate corrections. The volume of the gas can be estimated to 0.01 cm^{-3}; the uncertainty of the burette calibration is of the order of 0.03 cm^{-3}. Measurements of volume are corrected for the space occupied by the mercury meniscus. Pressures may be estimated to ±0.02 mm with a Herbrugg cathetometer. Measurements of pressure are corrected for the effects of differences in temperature and mercury meniscus heights of the two arms as well as for a small refraction effect due to the fact only one arm of the manometer could be placed in the water jacket. Experience showed that the standard deviation for a single measurement of the quantity of gas in the burette was 1, 0.15, and 0.10 percent for 2×10^{-5}, 2×10^{-4}, and 1.1×10^{-3} moles of gas, respectively.

9.4 Results of Analysis

Table 11 is a comparison of the analysis of about 2×10^{-5} moles of gas liberated by the reaction of KOH with the solid combustion products by molecular sieve separation and mass spectrometer. Mass spectrometer values for N_2, O_2, and Ar were added to the value for CH_4 since the "methane fraction" of the sieve analysis would be expected to contain all these components. The largest uncertainties of mass spectrometer analyses (estimated by the analyst) are those for hydrogen and methane. The uncertainty of the sieve analyses are the 95 percent confidence limits assuming the standard deviation of a single measurement of the quantity of gas is 1% (see section 9.3). Although it is apparent there may be some discrepancies between the two analyses, the agreement is well within the requirements for our problem (see section 9.1). Neither the origin of the small quantities of hydrocarbons, present in all the combustion product analyses, or the N_2 or O_2 is known with certainty.

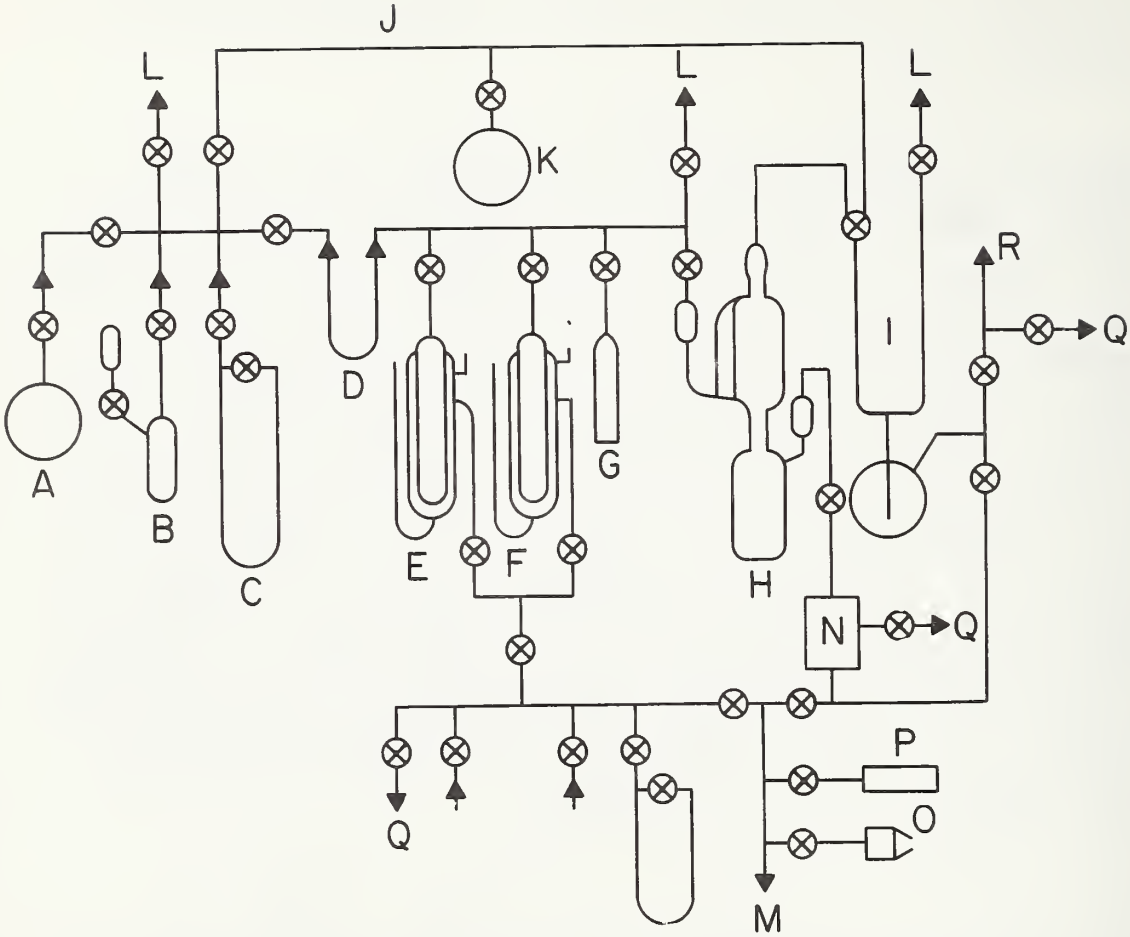

FIGURE 7 GAS ANALYSIS SYSTEM

A, sample bulb; B, reaction chamber; C, mercury manometer; D, U-tube cold trap; E, sieve separator; F, sieve pump; G, thermocouple gauge; H, Toepler pump; I, gas burettes; J, recycle line; K, storage bulb; L, connections to vacuum pump (1); M, connection to vacuum pump (2); N, solenoid valves to control Toepler pump; O, connection to reaction chamber head for degassing base; P, thermocouple gauge; Q, vent to air; R, connection to air pressure.

Table 11. Comparison of Mass Spectra and Sieve Analysis

Expt. No.	3,I		3,II		4,II		5,II	
Method of Analysis	Mass Spectra	Sieve	Mass Spectra	Sieve	Mass Spectra	Sieve	Mass Spectra	Sieve
H_2, %	67.0±3	63.4±1.5	74.2±3	64.3±1.8	46.1±3	40.4±1.1	50.5±3	45.7±1.3
CH_4, %	24.9±3		18.0±3		45.3±3		39.2±3	
N_2, %	4.5				4.1		5.8	
O_2, %	1.3		5.0		1.2		1.7	
Ar, %	0.1				0.1		0.1	
	30.8±3	36.6±2.5	23.0±3	26.1±2.1	50.7±3	55.5±2.3	46.8±3	48.2±1.5
propene, %	0.5				0.8		0.5	
propane, %	0.2				0.4		0.8	
H_2O vapor, %	0.8				1.0		0.3	
hydrocarbon, %	0.7		0.4		1.0		1.1	
acetone, %	---		2.4		---		---	
	2.2±5	0.0±2.9	2.8±5	9.6±2.7	3.2±5	4.1±2.5	2.7±5	6.1±1.9

Residues from the beryllium-Teflon combustions were collected quantitatively in glass fritted disc filters, weighed, and sent to the NBS Analysis and Purification Section for analysis of carbon and fluorine content. Although all these analyses have not been completed, preliminary results suggest that the carbon content of the residues from the series II combustions are higher than 87% (see section 8.3).

Table 12 is a summary of the combustion product analyses based on the molecular sieve gas separations. Methane, for experiments 3,I; 3II; 4II; and 5,II was calculated from the moles of gas in the "methane fraction" given by the sieve analyses and the percent of methane in this fraction given by the mass spectrometer analyses. Since no mass spectrometer analysis was made for experiment 2,II, the percent of methane in the sieve analysis "methane fraction" was estimated from the results of the above experiments. Methane and hydrogen for experiments 1,I and 6,I, where the total moles of gas was 2×10^{-3}, were calculated using the results of the sieve analysis and corrections for the relatively small amounts of impurities (air, methane in the hydrogen fraction of the sieve analysis from 0.2 to 0.4 percent) given by the mass spectrometer analyses. Uncertainties in Table 12 are the 95 percent confidence limits based on the standard deviation of single measurements of the moles of gas cited in section 9.3.

Table 12. Results of Combustion Product Analyses

Expt No.	Unburned Beryllium	Uncert.	Be_2C in Products	Uncert.	Residue	Uncert.
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
1, I	18.536	0.037	5.442	0.125	1.683	0.04
3, I	0.148	0.005	0.213	0.015	1.706	0.04
6, I	17.832	0.034	6.578	0.059	2.131	0.04
2, II	0.144	0.003	0.279	0.003	2.00	0.04
3, II	0.184	0.006	0.195	0.016	2.011	0.04
4, II	0.098	0.003	0.405	0.034	1.916	0.04
5, II	0.091	0.003	0.285	0.011	1.670	0.04

References

[1] J. Simmons, Unpublished data, Atlantic Research Corp., April 11, 1961; Private communication to E.S. Domalski, 1962.

[2] L. A. Cosgrove and P. E. Snyder, J. Am. Chem. Soc. 75, 1302 (1953).

[3] W. A. Roth, E. Borger, and H. Siemonsen, Z. anorg. Chem. 239, 321 (1938).

[4] B. Neuman, C. Kroger, and H. Kunz, Z. anorg. Chem. 218, 379 (1934).

[5] J. E. Moose and S. W. Parr, J. Am. Chem. Soc. 46, 2656 (1924).

[6] W. Mielenz and W. von Wartenburg, Z. anorg. Chem. 116, 267 (1921).

[7] V. P. Kolesov, M. M. Popov, and S. M. Skuratov, Zhur. Neorg. Khim. 4, 1233 (1959), (J. Inorg. Chem. (USSR) 4, 557 (1959)).

[8] H. Copaux and Ch. Phillips, Compt. Rend. 171, 630 (1920); 176, 597 (1923).

[9] H. Copaux and N. C. Matignon, Compt. Rend. 181, 550 (1925).

[10] M. C. Matignon and G. Marchal, Bull. soc. chim. France 39, 167-190 (1926; Compt. rend 181, 859 (1925).

[11] R. Fricke and B. Wullhorst, Z. anorg. Chem. 205, 127 (1932).

[12] M. C. Matignon and G. Marchal, Compt. rend. 183, 927 (1926).

[13] C. W. Beckett, W. G. Goodson, and T. B. Douglas, NBS ("ARPA") Report 7437, January 1962.

[14] G. T. Furukawa and M. L. Reilly, NBS ("ARPA") Report 8186, January 1964

[15] M. A. Greenbaum, J. N. Foster, M. L. Arin, and M. Farber, J. Phys. Chem. 67, 36 (1963).

[16] J. Efimenko, NBS Report 8033, July 1963.

[17] M. A. Greenbaum, M. L. Arin, and M. Farber, J. Phys. Chem. 67, 1191 (1963).

[18] G. T. Armstrong and L. A. Krieger, NBS Report 7192, July 1961.

[19] G. T. Armstrong and M. C. Bracken, NBS Report 8504, July 1964.

[20] P. Gross, Fulmer Research Institute Report R.163/14/20, December 1963; R.163/15/25, March 1964.

[21] K. L. Churney, NBS Report 8033, July 1963.

[22] CPIA Publication No. 44 (U), Proceedings of the First Meeting (Nov. 1963) of the Working Group on Thermochemistry, Vol. 1, Chemical Propulsion Information Agency, Silver Spring, Md., Feb. 1964.

[23] D. L. Hildenbrand, J. Chem. Phys. 40, 3438 (1964).

[24] T. B. Douglas, CPIA Publication No. 54 (U), Proceedings of the Second Meeting (June 1964) of the Working Group on Thermochemistry, Vol. 1, Chemical Propulsion Information Agency, Silver Spring, Md. August 1964.

[25] A. R. Taylor, Jr., CPIA Publication No. 54 (U), Proceedings of the Second Meeting (June 1964) of the Working Group on Thermochemistry, Vol. 1, Chemical Propulsion Information Agency, Silver Spring, Md., August 1964.

[26] A. Snelson, CPIA Publication No. 54 (U), Proceedings of the Second Meeting (June 1964) of the Working Group on Thermochemistry, Vol. 1, Chemical Propulsion Information Agency, Silver Spring, Md. August 1964.

[27] D. E. Mann, NBS Report 8504, July 1964.

[28] J. Efimenko, NBS Report 8504, July 1964.

[29] P. Gross, Fulmer Research Institute Report R.146/4/23, November 1960.

[30] E. S. Domalski and G. T. Armstrong, J. Research Natl. Bur. Standards 69A, No. 2, 137 (April 1965).

[31] C. F. Coyle and G. T. Armstrong, this report, Chapter B-9.

[32] G. T. Armstrong and R. S. Jessup, J. Research Natl. Bur. Standards 64A, 49-59 (1960).

[33] H. C. Dickinson, Bull. BS 11, 189-257 (1914).

[34] E. J. Prosen, W. H. Johnson, and F. Y. Pergiel, J. Research Natl. Bur. Standards 62, 43-7 (1959).

[35] J. Coops, R. S. Jessup, and K. Van Nes, Chapter 3, Experimental Thermochemistry, F. D. Rossini, Editor, (Interscience Publishers, Inc., New York, 1956).

[36] R. S. Jessup, NBS Monograph No. 7, February 26, 1960.

[37] G. E. Darwin and J. H. Buddery, Beryllium (Academic Press, Inc., New York, 1960).

[38] D. W. White, Jr. and J. E. Burke, The Metal Beryllium (The American Society for Metals, Cleveland, 1955).

[39] A. J. Breslin and W. B. Harris, Health Protection in Beryllium Facilities; Summary of Ten Years Experience, Health and Safety Laboratory, U.S.A.E.C., New York Operations Office, May 1, 1958.

[40] L. B. Tepper, H. L. Hardy, and R. I. Chamberlin, Toxicity of Beryllium Compounds (Elsevier Publishing Co., Amsterdam, New York, 1960).

[41] T. W. Mears, W. H. Johnson, and W. A. Gilliland, NBS, private communication, 1962.

[42] B. E. Warren and C. F. Hill, Zeit. F. Kristallographie 89, 31 (1935).

[43] W. N. Hubbard, D. W. Scott, and G. Waddington, Chapter 5, Experimental Thermochemistry, F. D. Rossini, Editor (Interscience Publishers, Inc., New York, 1956).

[44] W. N. Hubbard, Chapter 5, Vol. II, Experimental Thermochemistry, H. A. Skinner, Editor (Interscience Publishers, Inc., New York, 1962).

[45] O. E. Meyers and A. P. Brady, J. Phys. Chem. 64, 591 (1960).

[46] D. White, J. H. Hu, and H. L. Johnston, J. Phys. Chem. 21, 1149 (1953).

[47] D. R. Douslin, Paper 11, Progress in International Research on Thermodynamic and Transport Properties, J. F. Masi and D. H. Tsai, Editors (Academic Press, New York, 1962).

[48] NBS Report 6928, Table A34, July 1960.

[49] JANAF Thermochemical Tables, Quarterly Supplement No. 8, D. R. Stull, Editor, Dow Chemical Company, Midland, Michigan, December 31, 1962.

[50] Table 2-7, NBS Report 6484, July 1959.

[51] W. D. Good, D. W. Scott, and G. Waddington, J. Phys. Chem. 60, 1080 (1956).

[52] Table B58, NBS Report 8186, January 1964

[53] S. S. Wise, H. M. Teder, and W. N. Hubbard, J. Phys. Chem. 65, 2157 (1961).

[54] E. Rudzitis, H. M. Feder, and W. N. Hubbard, J. Phys. Chem. 68, 2978 (1964).

[55] S. S. Wise and J. L. Margrave, J. Phys. Chem. 67, 815, 1963.

[56] E. Rudzitis, H. M. Feder, and W. N. Hubbard, J. Phys. Chem. 67, 2388 (1963).

[57] J. L. Settle, H. M. Feder, and W. N. Hubbard, J. Phys. Chem. 65, 1337 (1961).

[58] W. H. Evans, NBS, Private communication, 1964.

[59] A. E. Cameron and E. Wichers, J. Am. Chem. Soc. 84, 4175 (1962).

[60] E. Rudzitis, Argonne National Laboratory, Argonne, Illinois, private communication.

[61] W. Braun, NBS, Private communication.

[62] T. L. Thomas and R. L. Mays, "Separations with Molecular Sieves", Physical Methods in Chemical Analysis, Vol. IV, W. G. Berl, Editor (Academic Press, New York, 1961).

[63] Y. Murakami and H. Okamoto, Vacuum 13, 93 (1963).

[64] C. R. Patrick, "The Thermochemistry of Organic Fluorine Compounds," Vol. 2, M. Stacey, J. C. Tatlow, A. G. Sharpe, Editors, (Butterworths, Washington, 1961).

APPENDIX I

FORMULA-PROPERTY INDEX FOR THE PRECEDING THIRTEEN OF THESE REPORTS

by Howard W. Flieger, Jr., Martin L. Reilly, and Thomas B. Douglas

In the preceding report, the thirteenth in this series, a formula-property index to the first twelve of the reports was given (NBS Report 8628, 1 January 1965, pp. 30-47). The following index is the result of correcting those errors in that index which came to our attention, of improving the format in several ways, and of making insertions to include also the thirteenth report (NBS Report 8628). (The present (fourteenth) report is not included.) The earlier formula-property index is thus superseded.

For the purpose of the present index the NBS report numbers are referred to as the following Volume numbers:

NBS REPORT NO.	VOLUME NUMBER
6297	1
6484	2
6645	3
6928	4
7093	5
7192	6
7437	7
7587	8
7796	9
8033	10
8186	11
8504	12
8628	13

The arrangement of the chemical formulas in the index is alphabetical, and the placement of the chemical symbols within a given formula is also alphabetical. Chemical isomers are not distinguished. In general, four printing spaces are allocated to each chemical symbol and its numerical occurrence in the formula (with two blanks in the numeric field whenever the number 1 is understood). If references are listed for a neutral species and for a positive ion and a negative ion all having the same chemical formula, the three are listed in this order, with an appropriate sign ending the formula of each of the ions. Two successive hyphens separate components in a chemical system (a system is indexed under each component and follows all other listings of that component). Although the printing of chemical symbols is restricted solely to capital letters, the above scheme

formally prevents ambiguity; e.g., Co and CO are given as CO and C O, respectively. This order and arrangement of chemical formulas may appear clearer from the following table, presented as an example. Several species are listed in the relative order in which they appear (with intervening entries) in the index. On each line a customary form of the formula is given at the left, and the corresponding entry in the index (including spaces) at the right.

	$BeA\ell O$	AL BE O
	Be	BE
	Be^{+}	BE +
	Be^{-}	BE -
	BeH	BE H
	BeH_2	BE H_2
	$BeOH^{+}$	BE H O +
	$Be(OH)_2$	BE H_2O_2
	BeO	BE O
System	$BeO-ZrO_2-MgO$	BE O --MG O --O_2 ZR
	Be_2C	BE_2 C
	Be_2O	BE_2 O

It will be noted that the present index traverses the two halves of each page consecutively. On each half page the chemical formula is followed (in an aligned block) by two symbols: The letter indicates the property or study, and the number indicates the source or treatment of the information. The interpretation of these letters and numbers is given in the key just preceding the index.

The specific reference for a given entry (in the third aligned block of each half page) gives first the Volume number of the report as identified in the first table above; and second, in parentheses, the page number (or initial page number). An exception to this rule occurs for Volumes 2, 3, and 4, in which the pages of the appendices were not numbered. In these cases the page number is replaced by the Table number, which always contains a letter or a hyphen and so is easily distinguishable from page numbers.

The following index is presented in its entirety in two alternative forms below. In the first, all chemical formulas are in order

as described above. In the second, the index is subdivided into groups each of which lists all entries with the same property-source classification (e.g., all with B5 appear together). Which form of the index one prefers to use would depend on whether one is more interested in all properties of a given substance, or all substances for which information on a given property is given in these reports. One could hardly hope to make a classification of thermodynamic properties that was mutually exclusive without being cumbersome, and we hold no brief for the freedom of ours from resulting ambiguity. However, in some cases alternative entries were included to provide some cross-referencing. It is appropriate to add also that the index, though carefully prepared, was not systematically checked for errors or omissions.

Several extensive bibliographies and tables found in some of the reports referenced have not been included in this index -- not through any lack of their importance but because of insufficient time for their inclusion. These bibliographies are listed below.

TITLE	VOLUME	PAGES
A Brief Review of the Heat Relationships Among the Crystalline Oxides and Oxyhydrates of Aluminum.	1	74-85
References to Recent Values for Heats of Formation.	5	169-173
The Heats of Formation of Inorganic Fluorine Compounds-- A Survey.	6	92-175
Recent Additions to the Literature on the Chemistry of the Light Elements.	7	39-60
Thermochemical Data for Some Simple Hydrides and Inorganic Oxidizers.	7	79-89
Recent Additions to the Literature Related to the Heats of Formation of Compounds of Selected Elements.	8	76-89
New Literature Relating to Heats of Formation of the Light Elements and Their Compounds	9	40-81
Substance-Property Index for 1962.	9	82-156

TITLE	VOLUME	PAGES
A Bibliography Relating to Heats of Formation, Enthalpy Changes Resulting from Phase Changes, and the Heat Capacities of Aluminum and Beryllium Fluorides, Oxyfluorides, Chlorides, and Oxychlorides, and of Lithium Fluoride.	10	22-35
New Literature Relating to Heats of Formation of Fluorine Compounds of Selected Elements.	11	122-142
Preliminary List of Ionization Potentials or Electron Affinities of Light Element Compounds.	12	185-202
Selected Thermochemical Values	13	79-88

In reality, the content of the Preliminary List of Ionization Potentials or Electron Affinities of Light Element Compounds in "Volume 12" is included in the index, since the latter covers the updated and amplified version that appeared as Appendix IV of "Volume 13." A brief explanation of this coverage is in order. All values in that appendix are classified here as A2 ("heats of formation taken from the literature", even though some values actually received some critical appraisal). Furthermore, such a reference is given not under the formula of the neutral species but rather under the formula of the positive or negative ion whose heat of formation (nominally at 0°K) from the neutral species is represented (with proper sign) by the tabulated ionization potential or electron affinity, respectively.

KEY to property or study:

Property or Study Letter	Interpretation
A	Heats of reaction, dissociation and formation.
B	Thermodynamic functions of solids, liquids and solutions.
C	Thermodynamic functions of gases.
D	Vapor pressure and vaporization equilibria, decomposition and dissociation studies, and heats of vaporization and sublimation.
E	Data of state and related physical properties.
F	Phase diagrams.
G	Absorption and emission spectroscopy including molecular constants.
H	Kinetic studies.
J	Chemical preparation and/or purification studies.
K	Electrical discharge (exploding wire) studies.
L	Calorimetry techniques.
M	Mass spectroscopy studies.

Source and Treatment Number	Source and/or treatment of information
1	NBS reported.
2	Literature (non-NBS) reported.
3	NBS critical evaluation, review and analysis of data.
4	Non-NBS critical evaluation, review and analysis of data.
5	Tables at a standard state.
6	Ideal Gas tables.
7	Theoretical or empirical estimate.
8	Apparatus description.
9	Tables of thermodynamic properties with temperature or pressure argument and other tables.

Formula Index

A. THE INDEX, IN ORDER OF FORMULA

AG	C5	12(184)
AG CL	C5	12(184)
AG_2 O	C5	12(184)
AG +	C5	12(184)
AL	A2	1(58)
AL	A2	2(101)
AL	A5	4(C 1)
AL	B2	1(7)
AL	B2	2(22)
AL	B3	1(26)
AL	B5	1(9)
AL	B5	2(20)
AL	B9	2(2- 1)
AL	B9	4(B 1)
AL	C6	2(1-13)
AL	C6	4(A13)
AL	D2	1(48)
AL	K1	12(26)
AL +	A2	13(108)
AL +	C6	6(229)
AL −	A2	13(108)
AL--B	F2	5(187)
AL B_3H_{12}	A1	13(1)
AL B_3H_{12}	A2	7(92)
AL B_3H_{12}	G1	13(8)
AL B_{10}	E2	5(150)
AL B_{12}	E2	5(150)
AL--BE	F2	5(188)
AL BE O	C6	12(140)
AL BE O	G7	12(85)
AL BE O	M1	13(25)
AL BR_3	B7	6(54)
AL BR_3 −	A2	13(108)
AL C	A2	3(2)
AL C	A2	3(65)
AL C	A5	4(C 2)
AL C	G2	4(43)
AL CL	A2	1(59)
AL CL	A2	1(66)
AL CL	A2	2(89)
AL CL	A2	2(102)
AL CL	A5	4(C 2)
AL CL	C6	1(125)
AL CL	C6	2(1-30)
AL CL	C6	4(A32)
AL CL	D3	8(114)
AL CL	G1	12(57)
AL CL	G2	1(42)
AL CL	G2	4(43)
AL CL	G6	12(64)
AL CL	G6	12(65)
AL CL	G6	12(66)
AL CL	G9	2(50)
AL CL +	A2	13(108)
AL CL F_2	C6	2(1-61)
AL CL F_2	C6	4(A65)
AL CL F_2	G2	1(44)
AL CL F_2	G9	2(51)
AL CL O	B5	1(9)
AL CL O	C6	2(1-58)
AL CL O	C6	4(A62)
AL CL O	G2	1(44)
AL CL O	G9	2(51)
AL CL_2	A2	1(59)
AL CL_2	A2	2(89)
AL CL_2	A2	2(102)
AL CL_2	A5	4(C 2)
AL CL_2	C6	2(1-63)
AL CL_2	C6	4(A67)
AL CL_2	D3	8(114)
AL CL_2	G2	1(44)
AL CL_2	G9	2(51)
AL CL_2 +	A2	13(108)
AL CL_2 F	C6	2(1-62)
AL CL_2 F	C6	4(A66)
AL CL_2 F	G2	1(44)
AL CL_2 F	G9	2(51)
AL CL_3	A2	1(59)
AL CL_3	A2	1(66)
AL CL_3	A2	2(89)
AL CL_3	A2	2(103)
AL CL_3	A3	4(36)
AL CL_3	A5	4(C 2)
AL CL_3	B2	3(64)
AL CL_3	B3	1(26)
AL CL_3	B5	1(9)
AL CL_3	B5	2(20)
AL CL_3	B9	2(2- 6)
AL CL_3	B9	4(B 6)
AL CL_3	C6	2(1-64)
AL CL_3	C6	4(A68)
AL CL_3	G2	1(44)
AL CL_3	G9	2(51)
AL CL_3	S2	4(36)
AL CL_3 +	A2	13(108)
AL CL_3 H 12^0 6	A2	2(89)
AL CL_3 H 12^0 6	A2	2(103)
AL CL_3 H 12^0 6	A5	4(C 2)
AL F	A2	1(59)
AL F	A2	1(65)
AL F	A2	2(88)
AL F	A2	2(102)
AL F	A2	3(65)
AL F	A5	4(C 2)
AL F	C6	1(123)
AL F	C6	2(1-29)
AL F	C6	4(A31)
AL F	D3	8(114)
AL F	G1	9(12)
AL F	G1	12(57)
AL F	G2	1(42)
AL F	G2	4(43)
AL F	G6	12(64)
AL F	G6	12(65)
AL F	G9	2(50)
AL F	G9	4(47)
AL F	G9	9(14)
AL F +	A2	13(108)
AL F O	B5	1(9)
AL F O	C6	2(1-57)
AL F O	C6	4(A61)
AL F O	G2	1(44)
AL F O	G9	2(51)
AL F O +	A2	13(108)
AL F_2	A2	1(59)
AL F_2	A2	1(66)
AL F_2	A2	2(88)
AL F_2	A2	2(102)
AL F_2	C6	2(1-59)
AL F_2	C6	4(A63)
AL F_2	G2	1(44)
AL F_2	G9	2(51)
AL F_2 +	A2	13(108)
AL F_3	A1	8(13)
AL F_3	A1	12(21)
AL F_3	A2	1(59)
AL F_3	A2	1(66)
AL F_3	A2	2(88)
AL F_3	A2	2(102)
AL F_3	A2	3(65)
AL F_3	A2	4(35)
AL F_3	A2	8(13)
AL F_3	A5	4(C 2)
AL F_3	B2	2(24)
AL F_3	B3	1(26)
AL F_3	B5	1(9)
AL F_3	B5	2(20)
AL F_3	B9	2(2- 5)
AL F_3	B9	4(B 5)
AL F_3	C6	2(1-60)
AL F_3	C6	4(A64)
AL F_3	D1	9(157)
AL F_3	D3	2(63)

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AL F 3	D8	9(158)
AL F 3	D9	9(164)
AL F 3	D9	9(165)
AL F 3	G2	1(44)
AL F 3	G9	2(51)
AL F 3	L1	8(13)
AL F 3 +	A2	13(108)
AL F 3-AL2 O 3-F LI	F2	5(156)
AL F 3-AL2 O 3-F LI	F2	5(206)
AL F 3-F K	F2	5(222)
AL F 3-F LI	F2	5(155)
AL F 3-F LI	F2	5(165)
AL F 3-F LI	F2	5(220)
AL F 3-F NA	F2	5(221)
AL F 3 H 6 O 3	A2	1(59)
AL F 6 LI O	B9	11(74)
AL F 6 LI3	B1	11(68)
AL F 6 LI3	B9	11(71)
AL F 6 LI3	B9	11(162)
AL F 6 NA3	B2	9(20)
AL F 6 NA3	B9	9(31)
AL F 6 NA3	B9	13(49)
AL H	A2	1(59)
AL H	A2	2(86)
AL H	A2	2(102)
AL H	A5	4(C 2)
AL H	A7	2(41)
AL H	C6	4(A30)
AL H	G2	4(43)
AL H	G9	4(47)
AL H	J2	1(99)
AL H +	A2	13(108)
AL H O	C6	2(1-55)
AL H O	C6	4(A59)
AL H O	G2	1(44)
AL H O	G2	1(44)
AL H O	G9	2(51)
AL H O	G9	2(51)
AL H O 2	C6	2(1-56)
AL H O 2	C6	4(A60)
AL H O 2	G2	1(44)
AL H O 2	G9	2(7)
AL H O 2 +	A2	13(108)
AL H 3	A2	1(59)
AL H 3	A2	1(65)
AL H 3	A2	2(87)
AL H 3	A2	2(102)
AL H 3	A5	4(C 2)
AL H 3	B5	1(9)
AL H 3 ME6 N 4	A9	3(59)
AL H 3 ME6 N 4	D9	3(57)
AL H 3 ME6 N 4	D9	3(59)
AL H 3 O 3	A2	1(59)
AL H 3 O 3	A2	1(65)
AL H 3 O 3	A2	2(88)
AL H 3 O 3	A2	2(102)
AL H 3 O 3	A5	4(C 2)
AL H 4 LI	A2	7(92)
AL H 4 LI	B2	1(21)
AL H 4 LI	B5	1(22)
AL I 3	B7	6(54)
AL K O 4 SI	B2	12(97)
AL K O 6 SI	B2	12(97)
AL K O 8 SI3	B2	12(97)
AL K O 8 SI3	B2	12(98)
AL--LI	F2	5(189)
AL LI O 2	B2	1(21)
AL LI O 2	B2	2(30)
AL LI O 2	B5	1(22)
AL LI O 2	B5	2(20)
AL LI O 2	B9	2(2-27)
AL LI O 2	B9	4(B27)
AL--MG	F2	5(190)
AL N	A2	2(90)
AL N	A2	2(103)
AL N	A2	3(2)
AL N	A2	3(65)
AL N	A2	4(35)
AL N	A2	4(36)
AL N	A3	4(36)
AL N	A5	4(C 2)
AL N	B2	3(14)
AL N	B3	3(14)
AL N	B5	3(16)
AL N	B7	3(21)
AL N	B9	3(22)
AL N	B9	3(2-31)
AL N	B9	4(B31)
AL N	D3	3(37)
AL N	J2	4(26)
AL N --AL4 C 3	D3	3(34)
AL NA O 2	B9	9(31)
AL O	A2	1(59)
AL O	A2	1(62)
AL O	A2	2(83)
AL O	A2	2(102)
AL O	A5	4(C 2)
AL O	C6	1(127)
AL O	C6	2(1-28)
AL O	C6	4(A29)
AL O	G2	1(42)
AL O	G2	4(45)
AL O	G9	2(50)
AL O +	A2	13(108)
AL--O	D2	1(50)
AL--O	D2	2(61)
AL--O	H1	8(55)
AL--O	M8	8(56)
AL O BE +	M1	12(118)
AL O 2	A2	1(59)
AL O 2 -	A2	1(63)
AL O 2 -	A2	2(84)
AL O 2 -	A2	2(102)
AL O 2 -	A5	4(C 2)
AL O 2 NA	B2	9(20)
AL S	C6	4(A33)
AL S	G2	4(45)
AL S	G9	4(47)
AL--SI	F2	5(191)
AL--TI	F2	5(192)
AL--ZR	F2	5(193)
AL2	A2	1(59)
AL2	A2	1(62)
AL2	A2	2(83)
AL2	A2	2(102)
AL2	A5	4(C 2)
AL2	A7	2(41)
AL2	G2	4(42)
AL2	C6	4(A28)
AL2	G9	4(47)
AL2 BA O 4	A2	6(83)
AL2 BA O 4	A3	6(83)
AL2 BA3 O 4	A2	6(83)
AL2 BA3 O 4	A3	6(83)
AL2 BE O 4	A2	6(83)
AL2 BE O 4	A3	6(83)
AL2 BE O 4	B1	8(44)
AL2 BE O 4	B1	11(50)
AL2 BE O 4	B1	11(62)
AL2 BE O 4	B2	8(50)
AL2 BE O 4	B5	1(12)
AL2 BE O 4	B9	8(49)
AL2 BE O 4	B9	8(52)
AL2 BE O 4	B9	8(172)
AL2 BE O 4	B9	11(58)
AL2 BE O 4	B9	11(64)
AL2 BE O 4	B9	11(160)
AL2 BE O 4	E2	5(160)
AL2 BE O 4	J1	12(83)
AL2 BE O 4	M1	13(25)
AL2 C 2	A2	2(90)
AL2 C 2	A2	2(103)
AL2 C 2	A2	3(3)
AL2 C 2	A2	3(65)
AL2 C 2	A5	4(C 2)
AL2 CA O 4	A2	6(83)
AL2 CA O 4	A3	6(83)
AL2 CA O 4	B2	12(89)
AL2 CA O 8 SI2	B2	12(89)
AL2 CA2 O 7 SI	B2	12(89)

$AL_2CA_3O_4$	A2	6(83)
$AL_2CA_3O_4$	A3	6(83)
$AL_2CA_3O_6$	B2	12(89)
AL_2CL_6	A2	1(59)
AL_2CL_6	A2	1(66)
AL_2CL_6	A2	1(67)
AL_2CL_6	A2	2(90)
AL_2CL_6	A2	2(103)
AL_2CL_6	A2	4(36)
AL_2CL_6	A3	4(36)
AL_2CL_6	A5	4(C 2)
AL_2CL_6	A5	4(C 2)
AL_2CL_6	C6	2(1-65)
AL_2CL_6	C6	4(A69)
AL_2CL_6	O3	2(66)
AL_2F_6	O3	2(65)
AL_2F_6	O3	9(157)
$AL_2FE\ O_4$	B2	12(96)
$AL_2H_2O_4$	A2	1(59)
$AL_2H_2O_4$	A2	1(64)
$AL_2H_2O_4$	A2	2(86)
$AL_2H_2O_4$	A2	2(102)
$AL_2H_2O_4$	A5	4(C 2)
$AL_2H_2O_4$	B2	1(7)
$AL_2H_2O_4$	B2	2(23)
$AL_2H_2O_4$	B5	1(9)
$AL_2H_2O_4$	B5	2(20)
$AL_2H_2O_4$	B9	2(2- 3)
$AL_2H_2O_4$	B9	4(B 3)
$AL_2H_2O_4$	E2	1(88)
$AL_2H_2O_4$	J2	1(90)
$AL_2H_2O_4$	J2	1(91)
$AL_2H_3O_4$	B3	1(26)
$AL_2H_6O_6$	A2	1(59)
$AL_2H_6O_6$	A2	1(64)
$AL_2H_6O_6$	A2	1(65)
$AL_2H_6O_6$	A2	2(86)
$AL_2H_6O_6$	A2	2(102)
$AL_2H_6O_6$	A5	4(C 2)
$AL_2H_6O_6$	B2	1(8)
$AL_2H_6O_6$	B2	2(23)
$AL_2H_6O_6$	B3	1(26)
$AL_2H_6O_6$	B5	1(9)
$AL_2H_6O_6$	B5	2(20)
$AL_2H_6O_6$	B9	2(2- 4)
$AL_2H_6O_6$	B9	4(B 4)
$AL_2H_6O_6$	E2	1(88)
$AL_2H_6O_6$	J2	1(90)
$AL_2LI_2O_4$	A2	6(83)
$AL_2LI_2O_4$	A3	6(83)
$AL_2MG\ O_4$	B2	1(16)
$AL_2MG\ O_4$	B2	2(28)
$AL_2MG\ O_4$	B5	1(17)
$AL_2MG\ O_4$	B5	2(20)
$AL_2MG\ O_4$	B9	4(B20)
$AL_2MG\ O_4$	B9	2(2-20)
$AL_2MG\ O_4$	E2	5(160)
$AL_2NA_2O_4$	A2	6(83)
$AL_2NA_2O_4$	A3	6(83)
AL_2O	A2	1(59)
AL_2O	A2	1(62)
AL_2O	A2	2(83)
AL_2O	A2	2(102)
AL_2O	A5	4(C 2)
AL_2O	C6	2(1-53)
AL_2O	C6	4(A57)
AL_2O	C6	11(144)
AL_2O	G1	11(119)
AL_2O	M1	13(25)
$AL_2O\ +$	A2	13(108)
$AL_2O\text{--}O_2TI$	E2	5(160)
AL_2O_2	A2	1(59)
AL_2O_2	A2	1(63)
AL_2O_2	A2	2(84)
AL_2O_2	A2	2(102)
AL_2O_2	A5	4(C 2)
AL_2O_2	C6	2(1-54)
AL_2O_2	C6	4(A58)
$AL_2O_2\ +$	A2	13(108)
AL_2O_3	A2	1(59)
AL_2O_3	A2	1(63)
AL_2O_3	A2	1(64)
AL_2O_3	A2	2(84)
AL_2O_3	A2	2(85)
AL_2O_3	A2	2(102)
AL_2O_3	A2	4(35)
AL_2O_3	A5	4(C 2)
AL_2O_3	A5	4(C 2)
AL_2O_3	A9	3(41)
AL_2O_3	B1	2(23)
AL_2O_3	B2	1(7)
AL_2O_3	B2	2(23)
AL_2O_3	B3	1(26)
AL_2O_3	B3	1(29)
AL_2O_3	B5	1(9)
AL_2O_3	B5	2(20)
AL_2O_3	B9	2(2- 2)
AL_2O_3	B9	4(B 2)
AL_2O_3	O1	8(61)
AL_2O_3	O1	11(99)
AL_2O_3	O1	12(81)
AL_2O_3	O2	4(33)
AL_2O_3	O9	3(41)
AL_2O_3	O9	8(67)
AL_2O_3	E2	1(88)
AL_2O_3	E2	5(160)
AL_2O_3	H1	13(12)
AL_2O_3	J1	13(12)
AL_2O_3	J2	1(91)
AL_2O_3	J2	1(92)
$AL_2O_3\text{-}AL\ F_3\text{-}F\ LI$	F2	5(156)
$AL_2O_3\text{-}AL\ F_3\text{-}F\ LI$	F2	5(206)
$AL_2O_3\text{-}AL_4C_3$	O3	3(40)
$AL_2O_3\text{-}BE\ O$	F2	5(155)
$AL_2O_3\text{-}BE\ O$	F2	5(206)
$AL_2O_3\text{-}BE\ O$	M1	12(118)
$AL_2O_3\text{-}BE\ O$	M1	13(25)
$AL_2O_3\text{-}BE\ O\text{--}MG\ O$	F2	5(156)
$AL_2O_3\text{-}BE\ O\text{--}MG\ O$	F2	5(207)
$AL_2O_3\text{-}BE\ O\text{--}O_2TI$	F2	5(156)
$AL_2O_3\text{-}BE\ O\text{--}O_2TI$	F2	5(207)
$AL_2O_3\text{-}BE\ O\text{--}O_2ZR$	F2	5(156)
$AL_2O_3\text{-}BE\ O\text{--}O_2ZR$	F2	5(207)
$AL_2O_3\text{-}CA\ O$	B9	13(60)
$AL_2O_3\text{-}CA_3O_3$	B9	13(56)
$AL_2O_3\text{-}MG\ O$	F2	5(156)
$AL_2O_3\text{-}MG\ O$	F2	5(208)
$AL_2O_3\text{-}MG\ O\text{--}O_2TI$	F2	5(156)
$AL_2O_3\text{-}MG\ O\text{--}O_2TI$	F2	5(209)
$AL_2O_3\text{-}O_2TI$	F2	5(156)
$AL_2O_3\text{-}O_2TI\text{--}O_2ZR$	F2	5(157)
$AL_2O_3\text{-}O_2TI$	F2	5(209)
$AL_2O_3\text{-}O_2TI\text{--}O_2ZR$	F2	5(210)
AL_2O_4ZR	E2	5(160)
AL_2O_5SI	A2	6(83)
AL_2O_5SI	A3	6(83)
AL_2O_5SI	B2	7(65)
AL_2O_5SI	B2	8(99)
AL_2O_5SI	B3	8(99)
AL_2O_5SI	B5	8(102)
AL_2O_5SI	B9	8(166)
AL_2O_5SI	B9	8(167)
AL_2O_5SI	B9	8(168)
AL_2O_5TI	B2	7(67)
AL_2O_5TI	B2	8(101)
AL_2O_5TI	B3	8(101)
AL_2O_5TI	B5	8(102)
AL_2O_5TI	B9	8(170)
AL_2O_5ZR	A2	6(83)
AL_2O_5ZR	A3	6(83)
AL_4C_3	A1	11(1)
AL_4C_3	A1	11(15)
AL_4C_3	A1	11(16)
AL_4C_3	A1	12(18)
AL_4C_3	A1	12(19)
AL_4C_3	A2	2(103)
AL_4C_3	A2	3(3)
AL_4C_3	A2	3(65)
AL_4C_3	A5	4(C 2)
AL_4C_3	A8	11(1)

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AL_4C_3	A9	11(15)
AL_4C_3	B1	7(13)
AL_4C_3	B1	8(39)
AL_4C_3	B1	11(21)
AL_4C_3	B1	11(43)
AL_4C_3	B2	3(12)
AL_4C_3	B2	8(41)
AL_4C_3	B3	3(12)
AL_4C_3	B5	3(16)
AL_4C_3	B7	3(21)
AL_4C_3	B9	3(22)
AL_4C_3	B9	3(2-37)
AL_4C_3	B9	4(B37)
AL_4C_3	B9	7(118)
AL_4C_3	B9	8(135)
AL_4C_3	B9	11(40)
AL_4C_3	B9	11(42)
AL_4C_3	B9	11(43)
AL_4C_3	D3	3(32)
AL_4C_3	D9	3(33)
AL_4C_3	D9	3(34)
AL_4C_3	J2	4(22)
AL_4C_3	L1	11(23)
AL_4C_3	L1	11(26)
AL_4C_3	L8	11(1)
AL_4C_3-AL N	D3	3(34)
AL_4C_3-AL_2O_3	D3	3(40)
AL_4CAO_7	B2	12(89)
AL_4CL_3	A2	2(90)
AL_4O_3	B9	11(44)
AL_4O_6-CA O	B9	13(62)
AL_5C_3N	D3	3(35)
AL_6BEO_{10}	A2	4(35)
$AL_{14}CA_{12}O_{23}$	B2	12(89)
$AL_{14}O_{ZI}CA_{12}O_{12}$	B9	13(58)
AR	C6	2(1-18)
AR	C6	4(A18)
AR +	C6	6(239)
ASH_3	A2	7(91)
B	A5	5(39)
B	B9	5(49)
B	B9	5(50)
B	B9	5(51)
B	C6	2(1- 5)
B	C6	4(A 5)
B	C6	5(53)
B +	A2	13(107)
B +	C6	6(213)
B −	A2	13(107)
B --AL	F2	5(187)
B BE_2	E2	5(150)
B BR	A5	5(40)
B BR	A5	5(40)
B BR	A5	5(40)
B BR	C6	2(1-42)
B BR	C6	4(A45)
B BR	C6	5(113)
B BR	G9	5(43)
B BR CL_2	A5	5(41)
B BR CL_2	C6	5(121)
B BR CL_2	G9	5(47)
B BR F_2	A5	5(41)
B BR F_2	C6	5(117)
B BR F_2	G9	5(47)
B BR_2	G9	5(47)
B BR_2 CL	A5	5(41)
B BR_2 CL	C6	5(123)
B BR_2 CL	G9	5(47)
B BR_2 F	A5	5(41)
B BR_2 F	C6	5(119)
B BR_2 F	G9	5(47)
B BR_3	C6	5(115)
B C +	A2	13(108)
B C SI +	A2	13(108)
B C_2 +	A2	13(108)
B CL	A5	5(40)
B CL	A5	5(40)
B CL	C6	2(1-41)
B CL	C6	4(A44)
B CL	C6	5(95)
B CL	G9	5(43)
B CL +	A2	13(107)
B CL F	A5	5(40)
B CL F	C6	5(107)
B CL F	G9	5(46)
B CL F_2	A5	5(40)
B CL F_2	C6	5(109)
B CL O	A5	5(40)
B CL O	C6	5(101)
B CL O	G9	5(46)
B CL O +	A2	13(107)
B CL_2	C6	5(97)
B CL_2	G9	5(46)
B CL_2 +	A2	13(107)
B CL_2 F	A5	5(40)
B CL_2 F	C6	5(111)
B CL_2 F	G9	5(47)
B CL_3	A5	5(40)
B CL_3	C6	5(99)
B CL_3	G9	5(46)
B CL_3 +	A2	13(107)
B F	A5	5(40)
B F	C6	2(1-40)
B F	C6	4(A43)
B F	C6	5(85)
B F	G9	5(43)
B F +	A2	13(107)
B F O	A5	5(40)
B F O	C6	5(91)
B F O	G9	5(46)
B F O +	A2	13(107)
B F_2	A5	5(40)
B F_2	C6	5(87)
B F_2	G9	5(46)
B F_2 +	A2	13(107)
B F_3	A5	5(40)
B F_3	C6	5(89)
B F_3	G9	5(46)
B F_3 +	A2	13(107)
B F_3 −	A2	13(107)
B H	A5	5(39)
B H	C6	2(1-39)
B H	C6	4(A42)
B H	C6	5(65)
B H	G9	5(43)
B H O_2 +	A2	13(107)
B H +	A2	13(107)
B H O_2	A5	5(39)
B H O_2	C6	5(77)
B H O_2	G9	5(45)
B H_2 +	A2	13(107)
B H_3	A2	7(91)
B H_3	A5	5(39)
B H_3	C6	5(67)
B H_3	G9	5(45)
B H_3 +	A2	13(107)
B H_3O_3	A2	7(90)
B H_3O_3	A5	5(39)
B H_3O_3	B9	5(79)
B H_3O_3	C6	5(81)
B H_3O_3	G9	5(46)
B H_4K	A2	7(92)
B H_4K	B2	11(92)
B H_4K	B3	11(92)
B H_4K	B9	11(177)
B H_4LI	A2	7(92)
B H_4LI	B2	11(89)
B H_4LI	B3	11(89)
B H_4LI	B9	11(164)
B H_4NA	A2	7(92)
B H_4NA	B2	9(21)
B H_4NA	B2	11(90)
B H_4NA	B3	11(90)
B H_4NA	B9	9(31)
B H_4NA	B9	11(169)
B I_3	A5	5(41)
B I_3	C6	5(125)
B I_3	G9	5(47)
B N	A2	7(90)
B N	A5	5(41)

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B N	A5	5(150)
B N	B2	3(13)
B N	B3	3(13)
B N	B5	3(16)
B N	B9	5(129)
B N	C6	2(1-44)
B N	C6	4(A47)
B N	C6	5(131)
B N	E2	5(150)
B N	G9	5(43)
B N +	A2	13(107)
B NA O_2	B3	10(40)
B NA O_2	B9	9(31)
B NA O_2	B9	10(73)
B O	A5	5(39)
B O	C6	2(1-38)
B O	C6	4(A41)
B O	C6	5(57)
B O	G9	5(43)
B O +	A2	13(107)
B O_2 NA	B2	9(22)
B S	A5	5(41)
B S	C6	2(1-43)
B S	C6	4(A46)
B S	C6	5(127)
B S	G9	5(43)
B SI +	A2	13(108)
B TI	A5	5(150)
B TI	E2	5(150)
B --TI	F2	5(194)
B TI_2	A5	5(150)
B ZR	A5	5(150)
B ZR	E2	5(150)
B --ZR	F2	5(195)
B_2	A5	5(39)
B_2	C6	2(1-37)
B_2	C6	4(A40)
B_2	C6	5(55)
B_2	G9	5(43)
B_2 +	A2	13(107)
B_2 BE H_8	G1	13(8)
B_2 C +	A2	13(108)
B_2 CL_4	A5	5(40)
B_2 CL_4	C6	5(101)
B_2 CL_4	G9	5(46)
B_2 H +	A2	13(107)
B_2 H_6	A2	7(91)
B_2 H_6	A5	5(39)
B_2 H_6	C6	5(69)
B_2 H_6	G9	5(45)
B_2 H_6 +	A2	13(107)
B_2 MG	B2	9(16)
B_2 MG	B3	10(40)
B_2 MG	B9	9(31)
B_2 MG	B9	10(64)
B_2 O_2	A5	5(39)
B_2 O_2	C6	5(59)
B_2 O_2	G9	5(45)
B_2 O_2 +	A2	13(107)
B_2 O_3	A2	7(90)
B_2 O_3	A5	5(39)
B_2 O_3	B9	5(62)
B_2 O_3	C6	5(61)
B_2 O_3	C6	5(63)
B_2 O_3	G9	5(45)
B_2 O_3 +	A2	13(107)
B_2 O_3-CA O	A2	6(79)
B_2 O_3-K_2 O	A2	6(78)
B_2 O_3-LI_2 O	A2	6(77)
B_2 O_3-LI_2 O	F2	5(157)
B_2 O_3-LI_2 O	F2	5(213)
B_2 O_3-MG O	F2	5(157)
B_2 O_3-MG O	F2	5(214)
B_2 O_3 NA_2 O	A2	6(77)
B_2 O_3-O PB	A2	6(80)
B_2 TI	A5	5(150)
B_2 TI	E2	5(150)
B_2 ZR	A5	5(150)
B_2 ZR	E2	5(150)
B_3 CL_3 O_3	A5	5(40)
B_3 CL_3 O_3	C6	5(105)
B_3 CL_3 O_3	G9	5(46)
B_3 F_3 O_3	A5	5(40)
B_3 F_3 O_3	C6	5(93)
B_3 F_3 O_3	G9	5(46)
B_3 F_3 O_3 +	A2	13(107)
B_3 H_2 N_3	C6	5(133)
B_3 H_3 O_6	A5	5(40)
B_3 H_3 O_6	C6	5(83)
B_3 H_3 O_6	G9	5(46)
B_3 H_6 N_3	A5	5(41)
B_3 H_6 N_3	G9	5(47)
B_4 C	A5	5(41)
B_4 C	A5	5(150)
B_4 C	B1	3(11)
B_4 C	B2	3(11)
B_4 C	B5	3(16)
B_4 C	B9	5(135)
B_4 C	E2	5(150)
B_4 H_{10}	A2	7(91)
B_4 MG	B2	9(16)
B_4 MG	B3	10(40)
B_4 MG	B9	9(31)
B_4 MG	B9	10(65)
B_4 NA_2 O_7	B2	9(22)
B_4 NA_2 O_7	B3	10(40)
B_4 NA_2 O_7	B9	9(31)
B_4 NA_2 O_7	B9	10(73)
B_5 H_8 K O_{12}	B9	6(266)
B_5 H_9	A2	7(91)
B_5 H_9	A5	5(39)
B_5 H_9	B9	5(71)
B_5 H_9	C6	5(72)
B_5 H_9	G9	5(45)
B_5 H_{10}NA O_{13}	B9	6(264)
B_5 H_{11}	A2	7(91)
B_5 H_{12}N O_{12}	B9	6(268)
B_5 TI_2	A5	5(150)
B_5 TI_2	E2	5(150)
B_6 BE	E2	5(150)
B_6 H_{10}	A2	7(91)
$B_{10}$$H_{14}$	A2	7(91)
$B_{10}$$H_{14}$	A5	5(39)
$B_{10}$$H_{14}$	B9	5(74)
$B_{10}$$H_{14}$	C6	5(75)
$B_{10}$$H_{14}$	G9	5(45)
B_{12}ZR	A5	5(150)
B_{12}ZR	E2	5(150)
$B_{13}$$C_2$	E2	5(150)
BA	B2	12(87)
BA CL_2	B2	12(87)
BA F +	A2	13(110)
BA F_2	B2	12(87)
BA H	C6	12(158)
BA O	B2	12(87)
BA O	B9	13(52)
BE	A2	1(58)
BE	A2	2(101)
BE	A5	4(C 1)
BE	B1	1(11)
BE	B1	2(24)
BE	B2	2(24)
BE	B3	1(26)
BE	B3	1(29)
BE	B5	1(12)
BE	B5	2(20)
BE	B9	2(2- 7)
BE	B9	4(B 7)
BE	C6	2(1- 4)

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BE	C6	4(A 4)
BE	O2	1(48)
BE	D2	1(54)
BE +	A2	13(109)
BE +	C6	6(211)
BE -	A2	13(109)
BE--AL	F2	5(188)
BE C_2	A2	2(93)
BE C_2	A2	2(103)
BE C_2	A5	4(C 2)
BE C_2	A7	3(4)
BE CL	A2	1(60)
BE CL	A2	1(68)
BE CL	A2	2(92)
BE CL	A2	2(103)
BE CL	A5	4(C 2)
BE CL	C6	1(113)
BE CL	C6	2(1-24)
BE CL	C6	4(A24)
BE CL	G2	1(42)
BE CL	G9	2(50)
BE CL +	A2	13(109)
BE CL F	C6	2(1-49)
BE CL F	C6	4(A53)
BE CL F	G2	1(43)
BE CL F	G9	2(51)
BE CL_2	A1	4(28)
BE CL_2	A2	1(60)
BE CL_2	A2	1(68)
BE CL_2	A2	2(92)
BE CL_2	A2	2(93)
BE CL_2	A2	2(103)
BE CL_2	A2	4(35)
BE CL_2	A2	4(37)
BE CL_2	A2	4(37)
BE CL_2	A2	7(90)
BE CL_2	A3	4(37)
BE CL_2	A3	4(37)
BE CL_2	A5	4(C 2)
BE CL_2	B5	1(12)
BE CL_2	C6	2(1-48)
BE CL_2	C6	4(A52)
BE CL_2	O2	2(71)
BE CL_2	G2	1(43)
BE CL_2	G9	2(51)
BE CL_2 +	A2	13(109)
BE F_2	A2	12(22)
BE F	A2	1(60)
BE F	A2	1(68)
BE F	A2	2(92)
BE F	A2	2(103)
BE F	A5	4(C 2)
BE F	C6	1(111)
BE F	C6	2(1-23)
BE F	C6	4(A23)
BE F	O3	8(114)
BE F	G2	1(42)
BE F	G2	4(45)
BE F	G3	8(109)
BE F	G9	2(50)
BE F	G9	4(47)
BE F +	A2	13(109)
BE--F --O	O1	8(55)
BE--F --O	M1	8(55)
BE--F --O	M1	10(55)
BE--F --O	M8	8(56)
BE F_2	A2	1(60)
BE F_2	A2	1(68)
BE F_2	A2	2(92)
BE F_2	A2	2(103)
BE F_2	A2	3(65)
BE F_2	A2	4(35)
BE F_2	A2	10(43)
BE F_2	A3	10(43)
BE F_2	A3	12(120)
BE F_2	A5	4(C 2)
BE F_2	B3	11(113)
BE F_2	B5	1(12)
BE F_2	B7	7(96)
BE F_2	B9	7(117)
BE F_2	B9	11(158)
BE F_2	C6	2(1-47)
BE F_2	C6	4(A51)
BE F_2	C6	12(138)
BE F_2	O2	2(71)
BE F_2	D2	4(35)
BE F_2	O3	8(119)
BE F_2	O3	11(113)
BE F_2	G2	1(43)
BE F_2	G7	12(85)
BE F_2	G9	2(51)
BE F_2	J8	11(84)
BE F_2	J8	12(73)
BE F_2	M1	8(55)
BE F_2	M1	10(55)
BE F_2	M9	10(57)
BE F_2 +	A2	13(109)
BE F_2-BE O	A1	11(109)
BE F_2-BE O	A1	11(110)
BE F_2-BE O	M1	10(56)
BE F_2-BE O	M1	11(103)
BE F_2-BE O	M9	11(109)
BE F_2-BE O	M9	11(110)
BE F_2-F LI	F2	5(163)
BE F_2-F LI	F2	5(218)
BE F_2-F_2 MG	F2	5(166)
BE F_2-F_2 MG	F2	5(224)
BE F_2-F_2 MG	F2	5(225)
BE F_4 LI_2	B1	11(75)
BE F_4 LI_2	B9	11(78)
BE F_4 LI_2	B9	11(163)
BE H	A2	1(60)
BE H	A2	2(91)
BE H	A2	2(103)
BE H	A5	4(C 2)
BE H	A7	2(41)
BE H +	A2	13(109)
BE H O +	A2	13(109)
BE H_2	A2	7(92)
BE H_2	B5	1(12)
BE H_2	J2	1(100)
BE H_2	J8	3(55)
BE H_2 +	A2	13(109)
BE H_2O_2	A2	1(60)
BE H_2O_2	A2	1(67)
BE H_2O_2	A2	2(91)
BE H_2O_2	A2	2(92)
BE H_2O_2	A2	2(103)
BE H_2O_2	A5	4(C 2)
BE H_2O_2	B5	1(12)
BE H_2O_2	J2	1(94)
BE O	A2	1(60)
BE O	A2	1(67)
BE O	A2	2(91)
BE O	A2	2(103)
BE O	A2	4(35)
BE O	A3	12(120)
BE O	A5	4(C 2)
BE O	B1	2(24)
BE O	B2	2(24)
BE O	B3	1(26)
BE O	B5	1(12)
BE O	B5	2(20)
BE O	B9	2(2- 8)
BE O	B9	4(B 8)
BE O	C6	1(115)
BE O	C6	2(1-22)
BE O	C6	4(A22)
BE O	D2	1(53)
BE O	D2	1(54)
BE O	O2	4(31)
BE O	E2	5(160)
BE O	G2	1(42)
BE O	G9	2(50)
BE O	J2	1(94)
BE O	M1	8(55)
BE O +	A2	13(109)
BE--O	O2	2(63)
BE--O	O3	2(63)
BE O --AL_2O_3	F2	5(155)

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BE O --AL$_2$ O $_3$	F2	5(206)
BE O --AL$_2$ O $_3$	M1	12(118)
BE O --AL$_2$ O $_3$	M1	13(25)
BE O --AL$_2$ O $_3$-MG O	F2	5(156)
BE O --AL$_2$ O $_3$-MG O	F2	5(207)
BE O --AL$_2$ O $_3$-O $_2$ ZR	F2	5(156)
BE O --AL$_2$ O $_3$-O $_2$ TI	F2	5(156)
BE O --AL$_2$ O $_3$-O $_2$ ZR	F2	5(207)
BE O --AL$_2$ O $_3$-O $_2$ TI	F2	5(207)
BE O --BE F $_2$	A1	11(109)
BE O --BE F $_2$	A1	11(110)
BE O --BE F $_2$	M1	10(56)
BE O --BE F $_2$	M1	11(103)
BE O --BE F $_2$	M9	11(109)
BE O --BE F $_2$	M9	11(110)
BE O --MG O --O $_2$ ZR	F2	5(157)
BE O --MG O --O $_2$ ZR	F2	5(211)
BE O --O $_2$ TI	F2	5(157)
BE O --O $_2$ TI	F2	5(211)
BE O --O $_2$ TI--O $_2$ ZR	F2	5(157)
BE O --O $_2$ TI--O $_2$ ZR	F2	5(212)
BE--SI	F2	5(196)
BE--ZR	F2	5(197)
BE$_2$	A2	1(60)
BE$_2$	A2	1(67)
BE$_2$	A2	2(91)
BE$_2$	A2	2(103)
BE$_2$	A5	4(C 2)
BE$_2$	A7	2(41)
BE$_2$ C	A2	2(93)
BE$_2$ C	A2	2(103)
BE$_2$ C	A5	4(C 2)
BE$_2$ C	B2	3(11)
BE$_2$ C	B5	3(16)
BE$_2$ C	B7	3(21)
BE$_2$ C	B9	3(22)
BE$_2$ C	B9	3(2-34)
BE$_2$ C	B9	4(B34)
BE$_2$ C	D3	3(41)
BE$_2$ C	J2	4(20)
BE$_2$ CL$_4$	A2	1(60)
BE$_2$ CL$_4$	A2	1(69)
BE$_2$ CL$_4$	A2	2(93)
BE$_2$ CL$_4$	A2	2(103)
BE$_2$ CL$_4$	A2	4(37)
BE$_2$ CL$_4$	A3	4(37)
BE$_2$ CL$_4$	A5	4(C 2)
BE$_2$ CL$_4$ +	A2	13(109)
BE$_2$ F $_2$ O	A3	12(120)
BE$_2$ F $_2$ O	A9	12(121)
BE$_2$ F $_2$ O	C6	11(146)
BE$_2$ F $_2$ O	G7	11(119)
BE$_2$ O +	A2	13(109)
BE$_2$ O $_2$	D2	1(54)
BE$_2$ O $_2$ +	A2	13(109)
BE$_2$ O $_4$ SI	A2	6(83)
BE$_2$ O $_4$ SI	A3	6(83)
BE$_2$ O $_4$ SI	B2	7(64)
BE$_2$ O $_4$ SI	B2	8(101)
BE$_2$ O $_4$ SI	B3	8(101)
BE$_2$ O $_4$ SI	B5	8(102)
BE$_2$ O $_4$ SI	B9	8(169)
BE$_3$ N $_2$	A2	2(93)
BE$_3$ N $_2$	A2	2(103)
BE$_3$ N $_2$	A2	3(4)
BE$_3$ N $_2$	A3	3(4)
BE$_3$ N $_2$	A5	4(C 2)
BE$_3$ N $_2$	B1	8(44)
BE$_3$ N $_2$	B2	3(13)
BE$_3$ N $_2$	B2	8(50)
BE$_3$ N $_2$	B5	3(16)
BE$_3$ N $_2$	B7	3(21)
BE$_3$ N $_2$	B9	3(22)
BE$_3$ N $_2$	B9	3(2-29)
BE$_3$ N $_2$	B9	4(B29)
BE$_3$ N $_2$	B9	8(48)
BE$_3$ N $_2$	B9	8(134)
BE$_3$ N $_2$	D3	3(43)
BE$_3$ N $_2$	J2	4(25)
BE$_3$ O $_2$ +	A2	13(109)
BE$_3$ O $_3$	D2	1(54)
BE$_3$ O $_3$ +	A2	13(109)
BE$_4$ O $_4$	D2	1(54)
BE$_4$ O $_4$ +	A2	13(109)
BE$_5$ O $_5$	D2	1(54)
BE$_5$ O $_5$ +	A2	13(109)
BE$_6$ O $_6$	D2	1(54)
BE$_6$ O $_6$ +	A2	13(109)
BR	C5	12(168)
BR +	C5	12(168)
BR +	C6	6(247)
BR -	B5	12(168)
BR -	C5	12(168)
BR CL	A2	7(94)
BR CL	B5	12(169)
BR CL	C5	12(169)
BR CS	G9	10(19)
BR F $_3$	B5	12(169)
BR F $_5$	B5	12(169)
BR F $_5$	C5	12(169)
BR H	B5	12(169)
BR H	C5	12(169)
BR H O	B5	12(169)
BR H O $_3$	B5	12(169)
BR H $_4$ N	B5	12(179)
BR H $_4$ P	B5	12(182)
BR H $_5$ N $_2$	B5	12(179)
BR I	B5	12(171)
BR I	C5	12(171)
BR K	B2	7(71)
BR K	B2	11(91)
BR K	B3	11(91)
BR K	G9	10(19)
BR K O $_3$	B2	9(26)
BR K O $_3$	B3	10(40)
BR K O $_3$	B9	9(32)
BR K O $_3$	B9	10(75)
BR LI	B7	6(54)
BR LI	G9	10(19)
BR N O	C5	12(179)
BR NA	G9	10(19)
BR O -	B5	12(169)
BR O $_2$	C5	12(169)
BR O $_3$ -	B5	12(169)
BR RB	G9	10(19)
BR$_2$	B5	12(168)
BR 2	B9	11(175)
BR$_2$	C5	12(168)
BR$_2$ +	C5	12(168)
BR$_2$ MG	B7	6(54)
BR$_2$ PB	B2	6(53)
BR$_2$ PB	B3	6(53)
BR$_3$ -	B5	12(168)
BR$_3$ O P	B5	12(182)
BR$_3$ O P	C5	12(182)
BR$_3$ P	B5	12(182)
BR$_3$ P S	B5	12(182)
BR$_3$ P S	C5	12(182)
BR$_4$ TE	B5	12(175)
BR$_5$ -	B5	12(168)
C	A2	2(101)
C	A5	4(C 1)
C GRAPHITE	B1	13(21)
C	B5	12(183)
C	B9	3(2-39)
C	B9	4(B39)
C	C5	12(183)
C	C6	2(1- 6)
C	C6	4(A 6)
C +	A2	13(103)
C +	C6	6(215)
C -	A2	13(102)
C CL +	A2	13(104)
C CL N +	A2	13(105)
C CL$_2$ +	A2	13(104)
C CL$_3$ +	A2	13(105)
C CL$_4$ +	A2	13(105)
C CL H $_2$ +	A2	13(104)
C CL H $_3$ +	A2	13(104)
C CL$_2$ F $_2$ +	A2	13(104)

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CCL_2H^+		A2	13(104)
CCL_2O^+		A2	13(105)
CF^+		A2	13(104)
CFH_2^+		A2	13(104)
CF_2^+		A2	13(104)
CF_2H^+		A2	13(104)
CF_3^+		A2	13(104)
CF_4^+		A2	13(104)
C--FE		B2	12(95)
CFE_3		B2	12(95)
CH^+		A2	13(103)
CH^-		A2	13(103)
CHN^+		A2	13(105)
CHO^+		A2	13(104)
CHO_3^-		B5	12(183)
CH_2^+		A2	13(103)
CH_2N_2		A2	7(91)
CH_2O^+		A2	13(104)
$CH_2O_2^+$		A2	13(104)
CH_2O_3		B5	12(183)
CH_3^+		A2	13(103)
CH_3^+		A2	13(104)
CH_3^-		A2	13(103)
CH_3NO^+		A2	13(105)
$CH_3NO_2^+$		A2	13(105)
$CH_3N_3^+$	METHYL AZIDE	A2	13(105)
CH_4^+		A2	13(103)
CH_4O^+		A2	13(104)
CH_4S^+		A2	13(105)
CH_5N		A2	7(91)
CH_5N^+		A2	13(105)
CH_6N_2		A2	7(91)
CN^+		A2	13(105)
CN^-		A2	13(105)
CO		C5	12(183)
CO^+		A2	13(104)
CO^+S^+		A2	13(105)
CO_2		A2	7(90)
CO_2		B5	12(183)
CO_2		C5	12(183)
CO_2^+		A2	13(104)
CO_2^-		A2	13(104)
CO_3--		B5	12(183)
CS^+		A2	13(105)
CS_2^+		A2	13(101)
CS_2^+		A2	13(105)
CSI		B2	3(12)
CSI		B2	12(99)
CSI		B3	3(12)
CSI		B5	3(16)
CSI^+		A2	13(106)
CSI^-		A2	13(106)
CTI		A2	3(6)
CTI		A2	3(6)
CTI		A5	4(C 2)
CTI		B2	3(21)
CTI		B5	3(16)
CTI		B7	3(21)
CTI		B9	3(22)
CTI		B9	3(2-38)
CTI		B9	4(B38)
CTI		D3	3(47)
CTI		D9	3(49)
C_2^+		A2	13(103)
C_2^-		A2	13(102)
C_2CA		B2	12(88)
C_2CA		B9	13(54)
C_2CR_3		B2	12(92)
C_2CR_5		B2	12(92)
$C_2F_4^+$		A2	13(104)
C_2H^+		A2	13(103)
$C_2H_2^+$		A2	13(103)
$C_2H_3^+$		A2	13(103)
$C_2H_4^+$		A2	13(103)
$C_2H_5^+$		A2	13(103)
$C_2H_6^+$		A2	13(103)
C_2H_5N		A2	7(91)
$C_2H_8N_2$		A2	7(91)
$C_2H_8N_2$		A2	7(91)
C_2LI_2		A2	2(100)
C_2LI_2		A2	2(105)
C_2LI_2		A3	3(5)
C_2LI_2		A5	4(C 2)
C_2LI_2		B2	3(11)
C_2LI_2		B5	3(16)
C_2LI_2		B7	3(21)
C_2LI_2		B9	3(22)
C_2LI_2		B9	4(B33)
C_2LI_2		D3	3(45)
C_2LI_2		J2	4(18)
C_2MG		A2	2(96)
C_2MG		A2	2(104)
C_2MG		A5	4(C 2)
C_2MG		B2	3(12)
C_2MG		B3	3(12)
C_2MG		B5	3(16)
C_2MG		B7	3(21)
C_2MG		B9	3(22)
C_2MG		B9	3(2-35)
C_2MG		B9	4(B35)
C_2MG		D3	3(43)
C_2MG		J2	4(21)
C_2N^+		A2	13(105)
C_2NA_2		B2	3(12)
C_2NA_2		B3	3(12)
C_2NA_2		B5	3(16)
C_2O_3-FE O		B9	13(74)
C_2SI^+		A2	13(106)
CSI_2^+		A2	13(106)
C_2TI_2		B9	3(2-33)
C_3^+		A2	13(103)
C_3^-		A2	13(102)
C_3CR_7		B2	12(92)
C_3HN^+		A2	13(105)
C_3MG_2		A2	2(96)
C_3MG_2		A2	2(104)
C_3MG_2		A5	4(C 2)
C_3MG_2		B2	3(12)
C_3MG_2		B5	3(16)
C_3MG_2		B7	3(21)
C_3MG_2		B9	3(22)
C_3MG_2		B9	3(2-36)
C_3MG_2		B9	4(B36)
C_3MG_2		D3	3(43)
C_3MG_2		J2	4(21)
C_3N^+		A2	13(105)
C_4^+		A2	13(103)
C_4^-		A2	13(102)
$C_4H_{12}N_4$		A2	7(91)
C_5^+		A2	13(103)
C_4N^+		A2	13(105)
C_5N^+	METHYL AMINE	A2	13(105)
C_6CR_{23}		B2	12(93)
$C_6F_6^+$		A2	13(104)
$C_6H_6^+$		A2	13(103)
$C_6H_6^-$		A2	13(103)
C_6N^+		A2	13(105)
$C_{10}H_8^-$		A2	13(104)
$C_{12}H_{10}^+$		A2	13(103)
$C_{12}H_{10}^-$		A2	13(103)
CA		B2	12(87)
$CACL_2$		B2	12(88)
CAF_2		B2	12(88)
$CAFE_2O_4$		B2	12(89)
CAH		C6	12(154)
CAO		B2	12(88)
CAO--AL_2O_3		B9	13(60)
CAO--AL_4O_6		B9	13(62)
CAO--B_2O_3		A2	6(79)
CAO--FE_2O_3		B9	13(69)
CAO_3SI		A2	6(83)
CAO_3SI		A3	6(83)
CAO_3SI		B2	12(90)
CAO_3TI		A2	6(83)
CAO_3TI		A3	6(83)
$CA_2FE_2O_5$		B2	12(90)
CA_2O_2-O_2SI	GAMMA	B9	13(65)
CA_2O_2-O_2SI	BETA	B9	13(67)
CA_2O_2-FE_2O_3		B9	13(71)
CA_3O_3-O_4SI_2		B9	13(64)

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CA_3O_3-AL_2O_3	B9	13(56)
CA_2O_4SI	A2	6(83)
CA_2O_4SI	A3	6(83)
CA_2O_4SI	B2	12(90)
CA_3O_5SI	A2	6(83)
CA_3O_5SI	A3	6(83)
CA_3O_5SI	B2	12(91)
$CA_3O_7SI_2$	B2	12(91)
CEH_2	A2	7(93)
CL	A2	1(58)
CL	A2	2(101)
CL	A2	7(90)
CL	A5	4(C 1)
CL	C5	12(167)
CL	C6	2(1-17)
CL	C6	4(A17)
CL +	A2	13(100)
CL +	C5	12(167)
CL +	C6	6(237)
CL −	A2	13(100)
CL −	B5	12(167)
CL −	C5	12(167)
CL −	C6	12(130)
CL CS	G9	10(19)
CL F	C5	12(168)
CL F	C6	1(133)
CL F	C6	2(1-36)
CL F	C6	4(A39)
CL F	G2	1(42)
CL F	G9	2(50)
CL F LI_2	A2	1(61)
CL F LI_2	A2	1(73)
CL F LI_2	A2	2(99)
CL F LI_2	A2	2(105)
CL F LI_2	A5	4(C 2)
CL F MG	C6	2(1-52)
CL F MG	C6	4(A56)
CL F MG	G2	1(43)
CL F MG	G9	2(51)
CL F O_3	C5	12(168)
CL F O_3 +	A2	13(100)
CL F_3	B5	12(168)
CL F_3 +	A2	13(100)
CL F_4H	C5	12(168)
CL F_5S	C5	12(174)
CL H	A2	7(90)
CL H	C5	12(167)
CL H	C6	2(1-34)
CL H	C6	4(A37)
CL H +	A2	13(100)
CL H MG O	B2	1(16)
CL H MG O	B5	1(17)
CL H MG O	B5	2(20)
CL H O	B5	12(168)
CL H O_2	B5	12(168)
CL H O_3	B5	12(168)
CL H O_4	A2	7(94)
CL H O_4	B5	12(168)
CL H_2LI O	B2	1(21)
CL H_2LI O	B5	1(22)
CL H_2LI O	B5	2(20)
CL H_4N	B5	12(178)
CL H_4N O	B5	12(178)
CL H_4N O_4	A1	3(53)
CL H_4N O_4	A1	4(28)
CL H_4N O_4	A2	7(94)
CL H_4N O_4	B5	12(179)
CL H_5N_2	B5	12(178)
CL $H_5N_2O_4$	A2	7(94)
CL $H_5N_2O_4$	B5	12(179)
CL HG	B2	9(30)
CL HG	B9	9(32)
CL I	A2	7(94)
CL I	B5	12(171)
CL I	C5	12(171)
CL K	A2	7(90)
CL K	B2	7(70)
CL K	B2	11(91)
CL K	B3	11(91)
CL K	B9	11(173)
CL K	G9	10(19)
CL K	B2	9(26)
CL K O_3	B3	10(40)
CL K O_3	B9	9(32)
CL K O_3	C5	12(184)
CL K O_3	A1	3(53)
CL K O_4	A1	4(28)
CL K O_4	A2	7(95)
CL K O_4	A9	7(10)
CL K O_4	B1	7(3)
CL K O_4	B2	9(26)
CL K O_4	B3	10(40)
CL K O_4	B9	9(32)
CL K O_4	B9	10(74)
CL K O_4	C5	12(184)
CL LI	A2	1(61)
CL LI	A2	1(72)
CL LI	A2	2(99)
CL LI	A2	2(105)
CL LI	A5	4(C 2)
CL LI	B1	1(20)
CL LI	B1	2(30)
CL LI	B1	3(63)
CL LI	B1	5(176)
CL LI	B2	1(20)
CL LI	B2	2(30)
CL LI	B2	3(63)
CL LI	B2	5(176)
CL LI	B3	1(27)
CL LI	B5	1(22)
CL LI	B5	2(20)
CL LI	B9	2(2-26)
CL LI	B9	4(B26)
CL LI	B9	5(229)
CL LI	C6	1(109)
CL LI	C6	2(1-21)
CL LI	C6	4(A21)
CL LI	D2	2(79)
CL LI	G1	10(13)
CL LI	G1	10(18)
CL LI	G2	1(42)
CL LI	G9	2(50)
CL LI	G9	10(18)
CL LI	G9	10(19)
CL LI--F LI	F2	5(163)
CL LI--F LI	F2	5(217)
CL LI O_4	A1	3(53)
CL LI O_4	A1	4(28)
CL LI O_4	A2	7(95)
CL MG	A2	1(60)
CL MG	A2	1(70)
CL MG	A2	2(95)
CL MG	A2	2(104)
CL MG	A5	4(C 2)
CL MG	C6	1(119)
CL MG	C6	2(1-27)
CL MG	C6	4(A27)
CL MG	G2	1(42)
CL MG	G9	2(50)
CL MG +	A2	13(110)
CL N O	A2	7(94)
CL N O	C5	12(178)
CL N O_2	A2	7(94)
CL N O_2	C5	12(178)
CL N O_5	A2	7(94)
CL N O_5	B5	12(178)
CL N O_6	A2	7(94)
CL N O_6	B5	12(178)
CL NA	A2	7(90)
CL NA	B2	9(21)
CL NA	B2	11(90)
CL NA	B3	11(90)
CL NA	B9	9(31)
CL NA	B9	11(167)
CL NA	G9	10(19)
CL NA O_4	A1	4(28)
CL NA O_4	A2	7(95)
CL O	A2	7(94)
CL O	C5	12(167)
CL O	C6	1(135)

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CL O	C6	2(1-35)
CL O	C6	4(A38)
CL O	G2	1(42)
CL O	G9	2(50)
CL O +	A2	13(100)
CL O -	A2	13(100)
CL O -	B5	12(167)
CL O_2	A2	7(94)
CL O_2	B5	12(167)
CL O_2 +	A2	13(100)
CL O_2 -	A2	13(100)
CL O_2 -	B5	12(167)
CL O_3	C5	12(167)
CL O_3 +	A2	13(100)
CL O_3 -	A2	13(100)
CL O_3 -	B5	12(167)
CL O_4 -	A2	13(100)
CL O_4 -	B5	12(167)
CL O_6 N	A1	7(3)
CL O_6 N	A8	7(3)
CL O_6 N	A9	7(9)
CL O_6 N	B1	7(3)
CL RB	G9	10(19)
CL SI +	A2	13(106)
CL_2	A2	1(58)
CL_2	A2	2(101)
CL_2	A5	4(C 1)
CL_2	A7	2(41)
CL_2	B5	12(167)
CL_2	C5	12(167)
CL_2	C6	1(131)
CL_2	C6	2(1-33)
CL_2	C6	4(A36)
CL_2	G2	1(42)
CL_2	G9	2(50)
CL_2 +	A2	13(100)
CL_2 +	C5	12(167)
CL_2 CR	B2	12(92)
CL_2 F_6	C5	12(168)
CL_2 H_2 MG O	A2	2(95)
CL_2 H_2 MG O	A2	2(104)
CL_2 H_2 MG O	A5	4(C 2)
CL_2 H_2 MG O	B2	1(15)
CL_2 H_2 MG O	B2	2(27)
CL_2 H_2 MG O	B5	1(17)
CL_2 H_2 MG O	B5	2(20)
CL_2 H_2 MG O	B9	2(2-16)
CL_2 H_2 MG O	B9	4(B16)
CL_2 H_4 MG O_2	A2	2(96)
CL_2 H_4 MG O_2	A2	2(104)
CL_2 H_4 MG O_2	A5	4(C 2)
CL_2 H_4 MG O_2	B2	1(15)
CL_2 H_4 MG O_2	B2	2(27)
CL_2 H_4 MG O_2	B5	1(17)
CL_2 H_4 MG O_2	B5	2(20)
CL_2 H_4 MG O_2	B9	4(B17)
CL_2 H_4 MG O_4	B9	2(2-17)
CL_2 H_6 N_2	B5	12(178)
CL_2 H_8 MG O_4	A2	2(96)
CL_2 H_8 MG O_4	A2	2(104)
CL_2 H_8 MG O_4	A5	4(C 2)
CL_2 H_8 MG O_4	B2	1(15)
CL_2 H_8 MG O_4	B2	2(27)
CL_2 H_8 MG O_4	B5	1(17)
CL_2 H_8 MG O_4	B5	2(20)
CL_2 H_8 MG O_4	B9	2(2-18)
CL_2 H_8 MG O_4	B9	4(B18)
C_2 H_{12}MG O_6	A2	2(96)
C_2 H_{12}MG O_6	A2	2(104)
C_2 H_{12}MG O_6	A5	4(C 2)
C_2 H_{12}MG O_6	B2	1(16)
CL_2 H_{12}MG O_6	B2	2(28)
CL_2 H_{12}MG O_6	B5	1(17)
CL_2 H_{12}MG O_6	B5	2(20)
CL_2 H_{12}MG O_6	B9	2(2-19)
CL_2 H_{12}MG O_6	B9	4(B19)
CL_2 LI_2	A2	1(61)
CL_2 LI_2	A2	1(72)
CL_2 LI_2	A2	2(99)
CL_2 LI_2	A2	2(105)
CL_2 LI_2	A5	4(C 2)
CL_2 LI_2	C6	2(1-46)
CL_2 LI_2	C6	4(A50)
CL_2 LI_2	G2	1(43)
CL_2 LI_2	G9	2(51)
CL_2 MG	A2	2(95)
CL_2 MG	A2	2(104)
CL_2 MG	A5	4(C 2)
CL_2 MG	B2	1(15)
CL_2 MG	B2	2(26)
CL_2 MG	B3	1(26)
CL_2 MG	B5	1(17)
CL_2 MG	B5	2(20)
CL_2 MG	B9	2(2-15)
CL_2 MG	B9	4(B15)
CL_2 MG	C6	2(1-51)
CL_2 MG	C6	4(A55)
CL_2 MG	D3	2(73)
CL_2 MG	G2	1(43)
CL_2 MG	G9	2(51)
CL_2 MG +	A2	13(110)
CL_2 O	A2	7(94)
CL_2 O	C5	12(167)
CL_2 O S	B5	12(173)
CL_2 O S	C5	12(173)
CL_2 O_2 S	B5	12(174)
CL_2 O_2 S	C5	12(174)
CL_2 O_5 S_2	B5	12(174)
CL_2 O_5 S_2	C5	12(174)
CL_2 O_7	A2	7(94)
CL_2 O_7	C5	12(167)
CL_2 PB	B2	6(53)
CL_2 PB	B3	6(53)
CL_2 PB	C5	12(184)
CL_2 S_2	B5	12(173)
CL_2 S_2	C5	12(173)
CL_2 SE_2	B5	12(174)
CL_2 SE_2	C5	12(174)
CL_2 SI +	A2	13(106)
CL_2 SI -	A2	13(106)
CL_3 CR	B2	12(92)
CL_3 FE	B2	12(96)
CL_3 I	A2	7(94)
CL_3 I	B5	12(171)
CL_3 LI_3	A2	1(61)
CL_3 LI_3	A2	2(99)
CL_3 LI_3	A2	2(105)
CL_3 LI_3	A5	4(C 2)
CL_3 N	A2	7(94)
CL_3 N	B5	12(178)
CL_3 O P	B5	12(182)
CL_3 O P	C5	12(182)
CL_3 P	B5	12(182)
CL_3 P	C5	12(182)
CL_3 P +	A2	13(102)
CL_3 P S	C5	12(182)
CL_3 P +	C5	12(182)
CL_3 SI +	A2	13(106)
CL_4 TE	B5	12(175)
CL_4 ZR	B2	5(179)
CL_4 ZR	B9	5(252)
CL_4 SI +	A2	13(106)
CL_5 P	B5	12(182)
CL_5 P	C5	12(182)
CO -	A2	13(111)
CO O --FE_2 O_3	B9	13(73)
CR	B2	12(91)
CR -	A2	13(111)
CR K_2 O_4	B2	12(98)
CR K_2 O_4	B9	13(78)
CR_2 FE O_4	B2	12(96)
CR_2 K_2 O_7	B2	12(98)
CR_2 O_3	B2	12(92)
CS I	G9	10(19)
CU -	A2	13(111)
D	C5	12(165)
D F_2 N	C1	8(125)
D F_2 N	C6	8(130)
D F_2 N	G1	8(125)
D H O	B5	12(165)

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D H O	C5	12(165)
D O	C5	12(165)
D_2	C5	12(165)
D_2O	B5	12(165)
D_2O	C5	12(165)
E -	C6	7(109)
F	A2	1(58)
F	A2	2(101)
F	A5	4(C 1)
F	C5	12(166)
F	C6	2(1- 9)
F	C6	4(A 9)
F +	A2	13(99)
F +	C5	12(166)
F +	C6	6(221)
F -	A2	13(99)
F -	B5	12(166)
F -	C5	12(166)
F -	C6	12(128)
F --BE--O	D1	8(55)
F --BE--O	M1	8(55)
F --BE--O	M1	10(55)
F --BE--O	M8	8(56)
F CS	G9	10(19)
F H	A2	7(90)
F H	B5	12(166)
F H	C5	12(166)
F H	C6	2(1-32)
F H	C6	4(A35)
F H	G1	4(46)
F H	G2	4(46)
F H	G9	4(47)
F H +	A2	13(100)
F H_4N	B2	9(27)
F H_4N	B3	10(40)
F H_4N	B5	12(178)
F H_4N	B9	9(32)
F H_4N	B9	10(79)
F H_6N O	B2	9(28)
F H_6N O	B3	10(40)
F H_6N O	B5	12(178)
F H_6N O	B9	9(32)
F H_6N O	B9	10(80)
F K	B2	7(70)
F K	B2	11(90)
F K	B3	11(90)
F K	B9	11(171)
F K	G9	10(19)
F K --AL F_3	F2	5(222)
F LI	A2	1(61)
F LI	A2	1(71)
F LI	A2	2(97)
F LI	A2	2(98)
F LI	A2	2(105)
F LI	A2	12(23)
F LI	A5	4(C 2)
F LI	B1	1(20)
F LI	B2	1(20)
F LI	B2	2(29)
F LI	B2	2(29)
F LI	B3	1(27)
F LI	B5	1(22)
F LI	B5	1(33)
F LI	B5	2(20)
F LI	B9	2(2-25)
F LI	B9	4(B24)
F LI	C6	1(107)
F LI	C6	2(1-20)
F LI	C6	4(A20)
F LI	D2	4(36)
F LI	D3	2(74)
F LI	D3	2(77)
F LI	G2	1(42)
F LI	G9	2(50)
F LI	G9	10(19)
F LI +	A2	13(110)
F LI--AL F_3	F2	5(155)
F LI--AL F_3	F2	5(165)
F LI--AL F_3	F2	5(220)
F LI--AL F_3-AL_2O_3	F2	5(156)
F LI--AL F_3-AL_2O_3	F2	5(206)
F LI--BE F_2	F2	5(163)
F LI--BE F_2	F2	5(218)
F LI--CL LI	F2	5(163)
F LI--CL LI	F2	5(217)
F LI--F_2 MG	F2	5(164)
F LI--F_2 MG	F2	5(219)
F LI--F_4 ZR	F2	5(166)
F LI--F_4 ZR	F2	5(223)
F MG	A2	1(60)
F MG	A2	1(70)
F MG	A2	2(95)
F MG	A2	2(104)
F MG	A5	4(C 2)
F MG	C6	1(117)
F MG	C6	2(1-26)
F MG	C6	4(A26)
F MG	G2	1(42)
F MG	G9	2(50)
F MG +	A2	13(109)
F N +	A2	13(102)
F N O	C5	12(178)
F N O_2	C5	12(178)
F N S	B5	12(180)
F NA	B2	9(20)
F NA	B2	11(89)
F NA	B3	11(89)
F NA	B9	9(31)
F NA	B9	11(165)
F NA	G9	10(19)
F NA--AL F_3	F2	5(221)
F O	C5	12(166)
F O +	A2	13(100)
F RB	G9	10(19)
F SI +	A2	13(106)
F SR +	A2	13(110)
F_2	A2	1(58)
F_2	A2	2(101)
F_2	A5	4(C 1)
F_2	A7	2(41)
F_2	C5	12(166)
F_2	C6	1(129)
F_2	C6	2(1-31)
F_2	C6	4(A34)
F_2	G2	1(42)
F_2	G9	2(50)
F_2 +	A2	13(99)
F_2 +	C5	12(166)
F_2 +	G1	13(24)
F_2 FE	B2	12(96)
F_2 H K	B2	7(70)
F_2 H LI	A2	2(99)
F_2 H LI	A2	2(105)
F_2 H LI	A5	4(C 2)
F_2 H LI	B2	9(15)
F_2 H LI	B9	9(31)
F_2 H N	C1	8(125)
F_2 H N	C5	12(178)
F_2 H N	C6	8(128)
F_2 H N	G1	8(125)
F_2 H N +	A2	13(102)
F_2 H NA	B2	9(20)
F_2 H NA	B3	10(40)
F_2 H NA	B9	9(31)
F_2 H NA	B9	10(69)
F_2 H +	B5	12(167)
F_2 LI_2	A2	1(61)
F_2 LI_2	A2	1(71)
F_2 LI_2	A2	2(98)
F_2 LI_2	A2	2(105)
F_2 LI_2	A5	4(C 2)
F_2 LI 2	C6	2(1-45)
F_2 LI_2	C6	4(A49)
F_2 LI_2	D3	2(74)
F_2 LI_2	G2	1(43)
F_2 MG	A2	1(60)
F_2 MG	A2	2(95)
F_2 MG	A2	2(104)
F_2 MG	A2	4(38)
F_2 MG	A2	12(22)

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F_2MG	A3	4(38)
F_2MG	A5	4(C 2)
F_2MG	B2	1(15)
F_2MG	B2	2(26)
F_2MG	B3	1(26)
F_2MG	B5	1(17)
F_2MG	B5	2(20)
F_2MG	B9	2(2-14)
F_2MG	B9	4(B14)
F_2MG	C6	2(1-50)
F_2MG	C6	4(A54)
F_2MG	O3	2(71)
F_2MG	O3	2(72)
F_2MG	G1	13(24)
F_2MG	G2	1(43)
F_2MG	G9	2(51)
F_2MG +	A2	13(110)
F_2MG--F LI	F2	5(164)
F_2MG--F LI	F2	5(219)
F_2MG--BE F_2	F2	5(166)
F_2MG--BE F_2	F2	5(224)
F_2MG--BE F_2	F2	5(225)
F_2MG--MG O	F2	5(158)
F_2N	C5	12(178)
F_2N	C6	6(241)
F_2N	G1	6(33)
F_2N	G2	6(33)
F_2N +	A2	13(102)
F_2N_2	C5	12(178)
F_2O	C5	12(166)
F_2O +	A2	13(100)
F_2O S	C5	12(173)
F_2O_2	C5	12(166)
F_2O_2S	C5	12(173)
F_2O_3	C5	12(166)
F_2PB	B7	6(53)
F_2SI +	A2	13(106)
F_3CR	B2	12(92)
F_3LI_3	A2	1(61)
F_3LI_3	A2	1(71)
F_3LI_3	A2	2(98) 2(73 ff)
F_3LI_3	A2	2(105)
F_3LI_3	A5	4(C 2)
F_3N	B2	9(28)
F_3N	B9	9(32)
F_3N	C5	12(178)
F_3N +	A2	13(102)
F_3N S	B5	12(180)
F_3O +	A2	13(100)
F_3O P	C5	12(182)
F_3P	C5	12(182)
F_3P +	A2	13(102)
F_3SI +	A2	13(106)
F_4LI_4	A2	1(61)
F_4LI_4	A2	1(72)
F_4LI_4	A2	2(98)
F_4N +	A2	13(102)
F_4N_2	C5	12(178)
F_4N_2	C6	6(243)
F_4N_2	G1	2(36)
F_4N_2	G1	6(33)
F_4N_2	G2	6(33)
F_4N_2	G9	2(38)
F_4N_2	G9	2(39)
F_4N_2	H1	10(36)
F_4N_2 +	A2	13(102)
F_4S	C5	12(173)
F_4SI +	A2	13(106)
F_4SI_2 +	A2	13(106)
F_4XE	B5	12(167)
F_4ZR--F LI	F2	5(166)
F_4ZR--F LI	F2	5(223)
F_5I	B5	12(171)
F_5I	C5	12(171)
F_5P	C5	12(182)
F_6S	C5	12(173)
F_6S +	A2	13(101)
F_6SE	C5	12(174)
F_6TE	C5	12(175)
F_7I	C5	12(171)
FE	B2	12(93)
FE -	A2	13(111)
FE--C	B2	12(95)
FE CL_2	B2	12(95)
FE O	B2	12(96)
FE O	B2	12(96)
FE O --CO_2O_3	B9	13(74)
FE_2O_3	B2	12(97)
FE_2O_3	B9	13(76)
FE_2O_3-CA O	B9	13(69)
FE_2O_3-CA_2O_2	B9	13(71)
FE_2O_3-CO O	B9	13(73)
FE_2O_3-NI O	B9	13(75)
FE_3O_4	B2	12(97)
FE_2O_4 SI	B2	12(96)
GO_2H	A2	7(93)
H	A2	1(58)
H	A2	2(101)
H	A2	7(91)
H	A5	4(C 1)
H	C5	12(165)
H	C6	2(1- 1)
H	C6	4(A 1)
H +	A2	13(99)
H +	B5	12(165)
H +	C5	12(165)
H +	C6	7(107)
H -	A2	13(99)
H -	C6	12(124)
H --	C5	12(165)
H BE	C6	12(144)
H D	C5	12(165)
H F_2 LI	B3	10(40)
H F_2 LI	B9	10(63)
H I	B5	12(170)
H I	C5	12(170)
H I O	B5	12(170)
H I O_3	B5	12(170)
H K	A2	7(92)
H K O	A2	7(90)
H K O	C5	12(184)
H LI	A2	1(61)
H LI	A2	1(870)
H LI	A2	2(97)
H LI	A2	2(104)
H LI	A2	7(92)
H LI	A5	4(C 2)
H LI	A7	2(41)
H LI	B2	1(19)
H LI	B5	1(22)
H LI	B5	2(20)
H LI	C6	12(142)
H LI +	A2	13(110)
H LI O	A2	1(61)
H LI O	A2	1(70)
H LI O	A2	2(97)
H LI O	A2	2(105)
H LI O	A5	4(C 2)
H LI O	B2	1(20)
H LI O	B2	2(29)
H LI O	B3	1(27)
H LI O	B5	1(22)
H LI O	B5	2(20)
H LI O	B9	2(2-23)
H LI O	B9	4(B23)
H LI O	J2	1(97)
H MG	A2	1(60)
H MG	A2	2(94)
H MG	A2	2(104)
H MG	A5	4(C 2)
H MG	A7	2(41)
H MG +	A2	13(109)
H MG O	A2	4(36)
H N	A2	7(91)
H N	C5	12(175)
H N	C6	12(146)
H N +	A2	13(101)
H N O_2	B5	12(176)
H N O_2	C5	12(176)
H N O_2	C5	12(176)

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HNO_3	A2	7(90)
HNO_3	A2	7(94)
HNO_3	B2	9(29)
HNO_3	B3	10(40)
HNO_3	B5	12(176)
HNO_3	B9	9(32)
HNO_3	B9	10(B1)
HN_3	A2	7(91)
HN_3	B5	12(176)
HN_3	C5	12(176)
HN_3^+	A2	13(101)
HN_3^+	C5	12(176)
HNA	A2	7(92)
HNA	B2	9(18)
HNA	B9	9(31)
HNA +	A2	13(110)
HNA O	A2	7(90)
HNA O	B2	9(19)
HNA O +	A2	13(110)
HO	A2	7(91)
HO	C5	12(165)
HO +	A2	13(99)
HO −	A2	7(90)
HO −	A2	13(99)
HO −	B5	12(165)
HO −	C5	12(165)
HO NA	B9	9(31)
HO NA	C5	12(184)
HO_2	C5	12(165)
HO_2^+	A2	13(99)
HO_2^+	C5	12(165)
HO_2^-	A2	13(99)
HO_2^-	B5	12(165)
HO_3P	B5	12(180)
HO_3P --	B5	12(180)
HO_3S −	B5	12(172)
HO_3SE −	B5	12(174)
HO_4P --	B5	12(180)
HO_4S --	B5	12(172)
HO_4SE −	B5	12(174)
HO_7P_2 ---	B5	12(181)
HP	C6	12(150)
HP +	A2	13(102)
HS +	A2	13(101)
HS −	A2	13(100)
HS −	B5	12(172)
HSE −	B5	12(174)
HSI +	A2	13(106)
HSR	C6	12(156)
HZR	B9	11(156)
H --ZR	B1	11(94)
H --ZR	B3	5(181)
H --ZR	B3	11(94)
H --ZR	B9	5(243)
H --ZR	B9	5(244)
H --ZR	B9	5(245)
H --ZR	B9	5(246)
H --ZR	B9	5(247)
H --ZR	B9	11(154)
H --ZR	B9	11(156)
H --ZR	B9	11(157)
H --ZR	D3	5(181)
H --ZR	D3	11(94)
H --ZR	F3	5(205)
H --ZR	F3	11(95)
H_2	A2	1(58)
H_2	A2	2(101)
H_2	A2	7(91)
H_2	A5	4(C 1)
H_2	A7	2(41)
H_2	B5	12(165)
H_2	C5	12(165)
H_2	C6	7(111)
H_2	C6	11(157)
H_2	C7	11(83)
H_2^+	A2	13(99)
H_2^+	C5	12(165)
H_3^+	A2	13(99)
H_2GD	A2	7(93)
H_2LA	A2	7(93)
H_2MG	A2	2(94)
H_2MG	A2	2(104)
H_2MG	A2	7(92)
H_2MG	A5	4(C 2)
H_2MG	B2	1(14)
H_2MG	B2	2(25)
H_2MG	B5	1(17)
H_2MG	B5	2(20)
H_2MG	B9	2(2-12)
H_2MG	B9	4(B12)
H_2MG	J2	1(101)
H_2MGO_2	A2	2(94)
H_2MGO_2	A2	2(104)
H_2MGO_2	B2	1(14)
H_2MGO_2	B2	2(26)
H_2MGO_2	B3	1(26)
H_2MGO_2	B5	1(17)
H_2MGO_2	B5	2(20)
H_2MGO_2	B9	2(2-13)
H_2MGO_2	B9	4(B13)
H_2MGO_2	J2	1(96)
H_2N	A2	7(91)
H_2N	C5	12(175)
H_2N^+	A2	13(101)
H_2N^-	A2	13(101)
H_2N NA	B2	9(19)
H_2N NA	B3	10(40)
H_2N NA	B9	9(31)
H_2N NA	B9	10(68)
H_2O	A2	7(90)
H_2O	B5	12(165)
H_2O	C5	12(165)
H_2O^+	A2	13(99)
H_2O^-	A2	13(99)
H_2O_2	A2	7(94)
$H_2O_2^+$	A2	13(99)
H_2O_2	B5	12(165)
H_2O_2	C5	12(165)
$H_2O_2^+$	C5	12(166)
H_2O_2MG	A5	4(C 2)
H_2O_3S	B5	12(172)
H_2O_3S	B5	12(172)
H_2O_3SE	B5	12(174)
H_2O_3TE	B5	12(175)
H_2O_4P −	B5	12(181)
H_2O_4S	B5	12(172)
H_2O_4SE	B5	12(174)
$H_2O_7P_2$ --	B5	12(181)
$H_2O_7S_2$	B5	12(173)
$H_2O_8S_2$	B5	12(173)
H_2O^+	C5	12(165)
H_2PR	A2	7(93)
H_2S	B5	12(172)
H_2S	C5	12(172)
H_2S^+	A2	13(101)
H_2SE	B5	12(174)
H_2SE	C5	12(174)
H_2TE	C5	12(175)
H_2ZR	A2	7(93)
$H_3I_3N_2$	B5	12(179)
H_3LIO_2	A2	2(97)
H_3LIO_2	B2	1(20)
H_3LIO_2	B2	2(29)
H_3LIO_2	B5	1(22)
H_3LIO_2	B5	2(20)
H_3LIO_2	B9	2(2-24)
H_3LIO_2	B9	4(B24)
H_3LIO_2	J2	1(97)
H_3LIO_3	J2	1(97)
H_3N	A2	7(91)
H_3N	B5	12(176)
H_3N	C5	12(175)
H_3N^+	A2	13(101)
$H_3N_2^+$	A2	13(101)
H_3NO	B5	12(177)
H_3NO_3S	B5	12(179)
H_3NO_4	B2	9(29)
H_3NO_4	B3	10(40)
H_3NO_4	B9	9(32)
H_3NO_4	B9	10(B2)

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H_3O +	A2	13(99)
H_3O_2P	B5	12(181)
H_3O_2P	B5	12(181)
H_3O_2TE +	B5	12(175)
H_3O_4P	B5	12(181)
$H_3O_7P_2$ -	B5	12(182)
H_3P	A2	7(91)
H_3P	B5	12(180)
H_3P	C5	12(180)
H_3P +	A2	13(102)
H_3P +	C5	12(180)
H_3U	A2	7(93)
H_4CLO_8P	B5	12(182)
H_4CLP	B5	12(182)
H_4IN	B5	12(179)
H_4IP	B5	12(182)
H_4N +	A2	13(101)
H_4NO +	B5	12(177)
H_4NTE	B5	12(180)
H_4N_2	A2	7(91)
H_4N_2	B5	12(176)
H_4N_2	C5	12(176)
$H_4N_2O_2$	B5	12(177)
$H_4N_2O_3$	A2	7(94)
$H_4N_2O_3$	B2	9(27)
$H_4N_2O_3$	B5	12(177)
$H_4N_2O_3$	B9	9(32)
$H_4N_2O_4$	B5	12(177)
H_4N_4	B5	12(176)
H_4N +	B5	12(176)
H_4O_6TE --	B5	12(175)
$H_4O_7P_2$	B5	12(182)
H_4P_2	A2	7(91)
H_4P_2	B5	12(180)
H_4P_2	C5	12(180)
H_4SI	A2	7(91)
H_4SI +	A2	13(106)
H_5NO	B2	9(27)
H_5NO	B3	10(40)
H_5NO	B5	12(177)
H_5NO	B9	9(32)
H_5NO	B9	10(78)
H_5NO_3S	B5	12(179)
H_5NO_4S	B5	12(179)
H_5NO_5S	B5	12(179)
H_5NS	B5	12(179)
H_5NSE	B5	12(180)
H_5N_2 +	B5	12(176)
$H_5N_3O_3$	B5	12(178)
H_5O_6TE	B5	12(175)
H_6NO_4P	B5	12(183)
H_6N_2O	B5	12(177)
H_6N_2O	C5	12(177)
H_6O_6TE	B5	12(175)
H_6SI_2	A2	7(91)
H_7NO_6	B2	9(29)
H_7NO_6	B3	10(40)
H_7NO_6	B9	9(32)
H_7NO_6	B9	10(83)
H_8N_2O	B2	9(26)
H_8N_2O	B3	10(40)
H_8N_2O	B9	9(32)
H_8N_2O	B9	10(77)
$H_8N_2O_3S$	B5	12(179)
$H_8N_2O_4S$	B5	12(179)
$H_8N_2O_6S$	B5	12(179)
$H_8N_2O_8S_2$	B5	12(179)
$H_9N_2O_4P$	B5	12(183)
$H_{10}N_2O_4S$	B5	12(179)
$H_{10}N_4O_4S$	B5	12(180)
$H_{12}N_3O_4P$	B5	12(183)
$H_{12}N_4O_5S$	B5	12(180)
$H_{18}N_3O_5P$	B5	12(183)
HE	C6	2(1- 2)
HE	C6	4(A 2)
HE +	C6	6(207)
HG	B1	9(29)
HG	B2	9(29)
HG	B9	9(32)
HG +	C6	6(261)
HG O	B2	9(30)
HG O	B9	9(32)
HG O	B9	10(84)
I	C5	12(169)
I +	C5	12(169)
I +	C6	6(255)
I -	B5	12(170)
I -	C5	12(170)
I K	B2	7(71)
I K	G9	10(19)
I K O_3	B2	9(26)
I K O_3	B3	10(40)
I K O_3	B9	10(76)
I LI	B7	6(54)
I LI	G9	10(19)
I LI +	A2	13(110)
I NA	G9	10(19)
I NA +	A2	13(110)
I O -	B5	12(170)
I O_3 -	B5	12(170)
I O_4 +	B5	12(170)
I RB	G9	10(19)
I_2	B5	12(170)
I_2	C5	12(170)
I_2 MG	B7	6(54)
I_2O_5	A2	7(94)
I_2O_5	C5	12(170)
I_3 -	B5	12(170)
I_3 P	B5	12(182)
I_3 P	C5	12(182)
K	B2	7(69)
K +	C5	12(184)
K +	C6	6(257)
K -	A2	13(111)
K H	C6	12(152)
K N O_3	A9	7(10)
K N O_3	B1	7(3)
K N O_3	B2	9(25)
K N O_3	B9	9(32)
K NA_2	B2	9(17)
K NA_2	B9	9(31)
K O_2	A2	7(95)
K O_2	B2	7(69)
K O_3	A2	7(95)
K_2O	A2	7(95)
K_2O --B_2O_3	A2	6(78)
K_2O_2	A2	7(95)
K_2O_3	A2	7(95)
$K_2O_5SI_2$	B2	7(66)
$K_2O_9SI_4$	B2	7(66)
LI	A2	1(58)
LI	A2	2(101)
LI	A5	4(C 1)
LI	B1	1(19)
LI	B1	5(175)
LI	B2	1(19)
LI	B2	2(28)
LI	B2	3(63)
LI	B2	5(175)
LI	B3	1(27)
LI	B5	1(22)
LI	B5	1(32)
LI	B5	2(20)
LI	B9	2(2-21)
LI	B9	4(B21)
LI	B9	5(227)
LI	C6	2(1- 3)
LI	C6	4(A 3)
LI	D2	1(48)
LI +	A2	13(110)
LI +	C6	6(209)
LI -	A2	13(110)
LI--AL	F2	5(189)
LI--MG	F2	5(198)
LI N	A2	1(61)
LI O	A2	1(61)
LI O	A2	1(70)
LI O	A2	2(97)
LI O	A2	2(104)
LI O	A5	4(C 2)

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LI O	C6	12(160)
LI O	G1	11(118)
LI O +	A2	13(110)
LI--O	O2	2(64)
LI O_3	A2	7(95)
LI_2	A2	1(61)
LI_2	A2	1(70)
LI_2	A2	2(96)
LI_2	A2	2(104)
LI_2	A5	4(C 2)
LI_2	A7	2(41)
LI_2	B5	1(22)
LI_2	C6	1(105)
LI_2	C6	2(1-19)
LI_2	C6	4(A19)
LI_2	G2	1(42)
LI_2	G9	2(50)
LI_2 +	A2	13(110)
LI_2 O	A2	1(61)
LI_2 O	A2	2(97)
LI_2 O	A2	2(104)
LI_2 O	A2	3(65)
LI_2 O	A2	7(95)
LI_2 O	A5	4(C 2)
LI_2 O	B2	1(19)
LI_2 O	B2	2(28)
LI_2 O	B3	1(27)
LI_2 O	B5	2(20)
LI_2 O	B9	2(2-22)
LI_2 O	B9	4(822)
LI_2 O	C6	11(148)
LI_2 O	E2	5(160)
LI_2 O	G1	11(118)
LI_2 O	J2	1(97)
LI_2 O +	A2	13(110)
LI_2 O --8 $_2$ O $_3$	A2	6(77)
LI_2 O --B $_2$ O $_3$	F2	5(157)
LI_2 O --8 $_2$ O $_3$	F2	5(213)
LI_2 O $_2$	A2	2(97)
LI_2 O $_2$	A2	2(104)
LI_2 O $_2$	A2	7(95)
LI_2 O $_2$	A5	4(C 2)
LI_2 O $_2$	C6	11(150)
LI_2 O $_2$	G1	11(118)
LI_2 O $_3$ SI	A2	6(83)
LI_2 O $_3$ SI	A3	6(83)
LI_2 O $_3$ TI	B2	7(66)
LI_2 O $_3$ TI	B2	8(93)
LI_2 O $_3$ TI	B3	8(93)
LI_2 O $_3$ TI	B5	8(102)
LI_2 O $_3$ TI	B9	8(144)
LI_2 O $_5$ SI_2	B2	7(64)
LI_2 O $_7$ SI_3	B2	7(64)
LI_3 N	A2	1(61)
LI_3 N	A2	2(100)
LI_3 N	A2	2(105)
LI_3 N	A2	3(5)
LI_3 N	A3	3(5)
LI_3 N	A5	4(C 2)
LI_3 N	B2	3(13)
LI_3 N	B5	3(16)
LI_3 N	B7	3(21)
LI_3 N	B9	3(22)
LI_3 N	B9	3(2-28)
LI_3 N	B9	4(828)
LI_3 N	O3	3(46)
LI_3 N	J2	4(24)
MG	A2	1(58)
MG	A2	2(101)
MG	A5	4(C 1)
MG	B2	1(14)
MG	B2	2(25)
MG	B3	1(26)
MG	B5	1(17)
MG	B5	2(20)
MG	B9	2(2- 9)
MG	B9	4(8 9)
MG	C6	2(1-12)
MG	C6	4(A12)
MG	O2	1(48)
MG +	A2	13(109)
MG +	C6	6(227)
MG -	A2	13(109)
MG--AL	F2	5(190)
MG--LI	F2	5(198)
MG--SI	F2	5(199)
MG--TI	F2	5(200)
MG--ZR	F2	5(201)
MG C $_2$	A2	3(5)
MG O	A2	1(60)
MG O	A2	1(69)
MG O	A2	2(94)
MG O	A2	2(103)
MG O	A2	4(36)
MG O	A5	4(C 2)
MG O	B1	2(25)
MG O	B2	1(14)
MG O	B2	2(25)
MG O	B3	1(26)
MG O	B5	1(17)
MG O	B5	2(20)
MG O	B9	2(2-10)
MG O	B9	2(2-11)
MG O	B9	4(B10)
MG O	B9	4(811)
MG O	C6	1(121)
MG O	C6	2(1-25)
MG O	C6	4(A25)
MG O	O1	12(83)
MG O	E2	5(160)
MG O	G2	1(42)
MG O	G9	2(50)
MG O	J2	1(96)
MG O +	A2	13(109)
MG--O	O2	2(64)
MG O --AL_2 O $_3$	F2	5(156)
MG O --AL_2 O $_3$	F2	5(208)
MG O --AL_2 O $_3$-8E O	F2	5(156)
MG O --AL_2 O $_3$-8E O	F2	5(207)
MG O --AL_2 O $_3$-O $_2$ TI	F2	5(156)
MG O --AL_2 O $_3$-O $_2$ TI	F2	5(209)
MG O --8 $_2$ O $_3$	F2	5(157)
MG O --B $_2$ O $_3$	F2	5(214)
MG O --8E O --O $_2$ ZR	F2	5(157)
MG O --8E O --O $_2$ ZR	F2	5(211)
MG O --F $_2$ MG	F2	5(158)
MG O --O $_2$ TI	F2	5(158)
MG O --O $_2$ TI	F2	5(214)
MG O --O $_2$ TI--O $_2$ ZR	F2	5(158)
MG O --O $_2$ TI--O $_2$ ZR	F2	5(216)
MG O --O $_2$ ZR	F2	5(158)
MG O --O $_2$ ZR	F2	5(215)
MG O $_2$	A2	1(60)
MG O $_2$	A2	1(69)
MG O $_2$	A2	2(94)
MG O $_2$	A2	2(104)
MG O $_2$	A5	4(C 2)
MG O $_3$ SI	A2	6(83)
MG O $_3$ SI	A3	6(83)
MG O $_3$ SI	B2	7(65)
MG O $_3$ SI	B2	8(94)
MG O $_3$ SI	B3	8(94)
MG O $_3$ SI	B5	8(102)
MG O $_3$ SI	B9	8(146)
MG O $_3$ TI	A2	6(83)
MG O $_3$ TI	A3	6(83)
MG O $_3$ TI	B2	7(67)
MG O $_3$ TI	B2	8(95)
MG O $_3$ TI	B3	8(95)
MG O $_3$ TI	B5	8(102)
MG O $_3$ TI	E2	5(160)
MG O $_4$ TI	B9	8(150)
MG O $_4$ W	B2	7(68)
MG O $_4$ W	B2	8(93)
MG O $_4$ W	B3	8(93)
MG O $_4$ W	B5	8(102)
MG O $_4$ W	B9	8(143)
MG O $_5$ TI	B2	8(95)
MG O $_5$ TI	B3	8(95)
MG O $_5$ TI_2	A2	6(83)

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MGO_5TI_2	A3	6(83)
MGO_5TI_2	B2	7(67)
MGO_5TI_2	B5	8(102)
MGO_5TI_2	B9	8(152)
MG_2	A2	1(60)
MG_2	A2	1(69)
MG_2	A2	2(93)
MG_2	A2	2(103)
MG_2	A5	4(C 2)
MG_2	A7	2(41)
MG_2C_3	A2	3(5)
MG_2O_4SI	A2	6(83)
MG_2O_4SI	A3	6(83)
MG_2O_4SI	B2	7(64)
MG_2O_4SI	B2	8(94)
MG_2O_4SI	B3	8(94)
MG_2O_4SI	B5	8(102)
MG_2O_4SI	B9	8(148)
MG_2O_4TI	A2	6(83)
MG_2O_4TI	A3	6(83)
MG_2O_4TI	B2	7(66)
MG_2O_4TI	B2	8(96)
MG_2O_4TI	B3	8(96)
MG_2O_4TI	B5	8(102)
MG_2O_4TI	B9	8(154)
MG_3N_2	A2	2(96)
MG_3N_2	A2	2(104)
MG_3N_2	A2	3(4)
MG_3N_2	A3	3(4)
MG_3N_2	A5	4(C 2)
MG_3N_2	B2	3(14)
MG_3N_2	B3	3(14)
MG_3N_2	B5	3(16)
MG_3N_2	B7	3(21)
MG_3N_2	B9	3(22)
MG_3N_2	B9	3(2-30)
MG_3N_2	B9	4(B30)
MG_3N_2	O3	3(45)
MG_3N_2	J2	4(25)
MN^-	A2	13(111)
MO^+	C6	6(253)
N	A2	2(101)
N	A2	7(90)
N	A5	4(C 1)
N	C5	12(175)
N	C6	2(1- 7)
N	C6	4(A 7)
N^+	A2	13(101)
N^+	C5	12(175)
N^+	C6	6(217)
N^-	A2	13(101)
N^{++}	A2	13(101)
$NNAO_3$	B2	9(23)
$NNAO_3$	B9	9(31)
NNA_3	B5	3(16)
NNA_3	B7	3(13)
NO	A2	7(94)
NO	C5	12(175)
NO^+	A2	13(101)
NO^+	C5	12(175)
NO^+	C6	12(136)
NO^{++}	A2	13(101)
NO^-	A2	13(101)
NO_2	A2	7(94)
NO_2^+	A2	13(102)
NO_2^+	C5	12(175)
NO_2^-	A2	13(102)
NO_2^-	B5	12(175)
NO_3^-	B5	12(175)
NP	C5	12(183)
NTI	A2	3(6)
NTI	A3	3(6)
NTI	A5	4(C 2)
NTI	B2	3(14)
NTI	B3	3(14)
NTI	B5	3(16)
NTI	B2	3(21)
NTI	B9	3(22)
NTI	B9	3(2-32)
NTI	B9	4(B32)
NTI	D3	3(49)
NZR	B2	5(179)
NZR	B9	5(250)
N_2	A2	2(101)
N_2	A5	4(C 1)
N_2	C5	12(175)
N_2	C6	3(1-66)
N_2	C6	4(A48)
N_2^+	A2	13(101)
N_2O	C5	12(175)
N_2O^+	A2	13(102)
N_2O_3	A2	7(94)
N_2O_3	B5	12(175)
N_2O_4	A2	7(94)
N_2O_4	B5	12(175)
N_2O_4	C5	12(175)
N_2O_5	A2	7(94)
N_2O_5	B5	12(175)
N_2P	C6	12(132)
N_3^+	C5	12(175)
N_3^-	A2	13(101)
N_3^-	B5	12(175)
N_3^-	C5	12(175)
N_3NA^+	A2	13(110)
N_4^+	A2	13(101)
N_4SI_3	B2	3(14)
N_4SI_3	B2	12(101)
N_4SI_3	B3	3(14)
N_4SI_3	B5	3(16)
N_5P_3	B5	12(183)
NA	B2	9(16)
NA	B9	9(31)
NA	C6	2(1-11)
NA	C6	4(A11)
NA^+	A2	13(110)
NA^+	C5	12(184)
NA^+	C6	6(225)
NA^-	A2	13(110)
NAH	C6	12(148)
NAO^+	A2	13(110)
NAO_2	A2	7(95)
NAO_2	B2	9(18)
NAO_2	B3	10(40)
NAO_2	B9	9(31)
NAO_2	B9	10(67)
NAO_3	A2	7(95)
NA_2^+	A2	13(110)
NA_2O	A2	7(95)
NA_2O	B1	9(18)
NA_2O	B2	9(18)
NA_2O	B9	9(31)
NA_2O^I	B2	9(18)
NA_2O_2	A2	7(95)
NA_2O_2	B3	10(40)
NA_2O_2	B9	9(31)
NA_2O_2	B9	10(66)
NA_2O_3SI	A2	6(83)
NA_2O_3SI	A3	6(83)
NA_2O_3SI	B2	9(23)
NA_2O_3SI	B9	9(31)
NA_2O_3TI	B2	9(24)
NA_2O_3TI	B9	9(31)
$NA_2O_5SI_2$	B2	9(24)
$NA_2O_5SI_2$	B9	9(31)
$NA_2O_5TI_2$	B2	9(24)
$NA_2O_5TI_2$	B9	9(31)
$NA_2O_5SI_2$	A2	6(83)
$NA_2O_5SI_2$	A3	6(83)
$NA_2O_7TI_3$	B2	9(25)
$NA_2O_7TI_3$	B9	9(31)
$NA_3O_7SI_2$	A2	6(83)
$NA_3O_7SI_2$	A3	6(83)
NA_4O_4SI	A2	6(83)
NA_4O_4SI	A3	6(83)
NA_4O_4SI	B2	9(24)
NA_4O_4SI	B9	9(31)
NA_4O_4SI	B9	13(51)
NE	C6	2(1-10)
NE	C6	4(A10)
NE^+	C6	6(223)

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O		A2	1(58)
O		A2	2(101)
O		A2	7(94)
O		A5	4(C 1)
O		C5	12(165)
O		C6	2(1- 8)
O		C6	4(A 8)
O		D2	1(54)
O		M1	13(25)
O +		A2	13(99)
O +		C5	12(165)
O +		C6	6(219)
O -		A2	13(99)
O -		C5	12(165)
O -		C6	12(126)
O --AL		D2	1(50)
O --AL		D2	2(61)
O --AL		H1	8(55)
O --AL		M8	8(56)
O --BE		D2	2(63)
O --BE		D3	2(63)
O --BE--F		M1	8(55)
O --BE--F		M1	10(55)
O --BE--F		M8	8(56)
O --LI		D2	2(64)
O --MG		D2	2(64)
O PB		B2	6(52)
O PB		B2	8(97)
O PB		B2	8(98)
O PB		B3	8(97)
O PB		B3	8(98)
O PB		B5	8(102)
O PB		B5	8(102)
O PB		B9	8(158)
O PB		B9	8(160)
O PB--B_2 O $_3$		A2	6(80)
O S		C5	12(171)
O S +		A2	13(101)
O S -		A2	13(101)
O SI +		A2	13(106)
O $_2$ SI--CA_2 O $_2$	GAMMA	B9	13(65)
O $_2$ SI--CA_2 O $_2$	BETA	B9	13(67)
O TI		B2	5(176)
O TI		B9	5(231)
O $_2$		A2	1(58)
O $_2$		A2	2(101)
O $_2$		A2	7(94)
O $_2$		A5	4(C 1)
O $_2$		A7	2(41)
O $_2$		B5	12(165)
O $_2$		C5	12(165)
O $_2$		C6	7(113)
O $_2$		D2	1(54)
O $_2$ +		A2	13(99)
O $_2$ +		C5	12(165)
O $_2$ +		C6	12(134)
O $_2$ -		A2	13(99)
O $_2$ PB		B2	6(53)
O $_2$ PB		B2	8(98)
O $_2$ PB		B3	6(53)
O $_2$ PB		B3	8(98)
O $_2$ PB		B5	8(102)
O $_2$ PB		B9	8(161)
O $_2$ S		B5	12(171)
O $_2$ S		C5	12(171)
O $_2$ S +		A2	13(101)
O $_2$ SE		B5	12(174)
O $_2$ SI		B2	7(68)
O $_2$ SI		B2	12(99)
O $_2$ SI		B2	12(100)
O $_2$ SI +		A2	13(106)
O $_2$ SI_2 +		A2	13(106)
O $_2$ TE		B5	12(175)
O $_2$ TI		A2	3(5)
O $_2$ TI		A3	3(5)
O $_2$ TI		A5	4(C 2)
O $_2$ TI		B2	5(177)
O $_2$ TI		B2	5(178)
O $_2$ TI		B9	5(237)
O $_2$ TI		B9	5(239)
O $_2$ TI		E2	5(160)
O $_2$ TI--AL_2 O $_3$		E2	5(160)
O $_2$ TI--AL_2 O $_3$		F2	5(156)
O $_2$ TI--AL_2 O $_3$		F2	5(209)
O $_2$ TI--AL_2 O $_3$-BE O		F2	5(156)
O $_2$ TI--AL_2 O $_3$-BE O		F2	5(207)
O $_2$ TI--AL_2 O $_3$-MG O		F2	5(156)
O $_2$ TI--AL_2 O $_3$-MG O		F2	5(209)
O $_2$ TI--AL_2 O $_3$-O $_2$ ZR		F2	5(157)
O $_2$ TI--AL_2 O $_3$-O $_2$ ZR		F2	5(210)
O $_2$ TI--BE O		F2	5(157)
O $_2$ TI--BE O		F2	5(211)
O $_2$ TI--BE O —O $_2$ ZR		F2	5(157)
O $_2$ TI--BE O —O $_2$ ZR		F2	5(212)
O $_2$ TI--MG O		F2	5(158)
O $_2$ TI--MG O		F2	5(214)
O $_2$ TI--MG O —O $_2$ ZR		F2	5(158)
O $_2$ TI--MG O —O $_2$ ZR		F2	5(216)
O $_2$ TI--O $_2$ ZR		F2	5(158)
O $_2$ TI--O $_2$ ZR		F2	5(216)
O $_2$ W		B2	6(51)
O $_2$ W		B2	8(92)
O $_2$ W		B3	8(92)
O $_2$ W		B5	8(102)
O $_2$ W		B9	8(139)
O $_2$ ZR		B2	5(179)
O $_2$ ZR		B9	5(248)
O $_2$ ZR		E2	5(160)
O $_2$ ZR--O $_2$ TI		F2	5(158)
O $_2$ ZR--O $_2$ TI		F2	5(216)
O $_2$ ZR--AL_2 O $_3$-BE O		F2	5(156)
O $_2$ ZR--AL_2 O $_3$-BE O		F2	5(207)
O $_2$ ZR--AL_2 O $_3$-O $_2$ TI		F2	5(157)
O $_2$ ZR--AL_2 O $_3$-O $_2$ TI		F2	5(210)
O $_2$ ZR--BE O —MG O		F2	5(157)
O $_2$ ZR--BE O —MG O		F2	5(211)
O $_2$ ZR--BE O —O $_2$ TI		F2	5(157)
O $_2$ ZR--BE O —O $_2$ TI		F2	5(212)
O $_2$ ZR--MG O		F2	5(158)
O $_2$ ZR--MG O		F2	5(215)
O $_2$ ZR--MG O —O $_2$ TI		F2	5(158)
O $_2$ ZR--MG O —O $_2$ TI		F2	5(216)
O $_3$		A2	7(94)
O $_3$		C5	12(165)
O $_3$ +		A2	13(99)
O $_3$ -		A2	13(99)
O $_3$ P -		B5	12(180)
O $_3$ PB SI		B2	8(99)
O $_3$ PB SI		B3	8(99)
O $_3$ PB SI		B5	8(102)
O $_3$ PB SI		B9	8(164)
O $_3$ PB_2		B2	6(52)
O $_3$ PB_2		B2	8(98)
O $_3$ PB_2		B3	8(98)
O $_3$ PB_2		B5	8(102)
O $_3$ PB_2		B9	8(162)
O $_3$ S		B5	12(172)
O $_3$ S		C5	12(172)
O $_3$ S --		B5	12(172)
O $_3$ S $_2$ --		B5	12(172)
O $_3$ SE		B5	12(174)
O $_3$ SE --		B5	12(174)
O $_3$ TE --		B5	12(175)
O $_3$ TI_2		B2	5(176)
O $_3$ TI_2		B9	5(233)
O $_3$ W		B2	8(92)
O $_3$ W		B3	8(92)
O $_3$ W		B5	8(102)
O $_3$ W		B9	8(141)
O $_4$ +		A2	13(99)
O $_4$ P ---		B5	12(180)
O $_4$ PB_2 SI		B2	8(99)
O $_4$ PB_2 SI		B3	8(99)
O $_4$ PB_2 SI		B5	8(102)
O $_4$ PB_2 SI		B9	8(165)
O $_4$ PB_3		B2	6(52)
O $_4$ PB_3		B2	8(98)
O $_4$ PB_3		B3	6(52)

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O_4PB_3	B3	8(98)
O_4PB_3	B5	8(102)
O_4PB_3	B9	8(163)
O_4S --	B5	12(172)
O_4SE --	B5	12(174)
O_4SI ZR	B2	7(67)
O_4SI_2-CA_3O_3	B9	13(64)
O_5TI_3	B2	5(177)
O_5TI_3	B9	5(235)
O_6P_4	B5	12(180)
O_7P_2 ----	B5	12(180)
O_8S_2 --	B5	12(172)
$O_{10}P_4$	B5	12(180)
P	B5	12(180)
P	C6	2(1-15)
P	C6	4(A15)
P +	A2	13(102)
P +	C6	6(233)
P -	A2	13(102)
P_2	B5	12(180)
P_2 +	A2	13(102)
P_2 -	A2	13(102)
P_2S_3	B5	12(182)
P_4	B5	12(180)
P_4 +	A2	13(102)
PB	B1	8(96)
PB	B2	6(51)
PB	B2	8(96)
PB	B3	6(51)
PB	B3	8(96)
PB	B5	8(102)
PB	B9	8(156)
PB +	C6	6(259)
S	B5	12(171)
S	C5	12(171)
S	C6	2(1-16)
S	C6	4(A16)
S +	A2	13(100)
S +	C5	12(171)
S +	C6	6(235)
S -	A2	13(100)
S -	C5	12(171)
S ----	B5	12(171)
S_2	C5	12(171)
S_2 +	A2	13(100)
S_3	C5	12(171)
S_4	C5	12(171)
S_5	C5	12(171)
S_6	C5	12(171)
S_7	C5	12(171)
S_8	C5	12(171)
S_8 +	A2	13(100)
SC -	A2	13(111)
SE	B5	12(174)
SE_2	C5	12(174)
SE_6	C5	12(174)
SI	B2	7(68)
SI	B2	12(98)
SI	C6	2(1-14)
SI	C6	4(A14)
SI +	A2	13(106)
SI +	C6	6(231)
SI -	A2	13(106)
SI--AL	F2	5(191)
SI--BE	F2	5(196)
SI--MG	F2	5(199)
SI--TI	F2	5(202)
SI--ZR	F2	5(203)
SI_2 +	A2	13(106)
TE	B5	12(174)
TE_2	C5	12(175)
TI	A5	4(C 1)
TI	B2	3(15)
TI	B3	3(15)
TI	B5	3(16)
TI	B2	3(21)
TI	B9	3(22)
TI	B9	3(2-40)
TI	B9	4(B40)
TI +	C6	6(245)
TI -	A2	13(111)
TI--AL	F2	5(192)
TI--B	F2	5(194)
TI--MG	F2	5(200)
TI--SI	F2	5(202)
TI--ZR	F2	5(204)
V -	A2	13(111)
W	B2	6(51)
W	B2	8(91)
W	B3	6(51)
W	B3	8(91)
W	B5	8(102)
W	B9	8(137)
W +	C6	6(249)
ZR	B1	5(180)
ZR	B2	5(178)
ZR	B2	5(180)
ZR	B3	11(94)
ZR	B9	5(241)
ZR	B9	11(154)
ZR +	C6	6(251)
ZR--AL	F2	5(193)
ZR--B	F2	5(195)
ZR--BE	F2	5(197)
ZR--H	B1	11(94)
ZR--H	B3	5(181)
ZR--H	B3	11(94)
ZR--H	B9	5(243)
ZR--H	B9	5(244)
ZR--H	B9	5(245)
ZR--H	B9	5(246)
ZR--H	B9	5(247)
ZR--H	B9	11(154)
ZR--H	B9	11(156)
ZR--H	B9	11(157)
ZR--H	D3	5(181)
ZR--H	D3	11(94)
ZR--H	F3	5(205)
ZR--H	F3	11(95)
ZR--MG	F2	5(201)
ZR--SI	F2	5(203)
ZR--TI	F2	5(204)

AL B3H12	A1	13(1)
AL F3	A1	8(13)
AL F3	A1	12(21)
AL4C3	A1	11(1)
AL4C3	A1	11(15)
AL4C3	A1	11(16)
AL4C3	A1	12(18)
AL4C3	A1	12(19)
BE CL2	A1	4(28)
BE F2-BE O	A1	11(109)
BE F2-BE O	A1	11(110)
BE O --BE F2	A1	11(109)
BE O --BE F2	A1	11(110)
CL H4N O4	A1	3(53)
CL H4N O4	A1	4(28)
CL K O4	A1	3(53)
CL K O4	A1	4(28)
CL LI O4	A1	3(53)
CL LI O4	A1	4(28)
CL NA O4	A1	4(28)
CL O6N	A1	7(3)
AL	A2	1(58)
AL	A2	2(101)
AL +	A2	13(108)
AL -	A2	13(108)
AL B3H12	A2	7(92)
AL BR3 -	A2	13(108)
AL C	A2	3(2)
AL C	A2	3(65)
AL CL	A2	1(59)
AL CL	A2	1(66)
AL CL	A2	2(89)
AL CL	A2	2(102)
AL CL +	A2	13(108)
AL CL2	A2	1(59)
AL CL2	A2	2(89)
AL CL2	A2	2(102)
AL CL2 +	A2	13(108)
AL CL3	A2	1(59)
AL CL3	A2	1(66)
AL CL3	A2	2(89)
AL CL3	A2	2(103)
AL CL3 +	A2	13(108)
AL CL3H12O6	A2	2(89)
AL CL3H12O6	A2	2(103)
AL F	A2	1(59)
AL F	A2	1(65)
AL F	A2	2(88)
AL F	A2	2(102)
AL F	A2	3(65)
AL F +	A2	13(108)
AL F O +	A2	13(108)
AL F2	A2	1(59)
AL F2	A2	1(66)
AL F2	A2	2(88)
AL F2	A2	2(102)
AL F2 +	A2	13(108)
AL F3	A2	1(59)
AL F3	A2	1(66)
AL F3	A2	2(88)
AL F3	A2	2(102)
AL F3	A2	3(65)
AL F3	A2	4(35)
AL F3	A2	8(13)
AL F3 +	A2	13(108)
AL F3H6O3	A2	1(59)
AL H	A2	1(59)
AL H	A2	2(86)
AL H	A2	2(102)
AL H +	A2	13(108)
AL H O2 +	A2	13(108)
AL H3	A2	1(59)
AL H3	A2	1(65)
AL H3	A2	2(87)
AL H3	A2	2(102)
AL H3O3	A2	1(59)
AL H3O3	A2	1(65)
AL H3O3	A2	2(88)
AL H3O3	A2	2(102)
AL H4LI	A2	7(92)
AL N	A2	2(90)
AL N	A2	2(103)
AL N	A2	3(2)
AL N	A2	3(65)
AL N	A2	4(35)
AL N	A2	4(36)
AL O	A2	1(59)
AL O	A2	1(62)
AL O	A2	2(83)
AL O	A2	2(102)
AL O +	A2	13(108)
AL O2	A2	1(59)
AL O2 -	A2	1(63)
AL O2 -	A2	2(84)
AL O2 -	A2	2(102)
AL2	A2	1(59)
AL2	A2	1(62)
AL2	A2	2(83)
AL2	A2	2(102)
AL2BA O4	A2	6(83)
AL2BA3O4	A2	6(83)
AL2BE O4	A2	6(83)
AL2C2	A2	2(90)
AL2C2	A2	2(103)
AL2C2	A2	3(3)
AL2C2	A2	3(65)
AL2CA O4	A2	6(83)
AL2CA3O4	A2	6(83)
AL2CL6	A2	1(59)
AL2CL6	A2	1(66)
AL2CL6	A2	1(67)
AL2CL6	A2	2(90)
AL2CL6	A2	2(103)
AL2CL6	A2	4(36)
AL2H2O4	A2	1(59)
AL2H2O4	A2	1(64)
AL2H2O4	A2	2(86)
AL2H2O4	A2	2(102)
AL2H6O6	A2	1(59)
AL2H6O6	A2	1(64)
AL2H6O6	A2	1(65)
AL2H6O6	A2	2(86)
AL2H6O6	A2	2(102)
AL2LI2O4	A2	6(83)
AL2NA2O4	A2	6(83)
AL2O	A2	1(59)
AL2O	A2	1(62)
AL2O	A2	2(83)
AL2O	A2	2(102)
AL2O +	A2	13(108)
AL2O2	A2	1(59)
AL2O2	A2	1(63)
AL2O2	A2	2(84)
AL2O2	A2	2(102)
AL2O2 +	A2	13(108)
AL2O3	A2	1(59)
AL2O3	A2	1(63)
AL2O3	A2	1(64)
AL2O3	A2	2(84)
AL2O3	A2	2(85)
AL2O3	A2	2(102)
AL2O3	A2	4(35)
AL2O5SI	A2	6(83)
AL2O5ZR	A2	6(83)
AL4C3	A2	2(103)
AL4C3	A2	3(3)
AL4C3	A2	3(65)
AL4CL3	A2	2(90)
AL6BE O10	A2	4(35)
AS H3	A2	7(91)
B +	A2	13(107)
B -	A2	13(107)
B C +	A2	13(108)
B C SI +	A2	13(108)
B C2 +	A2	13(108)
B CL +	A2	13(107)
B CL O +	A2	13(107)
B CL2 +	A2	13(107)

BCL_3 +	A2	13(107)
BF +	A2	13(107)
BFO +	A2	13(107)
BF_2 +	A2	13(107)
BF_3 +	A2	13(107)
BF_3 -	A2	13(107)
BHO_2 +	A2	13(107)
BH +	A2	13(107)
BH_2 +	A2	13(107)
BH_3	A2	7(91)
BH_3 +	A2	13(107)
BH_3O_3	A2	7(90)
BH_4K	A2	7(92)
BH_4LI	A2	7(92)
BH_4NA	A2	7(92)
BN	A2	7(90)
BN +	A2	13(107)
BO +	A2	13(107)
BSI +	A2	13(108)
B_2 +	A2	13(107)
B_2C +	A2	13(108)
B_2H +	A2	13(107)
B_2H_6	A2	7(91)
B_2H_6 +	A2	13(107)
B_2O_2 +	A2	13(107)
B_2O_3	A2	7(90)
B_2O_3 +	A2	13(107)
B_2O_3-CA O	A2	6(79)
B_2O_3-K_2O	A2	6(78)
B_2O_3-LI_2O	A2	6(77)
$B_2O_3NA_2O$	A2	6(77)
B_2O_3-O PB	A2	6(80)
$B_3F_3O_3$ +	A2	13(107)
B_4H_{10}	A2	7(91)
B_5H_9	A2	7(91)
B_5H_{11}	A2	7(91)
B_6H_{10}	A2	7(91)
$B_{10}H_{14}$	A2	7(91)
BAF +	A2	13(110)
BE	A2	1(58)
BE	A2	2(101)
BE +	A2	13(109)
BE -	A2	13(109)
BEC_2	A2	2(93)
BEC_2	A2	2(103)
BECL	A2	1(60)
BECL	A2	1(68)
BECL	A2	2(92)
BECL	A2	2(103)
BECL +	A2	13(109)
$BECL_2$	A2	1(60)
$BECL_2$	A2	1(68)
$BECL_2$	A2	2(92)
$BECL_2$	A2	2(93)
$BECL_2$	A2	2(103)
$BECL_2$	A2	4(35)
$BECL_2$	A2	4(37)
$BECL_2$	A2	7(90)
$BECL_2$ +	A2	13(109)
BEF	A2	1(60)
BEF	A2	1(68)
BEF	A2	2(92)
BEF	A2	2(103)
BEF +	A2	13(109)
BEF_2	A2	1(60)
BEF_2	A2	1(68)
BEF_2	A2	2(92)
BEF_2	A2	2(103)
BEF_2	A2	3(65)
BEF_2	A2	4(35)
BEF_2	A2	10(43)
BEF_2	A2	12(22)
BEF_2 +	A2	13(109)
BEH	A2	1(60)
BEH	A2	2(91)
BEH	A2	2(103)
BEH +	A2	13(109)
BEHO +	A2	13(109)
BEH_2	A2	7(92)
BEH_2 +	A2	13(109)
BEH_2O_2	A2	1(60)
BEH_2O_2	A2	1(67)
BEH_2O_2	A2	2(91)
BEH_2O_2	A2	2(92)
BEH_2O_2	A2	2(103)
BEO	A2	1(60)
BEO	A2	1(67)
BEO	A2	2(91)
BEO	A2	2(103)
BEO	A2	4(35)
BEO +	A2	13(109)
BE_2	A2	1(60)
BE_2	A2	1(67)
BE_2	A2	2(91)
BE_2	A2	2(103)
BE_2C	A2	2(93)
BE_2C	A2	2(103)
BE_2CL_4	A2	1(60)
BE_2CL_4	A2	1(69)
BE_2CL_4	A2	2(93)
BE_2CL_4	A2	2(103)
BE_2CL_4	A2	4(37)
BE_2CL_4 +	A2	13(109)
BE_2O +	A2	13(109)
BE_2O_2 +	A2	13(109)
BE_2O_4SI	A2	6(83)
BE_3N_2	A2	2(93)
BE_3N_2	A2	2(103)
BE_3N_2	A2	3(4)
BE_3O_2 +	A2	13(109)
BE_3O_3 +	A2	13(109)
BE_4O_4 +	A2	13(109)
BE_5O_5 +	A2	13(109)
BE_6O_6 +	A2	13(109)
BRCL	A2	7(94)
C	A2	2(101)
C +	A2	13(103)
C -	A2	13(102)
CCL +	A2	13(104)
CCLN +	A2	13(105)
CCL_2 +	A2	13(104)
CCL_3 +	A2	13(105)
CCL_4 +	A2	13(105)
CCL H_2 +	A2	13(104)
CCL H_3 +	A2	13(104)
CCL_2F_2 +	A2	13(104)
CCL_2H +	A2	13(104)
CCL_2O +	A2	13(105)
CF +	A2	13(104)
CF H_2 +	A2	13(104)
CF_2 +	A2	13(104)
CF_2H +	A2	13(104)
CF_3 +	A2	13(104)
CF_4 +	A2	13(104)
CH +	A2	13(103)
CH -	A2	13(103)
CHN +	A2	13(105)
CHO +	A2	13(104)
CH_2 +	A2	13(103)
CH_2N_2	A2	7(91)
CH_2O +	A2	13(104)
CH_2O_2 +	A2	13(104)
CH_3 +	A2	13(103)
CH_3 +	A2	13(104)
CH_3 -	A2	13(103)
CH_3NO	A2	13(105)
CH_3NO_2	A2	13(105)
CH_3N_3 + METHYL AZIDE	A2	13(105)
CH_4 +	A2	13(103)
CH_4O +	A2	13(104)
CH_4S +	A2	13(105)
CH_5N	A2	7(91)
CH_5N +	A2	13(105)
CH_6N_2	A2	7(91)
CN +	A2	13(105)
CN -	A2	13(105)
CO +	A2	13(104)
COS +	A2	13(105)
CO_2	A2	7(90)
CO_2 +	A2	13(104)

CO_2^-	A2	13(104)
CS +	A2	13(105)
CS_2 +	A2	13(101)
CS_2 +	A2	13(105)
CSI +	A2	13(106)
CSI -	A2	13(106)
CSI_2 +	A2	13(106)
CTI	A2	3(6)
C_2 +	A2	13(103)
C_2 -	A2	13(102)
C_2F_4 +	A2	13(104)
C_2H +	A2	13(103)
C_2H_2 +	A2	13(103)
C_2H_3 +	A2	13(103)
C_2H_4 +	A2	13(103)
C_2H_5 +	A2	13(103)
C_2H_6 +	A2	13(103)
C_2H_5N	A2	7(91)
$C_2H_8N_2$	A2	7(91)
$C_2H_8N_2$	A2	7(91)
C_2LI_2	A2	2(100)
C_2LI_2	A2	2(105)
C_2MG	A2	2(96)
C_2MG	A2	2(104)
C_2N +	A2	13(105)
C_2SI +	A2	13(106)
C_3 +	A2	13(103)
C_3 -	A2	13(102)
C_3HN +	A2	13(105)
C_3MG_2	A2	2(96)
C_3MG_2	A2	2(104)
C_3N +	A2	13(105)
C_4 +	A2	13(103)
C_4 -	A2	13(102)
$C_4H_{12}N_4$	A2	7(91)
C_5 +	A2	13(103)
C_4N +	A2	13(105)
C_5N + METHYL AMINE	A2	13(105)
C_6F_6 +	A2	13(104)
C_6H_6 +	A2	13(103)
C_6H_6 -	A2	13(103)
C_6N +	A2	13(105)
$C_{10}H_8$ -	A2	13(104)
$C_{12}H_{10}$+	A2	13(103)
$C_{12}H_{10}$-	A2	13(103)
CAO--B_2O_3	A2	6(79)
CAO_3SI	A2	6(83)
CAO_3TI	A2	6(83)
CA_2O_4SI	A2	6(83)
CA_3O_5SI	A2	6(83)
CEH_2	A2	7(93)
CL	A2	1(58)
CL	A2	2(101)
CL	A2	7(90)
CL +	A2	13(100)
CL -	A2	13(100)
CLF LI_2	A2	1(61)
CLF LI_2	A2	1(73)
CLF LI_2	A2	2(99)
CLF LI_2	A2	2(105)
CLF O_3 +	A2	13(100)
CLF_3 +	A2	13(100)
CLH	A2	7(90)
CLH +	A2	13(100)
CLH O_4	A2	7(94)
CLH_4N O_4	A2	7(94)
$CLH_5N_2O_4$	A2	7(94)
CLI	A2	7(94)
CLK	A2	7(90)
CLK O_4	A2	7(95)
CLLI	A2	1(61)
CLLI	A2	1(72)
CLLI	A2	2(99)
CLLI	A2	2(105)
$CLLI$ O_4	A2	7(95)
CLMG	A2	1(60)
CLMG	A2	1(70)
CLMG	A2	2(95)
CLMG	A2	2(104)
CLMG +	A2	13(110)
CLN O	A2	7(94)
$CLNO_2$	A2	7(94)
$CLNO_5$	A2	7(94)
$CLNO_6$	A2	7(94)
CLNA	A2	7(90)
$CLNA$ O_4	A2	7(95)
CLO	A2	7(94)
CLO +	A2	13(100)
CLO -	A2	13(100)
CLO_2	A2	7(94)
CLO_2 +	A2	13(100)
CLO_2 -	A2	13(100)
CLO_3 +	A2	13(100)
CLO_3 -	A2	13(100)
CLO_4 -	A2	13(100)
CLSI +	A2	13(106)
CL_2	A2	1(58)
CL_2	A2	2(101)
CL_2 +	A2	13(100)
CL_2H_2MGO	A2	2(95)
CL_2H_2MGO	A2	2(104)
$CL_2H_4MGO_2$	A2	2(96)
$CL_2H_4MGO_2$	A2	2(104)
$CL_2H_8MGO_4$	A2	2(96)
$CL_2H_8MGO_4$	A2	2(104)
$CL_2H_{12}MGO_6$	A2	2(96)
$CL_2H_{12}MGO_6$	A2	2(104)
CL_2LI_2	A2	1(61)
CL_2LI_2	A2	1(72)
CL_2LI_2	A2	2(99)
CL_2LI_2	A2	2(105)
CL_2MG	A2	2(95)
CL_2MG	A2	2(104)
CL_2MG +	A2	13(110)
CL_2O	A2	7(94)
CL_2O_7	A2	7(94)
CL_2SI +	A2	13(106)
CL_2SI -	A2	13(106)
CL_3I	A2	7(94)
CL_3LI_3	A2	1(61)
CL_3LI_3	A2	2(99)
CL_3LI_3	A2	2(105)
CL_3N	A2	7(94)
CL_3P +	A2	13(102)
CL_3SI +	A2	13(106)
CL_4SI +	A2	13(106)
CO -	A2	13(111)
CR -	A2	13(111)
CU -	A2	13(111)
F	A2	1(58)
F	A2	2(101)
F +	A2	13(99)
F -	A2	13(99)
FH	A2	7(90)
FH +	A2	13(100)
FLI	A2	1(61)
FLI	A2	1(71)
FLI	A2	2(97)
FLI	A2	2(98)
FLI	A2	2(105)
FLI	A2	12(23)
FLI +	A2	13(110)
FMG	A2	1(60)
FMG	A2	1(70)
FMG	A2	2(95)
FMG	A2	2(104)
FMG +	A2	13(109)
FN +	A2	13(102)
FO +	A2	13(100)
FSI +	A2	13(106)
FSR +	A2	13(110)
F_2	A2	1(58)
F_2	A2	2(101)
F_2 +	A2	13(99)
F_2HLI	A2	2(99)
F_2HLI	A2	2(105)
F_2HN +	A2	13(102)
F_2LI_2	A2	1(61)
F_2LI_2	A2	1(71)
F_2LI_2	A2	2(98)

F_2LI_2	A2	2(105)
F_2MG	A2	1(60)
F_2MG	A2	2(95)
F_2MG	A2	2(104)
F_2MG	A2	4(38)
F_2MG	A2	12(22)
F_2MG +	A2	13(110)
F_2N +	A2	13(102)
F_2O +	A2	13(100)
F_2SI +	A2	13(106)
F_3LI_3	A2	1(61)
F_3LI_3	A2	1(71)
F_3LI_3	A2	2(98)
F_3LI_3	A2	2(105)
F_3N +	A2	13(102)
F_3O +	A2	13(100)
F_3P +	A2	13(102)
F_3SI +	A2	13(106)
F_4LI_4	A2	1(61)
F_4LI_4	A2	1(72)
F_4LI_4	A2	2(98)
F_4N +	A2	13(102)
F_4N_2 +	A2	13(102)
F_4SI +	A2	13(106)
F_4SI_2 +	A2	13(106)
F_6S +	A2	13(101)
FE -	A2	13(111)
GD H_2	A2	7(93)
H	A2	1(58)
H	A2	2(101)
H	A2	7(91)
H +	A2	13(99)
H -	A2	13(99)
H K	A2	7(92)
H K O	A2	7(90)
H LI	A2	1(61)
H LI	A2	1(870)
H LI	A2	2(97)
H LI	A2	2(104)
H LI	A2	7(92)
H LI +	A2	13(110)
H LI O	A2	1(61)
H LI O	A2	1(70)
H LI O	A2	2(97)
H LI O	A2	2(105)
H MG	A2	1(60)
H MG	A2	2(94)
H MG	A2	2(104)
H MG +	A2	13(109)
H MG O	A2	4(36)
H N	A2	7(91)
H N +	A2	13(101)
H N O_3	A2	7(90)
H N O_3	A2	7(94)
H N_3	A2	7(91)
H N_3 +	A2	13(101)
H NA	A2	7(92)
H NA +	A2	13(110)
H NA O	A2	7(90)
H NA O +	A2	13(110)
H O	A2	7(91)
H O +	A2	13(99)
H O -	A2	7(90)
H O -	A2	13(99)
H O_2 +	A2	13(99)
H O_2 -	A2	13(99)
H P +	A2	13(102)
H S +	A2	13(101)
H S -	A2	13(100)
H SI +	A2	13(106)
H_2	A2	1(58)
H_2	A2	2(101)
H_2	A2	7(91)
H_2 +	A2	13(99)
H_3 +	A2	13(99)
H_2 GD	A2	7(93)
H_2 LA	A2	7(93)
H_2 MG	A2	2(94)
H_2 MG	A2	2(104)
H_2 MG	A2	7(92)
H_2MGO_2	A2	2(94)
H_2MGO_2	A2	2(104)
H_2N	A2	7(91)
H_2N +	A2	13(101)
H_2N -	A2	13(101)
H_2O	A2	7(90)
H_2O +	A2	13(99)
H_2O -	A2	13(99)
H_2O_2	A2	7(94)
H_2O_2 +	A2	13(99)
H_2PR	A2	7(93)
H_2S +	A2	13(101)
H_2ZR	A2	7(93)
H_3LIO_2	A2	2(97)
H_3N	A2	7(91)
H_3N +	A2	13(101)
H_3N_2 +	A2	13(101)
H_3O +	A2	13(99)
H_3P	A2	7(91)
H_3P +	A2	13(102)
H_3U	A2	7(93)
H_4N +	A2	13(101)
H_4N_2	A2	7(91)
$H_4N_2O_3$	A2	7(94)
H_4P_2	A2	7(91)
H_4SI	A2	7(91)
H_4SI +	A2	13(106)
H_6SI_2	A2	7(91)
I LI +	A2	13(110)
I NA +	A2	13(110)
I_2O_5	A2	7(94)
K -	A2	13(111)
K O_2	A2	7(95)
K O_3	A2	7(95)
K_2O	A2	7(95)
K_2O --B_2O_3	A2	6(78)
K_2O_2	A2	7(95)
K_2O_3	A2	7(95)
LI	A2	1(58)
LI	A2	2(101)
LI +	A2	13(110)
LI -	A2	13(110)
LI N	A2	1(61)
LI O	A2	1(61)
LI O	A2	1(70)
LI O	A2	2(97)
LI O	A2	2(104)
LI O +	A2	13(110)
LI O_3	A2	7(95)
LI_2	A2	1(61)
LI_2	A2	1(70)
LI_2	A2	2(96)
LI_2	A2	2(104)
LI_2 +	A2	13(110)
LI_2O	A2	1(61)
LI_2O	A2	2(97)
LI_2O	A2	2(104)
LI_2O	A2	3(65)
LI_2O	A2	7(95)
LI_2O +	A2	13(110)
LI_2O --B_2O_3	A2	6(77)
LI_2O_2	A2	2(97)
LI_2O_2	A2	2(104)
LI_2O_2	A2	7(95)
LI_2O_3SI	A2	6(83)
LI_3N	A2	1(61)
LI_3N	A2	2(100)
LI_3N	A2	2(105)
LI_3N	A2	3(5)
MG	A2	1(58)
MG	A2	2(101)
MG +	A2	13(109)
MG -	A2	13(109)
MG C_2	A2	3(5)
MG O	A2	1(60)
MG O	A2	1(69)
MG O	A2	2(94)
MG O	A2	2(103)
MG O	A2	4(36)
MG O +	A2	13(109)

MG O 2	A2	1(60)
MG O 2	A2	1(69)
MG O 2	A2	2(94)
MG O 2	A2	2(104)
MG O 3 SI	A2	6(83)
MG O 3 TI	A2	6(83)
MG O 5 TI2	A2	6(83)
MG2	A2	1(60)
MG2	A2	1(69)
MG2	A2	2(93)
MG2	A2	2(103)
MG2 C 3	A2	3(5)
MG2 O 4 SI	A2	6(83)
MG2 O 4 TI	A2	6(83)
MG3 N 2	A2	2(96)
MG3 N 2	A2	2(104)
MG3 N 2	A2	3(4)
MN -	A2	13(111)
N	A2	2(101)
N	A2	7(90)
N +	A2	13(101)
N -	A2	13(101)
N ++	A2	13(101)
N O	A2	7(94)
N O +	A2	13(101)
N O ++	A2	13(101)
N O -	A2	13(101)
N O 2	A2	7(94)
N O 2 +	A2	13(102)
N O 2 -	A2	13(102)
N TI	A2	3(6)
N 2	A2	2(101)
N 2 +	A2	13(101)
N 2 O +	A2	13(102)
N 2 O 3	A2	7(94)
N 2 O 4	A2	7(94)
N 2 O 5	A2	7(94)
N 3 -	A2	13(101)
N 3 NA +	A2	13(110)
N 4 +	A2	13(101)
NA +	A2	13(110)
NA -	A2	13(110)
NA O +	A2	13(110)
NA O 2	A2	7(95)
NA O 3	A2	7(95)
NA2 +	A2	13(110)
NA2 O	A2	7(95)
NA2 O 2	A2	7(95)
NA2 O 3 SI	A2	6(83)
NA2 O 5 SI2	A2	6(83)
NA3 O 7 SI2	A2	6(83)
NA4 O 4 SI	A2	6(83)
NI -	A2	13(111)
O	A2	1(58)
O	A2	2(101)
O	A2	7(94)
O +	A2	13(99)
O -	A2	13(99)
O PB--B 2 O 3	A2	6(80)
O S +	A2	13(101)
O S -	A2	13(101)
O SI +	A2	13(106)
O 2	A2	1(58)
O 2	A2	2(101)
O 2	A2	7(94)
O 2 +	A2	13(99)
O 2 -	A2	13(99)
O 2 S +	A2	13(101)
O 2 SI +	A2	13(106)
O 2 SI2 +	A2	13(106)
O 2 TI	A2	3(5)
O 3	A2	7(94)
O 3 +	A2	13(99)
O 3 -	A2	13(99)
O 4 +	A2	13(99)
P +	A2	13(102)
P -	A2	13(102)
P 2 +	A2	13(102)
P 2 -	A2	13(102)
P 4 +	A2	13(102)
S +	A2	13(100)
S -	A2	13(100)
S 2 +	A2	13(100)
S 8 +	A2	13(100)
SC -	A2	13(111)
SI +	A2	13(106)
SI -	A2	13(106)
SI2 +	A2	13(106)
TI -	A2	13(111)
V -	A2	13(111)
AL CL3	A3	4(36)
AL N	A3	4(36)
AL2 BA O 4	A3	6(83)
AL2 BA3 O 4	A3	6(83)
AL2 BE O 4	A3	6(83)
AL2 CA O 4	A3	6(83)
AL2 CA3 O 4	A3	6(83)
AL2 CL6	A3	4(36)
AL2 LI2 O 4	A3	6(83)
AL2 NA2 O 4	A3	6(83)
AL2 O 5 SI	A3	6(83)
AL2 O 5 ZR	A3	6(83)
BE CL2	A3	4(37)
BE F 2	A3	10(43)
BE F 2	A3	12(120)
BE O	A3	12(120)
BE2 CL4	A3	4(37)
BE2 F 2 O	A3	12(120)
BE2 O 4 SI	A3	6(83)
BE3 N 2	A3	3(4)
C 2 LI2	A3	3(5)
CA O 3 SI	A3	6(83)
CA O 3 TI	A3	6(83)
CA2 O 4 SI	A3	6(83)
CA3 O 5 SI	A3	6(83)
F 2 MG	A3	4(38)
LI2 O 3 SI	A3	6(83)
LI3 N	A3	3(5)
MG O 3 SI	A3	6(83)
MG O 3 TI	A3	6(83)
MG O 5 TI2	A3	6(83)
MG2 O 4 SI	A3	6(83)
MG2 O 4 TI	A3	6(83)
MG3 N 2	A3	3(4)
N TI	A3	3(6)
NA2 O 3 SI	A3	6(83)
NA2 O 5 SI2	A3	6(83)
NA3 O 7 SI2	A3	6(83)
NA4 O 4 SI	A3	6(83)
O 2 TI	A3	3(5)
AL	A5	4(C 1)
AL C	A5	4(C 2)
AL CL	A5	4(C 2)
AL CL2	A5	4(C 2)
AL CL3	A5	4(C 2)
AL CL3 H 12O 6	A5	4(C 2)
AL F	A5	4(C 2)
AL F 3	A5	4(C 2)
AL H	A5	4(C 2)
AL H 3	A5	4(C 2)
AL H 3 O 3	A5	4(C 2)
AL N	A5	4(C 2)
AL O	A5	4(C 2)
AL O 2 -	A5	4(C 2)
AL2	A5	4(C 2)
AL2 C 2	A5	4(C 2)
AL2 CL6	A5	4(C 2)
AL2 H 2 O 4	A5	4(C 2)
AL2 H 6 O 6	A5	4(C 2)
AL2 O	A5	4(C 2)
AL2 O 2	A5	4(C 2)
AL2 O 3	A5	4(C 2)
AL4 C 3	A5	4(C 2)
B	A5	5(39)
B BR	A5	5(40)
B BR CL2	A5	5(41)

B BR F 2	A5	5(41)
B BR2 CL	A5	5(41)
B BR2 F	A5	5(41)
B CL	A5	5(40)
B CL F	A5	5(40)
B CL F 2	A5	5(40)
B CL O	A5	5(40)
B CL2 F	A5	5(40)
B CL3	A5	5(40)
B F	A5	5(40)
B F O	A5	5(40)
B F 2	A5	5(40)
B F 3	A5	5(40)
B H	A5	5(39)
B H O 2	A5	5(39)
B H 3	A5	5(39)
B H 3 O 3	A5	5(39)
B I 3	A5	5(41)
B N	A5	5(41)
B N	A5	5(150)
B O	A5	5(39)
B S	A5	5(41)
B TI	A5	5(150)
B TI2	A5	5(150)
B ZR	A5	5(150)
B 2	A5	5(39)
B 2 CL4	A5	5(40)
B 2 H 6	A5	5(39)
B 2 O 2	A5	5(39)
B 2 O 3	A5	5(39)
B 2 TI	A5	5(150)
B 2 ZR	A5	5(150)
B 3 CL3 O 3	A5	5(40)
B 3 F 3 O 3	A5	5(40)
B 3 H 3 O 6	A5	5(40)
B 3 H 6 N 3	A5	5(41)
B 4 C	A5	5(41)
B 4 C	A5	5(150)
B 5 H 9	A5	5(39)
B 5 TI2	A5	5(150)
B 10H 14	A5	5(39)
B 12ZR	A5	5(150)
BE	A5	4(C 1)
BE C 2	A5	4(C 2)
BE CL	A5	4(C 2)
BE CL2	A5	4(C 2)
BE F	A5	4(C 2)
BE F 2	A5	4(C 2)
BE H	A5	4(C 2)
BE H 2 O 2	A5	4(C 2)
BE O	A5	4(C 2)
BE2	A5	4(C 2)
BE2 C	A5	4(C 2)
BE2 CL4	A5	4(C 2)
BE3 N 2	A5	4(C 2)
C	A5	4(C 1)
C TI	A5	4(C 2)
C 2 LI2	A5	4(C 2)
C 2 MG	A5	4(C 2)
C 3 MG2	A5	4(C 2)
CL	A5	4(C 1)
CL F LI2	A5	4(C 2)
CL LI	A5	4(C 2)
CL MG	A5	4(C 2)
CL2	A5	4(C 1)
CL2 H 2 MG O	A5	4(C 2)
CL2 H 4 MG O 2	A5	4(C 2)
CL2 H 8 MG O 4	A5	4(C 2)
CL2 H 12MG O 6	A5	4(C 2)
CL2 LI2	A5	4(C 2)
CL2 MG	A5	4(C 2)
CL3 LI3	A5	4(C 2)
F	A5	4(C 1)
F LI	A5	4(C 2)
F MG	A5	4(C 2)
F 2	A5	4(C 1)
F 2 H LI	A5	4(C 2)
F 2 LI2	A5	4(C 2)
F 2 MG	A5	4(C 2)
F 3 LI3	A5	4(C 2)

H	A5	4(C 1)
H LI	A5	4(C 2)
H LI O	A5	4(C 2)
H MG	A5	4(C 2)
H 2	A5	4(C 1)
H 2 MG	A5	4(C 2)
H 2 O 2 MG	A5	4(C 2)
LI	A5	4(C 1)
LI O	A5	4(C 2)
LI2	A5	4(C 2)
LI2 O	A5	4(C 2)
LI2 O 2	A5	4(C 2)
LI3 N	A5	4(C 2)
MG	A5	4(C 1)
MG O	A5	4(C 2)
MG O 2	A5	4(C 2)
MG2	A5	4(C 2)
MG3 N 2	A5	4(C 2)
N	A5	4(C 1)
N TI	A5	4(C 2)
N 2	A5	4(C 1)
O	A5	4(C 1)
O 2	A5	4(C 1)
O 2 TI	A5	4(C 2)
TI	A5	4(C 1)
AL H	A7	2(41)
AL2	A7	2(41)
BE C 2	A7	3(4)
BE H	A7	2(41)
BE2	A7	2(41)
CL2	A7	2(41)
F 2	A7	2(41)
H LI	A7	2(41)
H MG	A7	2(41)
H 2	A7	2(41)
LI2	A7	2(41)
MG2	A7	2(41)
O 2	A7	2(41)
AL4 C 3	A8	11(1)
CL O 6 N	A8	7(3)
AL H 3 ME6 N 4	A9	3(59)
AL2 O 3	A9	3(41)
AL4 C 3	A9	11(15)
BE2 F 2 O	A9	12(121)
CL K O 4	A9	7(10)
CL O 6 N	A9	7(9)
K N O 3	A9	7(10)
AL F 6 LI3	B1	11(68)
AL2 BE O 4	B1	8(44)
AL2 BE O 4	B1	11(50)
AL2 BE O 4	B1	11(62)
AL2 O 3	B1	2(23)
AL4 C 3	B1	7(13)
AL4 C 3	B1	8(39)
AL4 C 3	B1	11(21)
AL4 C 3	B1	11(43)
B 4 C	B1	3(11)
BE	B1	1(11)
BE	B1	2(24)
BE F 4 LI2	B1	11(75)
BE O	B1	2(24)
BE3 N 2	B1	8(44)
C GRAPHITE	B1	13(21)
CL K O 4	B1	7(3)
CL LI	B1	1(20)
CL LI	B1	2(30)
CL LI	B1	3(63)
CL LI	B1	5(176)
CL O 6 N	B1	7(3)
F LI	B1	1(20)
H --ZR	B1	11(94)
HG	B1	9(29)

K N O 3	B1	7(3)
LI	B1	1(19)
LI	B1	5(175)
MG O	B1	2(25)
NA2 O	B1	9(18)
PB	B1	8(96)
ZR	B1	5(180)
ZR--H	B1	11(94)
AL	B2	1(7)
AL	B2	2(22)
AL CL3	B2	3(64)
AL F 3	B2	2(24)
AL F 6 NA3	B2	9(20)
AL H 4 LI	B2	1(21)
AL K O 4 SI	B2	12(97)
AL K O 6 SI	B2	12(97)
AL K O 8 SI3	B2	12(97)
AL K O 8 SI3	B2	12(98)
AL LI O 2	B2	1(21)
AL LI O 2	B2	2(30)
AL N	B2	3(14)
AL O 2 NA	B2	9(20)
AL2 BE O 4	B2	8(50)
AL2 CA O 4	B2	12(89)
AL2 CA O 3 SI2	B2	12(89)
AL2 CA2 O 7 SI	B2	12(89)
AL2 CA3 O 6	B2	12(89)
AL2 FE O 4	B2	12(96)
AL2 H 2 O 4	B2	1(7)
AL2 H 2 O 4	B2	2(23)
AL2 H 6 O 6	B2	1(8)
AL2 H 6 O 6	B2	2(23)
AL2 MG O 4	B2	1(16)
AL2 MG O 4	B2	2(28)
AL2 O 3	B2	1(7)
AL2 O 3	B2	2(23)
AL2 O 5 SI	B2	7(65)
AL2 O 5 SI	B2	8(99)
AL2 O 5 TI	B2	7(67)
AL2 O 5 TI	B2	8(101)
AL4 C 3	B2	3(12)
AL4 C 3	B2	8(41)
AL4 CA O 7	B2	12(89)
AL14CA12O 23	B2	12(89)
B H 4 K	B2	11(92)
B H 4 LI	B2	11(89)
B H 4 NA	B2	9(21)
B H 4 NA	B2	11(90)
B N	B2	3(13)
B O 2 NA	B2	9(22)
B 2 MG	B2	9(16)
B 4 C	B2	3(11)
B 4 MG	B2	9(16)
B 4 NA2 O 7	B2	9(22)
BA	B2	12(87)
BA CL2	B2	12(87)
BA F 2	B2	12(87)
BA O	B2	12(87)
BE	B2	2(24)
BE O	B2	2(24)
BE2 C	B2	3(11)
BE2 O 4 SI	B2	7(64)
BE2 O 4 SI	B2	8(101)
BE3 N 2	B2	3(13)
BE3 N 2	B2	8(50)
BR K	B2	7(71)
BR K	B2	11(91)
BR K O 3	B2	9(26)
BR2 PB	B2	6(53)
C --FE	B2	12(95)
C FE3	B2	12(95)
C SI	B2	3(12)
C SI	B2	12(99)
C TI	B2	3(21)
C 2 CA	B2	12(88)
C 2 CR3	B2	12(92)
C 2 CR5	B2	12(92)
C 2 LI2	B2	3(11)
C 2 MG	B2	3(12)
C 2 NA2	B2	3(12)
C 3 CR7	B2	12(92)
C 3 MG2	B2	3(12)
C 6 CR23	B2	12(93)
CA	B2	12(87)
CA CL2	B2	12(88)
CA F 2	B2	12(88)
CA FE2 O 4	B2	12(89)
CA O	B2	12(88)
CA O 3 SI	B2	12(90)
CA2 FE2 O 5	B2	12(90)
CA2 O 4 SI	B2	12(90)
CA3 O 5 SI	B2	12(91)
CA3 O 7 SI2	B2	12(91)
CL H MG O	B2	1(16)
CL H 2 LI O	B2	1(21)
CL HG	B2	9(30)
CL K	B2	7(70)
CL K	B2	11(91)
CL K O 3	B2	9(26)
CL K O 4	B2	9(26)
CL LI	B2	1(20)
CL LI	B2	2(30)
CL LI	B2	3(63)
CL LI	B2	5(176)
CL NA	B2	9(21)
CL NA	B2	11(90)
CL2 CR	B2	12(92)
CL2 H 2 MG O	B2	1(15)
CL2 H 2 MG O	B2	2(27)
CL2 H 4 MG O 2	B2	1(15)
CL2 H 4 MG O 2	B2	2(27)
CL2 H 8 MG O 4	B2	1(15)
CL2 H 8 MG O 4	B2	2(27)
C 2 H 12MG O 6	B2	1(16)
CL2 H 12MG O 6	B2	2(28)
CL2 MG	B2	1(15)
CL2 MG	B2	2(26)
CL2 PB	B2	6(53)
CL3 CR	B2	12(92)
CL3 FE	B2	12(96)
CL4 ZR	B2	5(179)
CR	B2	12(91)
CR K 2 O 4	B2	12(98)
CR2 FE O 4	B2	12(96)
CR2 K 2 O 7	B2	12(98)
CR2 O 3	B2	12(92)
F H 4 N	B2	9(27)
F H 6 N O	B2	9(28)
F K	B2	7(70)
F K	B2	11(90)
F LI	B2	1(20)
F LI	B2	2(29)
F NA	B2	9(20)
F NA	B2	11(89)
F 2 FE	B2	12(96)
F 2 H K	B2	7(70)
F 2 H LI	B2	9(15)
F 2 H NA	B2	9(20)
F 2 MG	B2	1(15)
F 2 MG	B2	2(26)
F 3 CR	B2	12(92)
F 3 N	B2	9(28)
FE	B2	12(93)
FE--C	B2	12(95)
FE CL2	B2	12(95)
FE O	B2	12(96)
FE2 O 3	B2	12(97)
FE3 O 4	B2	12(97)
FE2 O 4 SI	B2	12(96)
H LI	B2	1(19)
H LI O	B2	1(20)
H LI O	B2	2(29)
H N O 3	B2	9(29)
H NA	B2	9(18)
H NA O	B2	9(19)
H 2 MG	B2	1(14)
H 2 MG	B2	2(25)
H 2 MG O 2	B2	1(14)

H_2MGO_2	B2	2(26)
H_2NNA	B2	9(19)
H_3LIO_2	B2	1(20)
H_3LIO_2	B2	2(29)
H_3NO_4	B2	9(29)
$H_4N_2O_3$	B2	9(27)
H_5NO	B2	9(27)
H_7NO_6	B2	9(29)
H_8N_2O	B2	9(26)
HG	B2	9(29)
HGO	B2	9(30)
IK	B2	7(71)
IKO_3	B2	9(26)
K	B2	7(69)
KNO_3	B2	9(25)
KNA_2	B2	9(17)
KO_2	B2	7(69)
$K_2O_5SI_2$	B2	7(66)
$K_2O_9SI_4$	B2	7(66)
LI	B2	1(19)
LI	B2	2(28)
LI	B2	3(63)
LI	B2	5(175)
LI_2O	B2	1(19)
LI_2O	B2	2(28)
LI_2O_3TI	B2	7(66)
LI_2O_3TI	B2	8(93)
$LI_2O_5SI_2$	B2	7(64)
$LI_2O_7SI_3$	B2	7(64)
LI_3N	B2	3(13)
MG	B2	1(14)
MG	B2	2(25)
MGO	B2	1(14)
MGO	B2	2(25)
MGO_3SI	B2	7(65)
MGO_3SI	B2	8(94)
MGO_3TI	B2	7(67)
MGO_3TI	B2	8(95)
MGO_4W	B2	7(68)
MGO_4W	B2	8(93)
MGO_5TI	B2	8(95)
MGO_5TI_2	B2	7(67)
MG_2O_4SI	B2	7(64)
MG_2O_4SI	B2	8(94)
MG_2O_4TI	B2	7(66)
MG_2O_4TI	B2	8(96)
MG_3N_2	B2	3(14)
$NNAO_3$	B2	9(23)
NTI	B2	3(14)
NTI	B2	3(21)
NZR	B2	5(179)
N_4SI_3	B2	3(14)
N_4SI_3	B2	12(101)
NA	B2	9(16)
NAO_2	B2	9(18)
NA_2O	B2	9(18)
NA_2OI	B2	9(18)
NA_2O_3SI	B2	9(23)
NA_2O_3TI	B2	9(24)
$NA_2O_5SI_2$	B2	9(24)
$NA_2O_5TI_2$	B2	9(24)
$NA_2O_7TI_3$	B2	9(25)
NA_4O_4SI	B2	9(24)
OPB	B2	6(52)
OPB	B2	8(97)
OPB	B2	8(98)
OTI	B2	5(176)
O_2PB	B2	6(53)
O_2PB	B2	8(98)
O_2SI	B2	7(68)
O_2SI	B2	12(99)
O_2SI	B2	12(100)
O_2TI	B2	5(177)
O_2TI	B2	5(178)
O_2W	B2	6(51)
O_2W	B2	8(92)
O_2ZR	B2	5(179)
O_3PBSI	B2	8(99)
O_3PB_2	B2	6(52)
O_3PB_2	B2	8(98)
O_3TI_2	B2	5(176)
O_3W	B2	8(92)
O_4PB_2SI	B2	8(99)
O_4PB_3	B2	6(52)
O_4PB_3	B2	8(98)
O_4SIZR	B2	7(67)
O_5TI_3	B2	5(177)
PB	B2	6(51)
PB	B2	8(96)
SI	B2	7(68)
SI	B2	12(98)
TI	B2	3(15)
TI	B2	3(21)
W	B2	6(51)
W	B2	8(91)
ZR	B2	5(178)
ZR	B2	5(180)
AL	B3	1(26)
$ALCL_3$	B3	1(26)
ALF_3	B3	1(26)
ALN	B3	3(14)
$AL_2H_3O_4$	B3	1(26)
$AL_2H_6O_6$	B3	1(26)
AL_2O_3	B3	1(26)
AL_2O_3	B3	1(29)
AL_2O_5SI	B3	8(99)
AL_2O_5TI	B3	8(101)
AL_4C_3	B3	3(12)
BH_4K	B3	11(92)
BH_4LI	B3	11(89)
BH_4NA	B3	11(90)
BN	B3	3(13)
$BNAO_2$	B3	10(40)
B_2MG	B3	10(40)
B_4MG	B3	10(40)
$B_4NA_2O_7$	B3	10(40)
BE	B3	1(26)
BE	B3	1(29)
BEO	B3	1(26)
BE_2O_4SI	B3	8(101)
BRK	B3	11(91)
$BRKO_3$	B3	10(40)
BR_2PB	B3	6(53)
CSI	B3	3(12)
C_2MG	B3	3(12)
C_2NA_2	B3	3(12)
BEF_2	B3	11(113)
CLK	B3	11(91)
$CLKO_3$	B3	10(40)
$CLKO_4$	B3	10(40)
CLLI	B3	1(27)
CLNA	B3	11(90)
CL_2MG	B3	1(26)
CL_2PB	B3	6(53)
FH_4N	B3	10(40)
FH_6NO	B3	10(40)
FK	B3	11(90)
FLI	B3	1(27)
FNA	B3	11(89)
F_2HNA	B3	10(40)
F_2MG	B3	1(26)
H--ZR	B3	5(181)
H--ZR	B3	11(94)
HF_2LI	B3	10(40)
HLIO	B3	1(27)
HNO_3	B3	10(40)
H_2MGO_2	B3	1(26)
H_2NNA	B3	10(40)
H_3NO_4	B3	10(40)
H_5NO	B3	10(40)
H_7NO_6	B3	10(40)
H_8N_2O	B3	10(40)
IKO_3	B3	10(40)
LI	B3	1(27)
LI_2O	B3	1(27)
LI_2O_3TI	B3	8(93)
MG	B3	1(26)
MGO	B3	1(26)

MG O3 SI	B3	8(94)
MG O3 TI	B3	8(95)
MG O4 W	B3	8(93)
MG O5 TI	B3	8(95)
MG2 O4 SI	B3	8(94)
MG2 O4 TI	B3	8(96)
MG3 N2	B3	3(14)
N TI	B3	3(14)
N4 SI3	B3	3(14)
NA O2	B3	10(40)
NA2 O2	B3	10(40)
O PB	B3	8(97)
O PB	B3	8(98)
O2 PB	B3	6(53)
O2 PB	B3	8(98)
O2 W	B3	8(92)
O3 PB SI	B3	8(99)
O3 PB2	B3	8(98)
O3 W	B3	8(92)
O4 PB2 SI	B3	8(99)
O4 PB3	B3	6(52)
O4 PB3	B3	8(98)
PB	B3	6(51)
PB	B3	8(96)
TI	B3	3(15)
W	B3	6(51)
W	B3	8(91)
ZR	B3	11(94)
ZR--H	B3	5(181)
ZR--H	B3	11(94)
AL	B5	1(9)
AL	B5	2(20)
AL CL O	B5	1(9)
AL CL3	B5	1(9)
AL CL3	B5	2(20)
AL F O	B5	1(9)
AL F3	B5	1(9)
AL F3	B5	2(20)
AL H3	B5	1(9)
AL H4 LI	B5	1(22)
AL LI O2	B5	1(22)
AL LI O2	B5	2(20)
AL N	B5	3(16)
AL2 BE O4	B5	1(12)
AL2 H2 O4	B5	1(9)
AL2 H2 O4	B5	2(20)
AL2 H6 O6	B5	1(9)
AL2 H6 O6	B5	2(20)
AL2 MG O4	B5	1(17)
AL2 MG O4	B5	2(20)
AL2 O3	B5	1(9)
AL2 O3	B5	2(20)
AL2 O5 SI	B5	8(102)
AL2 O5 TI	B5	8(102)
AL4 C3	B5	3(16)
B N	B5	3(16)
B4 C	B5	3(16)
BE	B5	1(12)
BE	B5	2(20)
BE CL2	B5	1(12)
BE F2	B5	1(12)
BE H2	B5	1(12)
BE H2 O2	B5	1(12)
BE O	B5	1(12)
BE O	B5	2(20)
BE2 C	B5	3(16)
BE2 O4 SI	B5	8(102)
BE3 N2	B5	3(16)
BR -	B5	12(168)
BR CL	B5	12(169)
BR F3	B5	12(169)
BR F5	B5	12(169)
BR H	B5	12(169)
BR H O	B5	12(169)
BR H O3	B5	12(169)
BR H4 N	B5	12(179)
BR H4 P	B5	12(182)
BR H5 N2	B5	12(179)
BR I	B5	12(171)
BR O -	B5	12(169)
BR O3 -	B5	12(169)
BR2	B5	12(168)
BR3 -	B5	12(168)
BR3 O P	B5	12(182)
BR3 P	B5	12(182)
BR3 P S	B5	12(182)
BR4 TE	B5	12(175)
BR5 -	B5	12(168)
C	B5	12(183)
C H O3 -	B5	12(183)
C H2 O3	B5	12(183)
C O2	B5	12(183)
C O3 --	B5	12(183)
C SI	B5	3(16)
C TI	B5	3(16)
C2 LI2	B5	3(16)
C2 MG	B5	3(16)
C2 NA2	B5	3(16)
C3 MG2	B5	3(16)
CL -	B5	12(167)
CL F3	B5	12(168)
CL H MG O	B5	1(17)
CL H MG O	B5	2(20)
CL H O	B5	12(168)
CL H O2	B5	12(168)
CL H O3	B5	12(168)
CL H O4	B5	12(168)
CL H2 LI O	B5	1(22)
CL H2 LI O	B5	2(20)
CL H4 N	B5	12(178)
CL H4 N O	B5	12(178)
CL H4 N O4	B5	12(179)
CL H5 N2	B5	12(178)
CL H5 N2 O4	B5	12(179)
CL I	B5	12(171)
CL LI	B5	1(22)
CL LI	B5	2(20)
CL N O5	B5	12(178)
CL N O6	B5	12(178)
CL O -	B5	12(167)
CL O2	B5	12(167)
CL O2 -	B5	12(167)
CL O3 -	B5	12(167)
CL O4 -	B5	12(167)
CL2	B5	12(167)
CL2 H2 MG O	B5	1(17)
CL2 H2 MG O	B5	2(20)
CL2 H4 MG O2	B5	1(17)
CL2 H4 MG O2	B5	2(20)
CL2 H6 N2	B5	12(178)
CL2 H8 MG O4	B5	1(17)
CL2 H8 MG O4	B5	2(20)
CL2 H12MG O6	B5	1(17)
CL2 H12MG O6	B5	2(20)
CL2 MG	B5	1(17)
CL2 MG	B5	2(20)
CL2 O S	B5	12(173)
CL2 O2 S	B5	12(174)
CL2 O5 S2	B5	12(174)
CL2 S2	B5	12(173)
CL2 SE2	B5	12(174)
CL3 I	B5	12(171)
CL3 N	B5	12(178)
CL3 O P	B5	12(182)
CL3 P	B5	12(182)
CL4 TE	B5	12(175)
CL5 P	B5	12(182)
D H O	B5	12(165)
D2 O	B5	12(165)
F -	B5	12(166)
F H	B5	12(166)
F H4 N	B5	12(178)
F H6 N O	B5	12(178)
F LI	B5	1(22)
F LI	B5	1(33)
F LI	B5	2(20)
F N S	B5	12(180)
F2 H +	B5	12(167)

F_2MG	B5	1(17)
F_2MG	B5	2(20)
F_3NS	B5	12(180)
F_4XE	B5	12(167)
F_5I	B5	12(171)
H +	B5	12(165)
H I	B5	12(170)
H I O	B5	12(170)
H I O_3	B5	12(170)
H LI	B5	1(22)
H LI	B5	2(20)
H LI O	B5	1(22)
H LI O	B5	2(20)
H N O_2	B5	12(176)
H N O_3	B5	12(176)
H N_3	B5	12(176)
H O -	B5	12(165)
H O_2 -	B5	12(165)
H O_3P	B5	12(180)
H O_3P --	B5	12(180)
H O_3S -	B5	12(172)
H O_3SE -	B5	12(174)
H O_4P --	B5	12(180)
H O_4S --	B5	12(172)
H O_4SE -	B5	12(174)
H O_7P_2 ---	B5	12(181)
H S -	B5	12(172)
H SE -	B5	12(174)
H_2	B5	12(165)
H_2MG	B5	1(17)
H_2MG	B5	2(20)
H_2MG O_2	B5	1(17)
H_2MG O_2	B5	2(20)
H_2O	B5	12(165)
H_2O_2	B5	12(165)
H_2O_3S	B5	12(172)
H_2O_3SE	B5	12(174)
H_2O_3TE	B5	12(175)
H_2O_4P -	B5	12(181)
H_2O_4S	B5	12(172)
H_2O_4SE	B5	12(174)
$H_2O_7P_2$ --	B5	12(181)
$H_2O_7S_2$	B5	12(173)
$H_2O_8S_2$	B5	12(173)
H_2S	B5	12(172)
H_2SE	B5	12(174)
$H_3I_3N_2$	B5	12(179)
H_3LI O_2	B5	1(22)
H_3LI O_2	B5	2(20)
H_3N	B5	12(176)
H_3N O	B5	12(177)
H_3N O_3S	B5	12(179)
H_3O_2P	B5	12(181)
H_3O_3P	B5	12(181)
H_3O_3TE +	B5	12(175)
H_3O_4P	B5	12(181)
$H_3O_7P_2$ -	B5	12(182)
H_3P	B5	12(180)
H_4CL O_8P	B5	12(182)
H_4CL P	B5	12(182)
H_4I N	B5	12(179)
H_4I P	B5	12(182)
H_4N O +	B5	12(177)
H_4N TE	B5	12(180)
H_4N_2	B5	12(176)
$H_4N_2O_2$	B5	12(177)
$H_4N_2O_3$	B5	12(177)
$H_4N_2O_4$	B5	12(177)
H_4N_4	B5	12(176)
H_4N +	B5	12(176)
H_4O_6TE --	B5	12(175)
$H_4O_7P_2$	B5	12(182)
H_4P_2	B5	12(180)
H_5N O	B5	12(177)
H_5N O_3S	B5	12(179)
H_5N O_4S	B5	12(179)
H_5N O_5S	B5	12(179)
H_5N S	B5	12(179)
H_5N SE	B5	12(180)
H_5N_2 +	B5	12(176)
$H_5N_3O_3$	B5	12(178)
H_5O_6TE	B5	12(175)
H_6N O_4P	B5	12(183)
H_6N_2O	B5	12(177)
H_6O_6TE	B5	12(175)
$H_8N_2O_3S$	B5	12(179)
$H_8N_2O_4S$	B5	12(179)
$H_8N_2O_6S$	B5	12(179)
$H_8N_2O_8S_2$	B5	12(179)
$H_9N_2O_4P$	B5	12(183)
$H_{10}N_2O_4S$	B5	12(179)
$H_{10}N_4O_4S$	B5	12(180)
$H_{12}N_3O_4P$	B5	12(183)
$H_{12}N_4O_5S$	B5	12(180)
$H_{18}N_3O_5P$	B5	12(183)
I -	B5	12(170)
I O -	B5	12(170)
I O_3 -	B5	12(170)
I O_4 +	B5	12(170)
I_2	B5	12(170)
I_3 -	B5	12(170)
I_3P	B5	12(182)
LI	B5	1(22)
LI	B5	1(32)
LI	B5	2(20)
LI_2	B5	1(22)
LI_2O	B5	2(20)
LI_2O_3TI	B5	8(102)
LI_3N	B5	3(16)
MG	B5	1(17)
MG	B5	2(20)
MG O	B5	1(17)
MG O	B5	2(20)
MG O_3SI	B5	8(102)
MG O_3TI	B5	8(102)
MG O_4W	B5	8(102)
MG O_5TI_2	B5	8(102)
MG_2O_4SI	B5	8(102)
MG_2O_4TI	B5	8(102)
MG_3N_2	B5	3(16)
N NA_3	B5	3(16)
N O_2 -	B5	12(175)
N O_3 -	B5	12(175)
N TI	B5	3(16)
N_2O_3	B5	12(175)
N_2O_4	B5	12(175)
N_2O_5	B5	12(175)
N_3 -	B5	12(175)
N_4SI_3	B5	3(16)
N_5P_3	B5	12(183)
O PB	B5	8(102)
O PB	B5	8(102)
O_2	B5	12(165)
O_2PB	B5	8(102)
O_2S	B5	12(171)
O_2SE	B5	12(174)
O_2TE	B5	12(175)
O_2W	B5	8(102)
O_3P -	B5	12(180)
O_3PB SI	B5	8(102)
O_3PB_2	B5	8(102)
O_3S	B5	12(172)
O_3S --	B5	12(172)
O_3S_2 --	B5	12(172)
O_3SE	B5	12(174)
O_3SE --	B5	12(174)
O_3TE --	B5	12(175)
O_3W	B5	8(102)
O_4P ---	B5	12(180)
O_4PB_2SI	B5	8(102)
O_4PB_3	B5	8(102)
O_4S --	B5	12(172)
O_4SE --	B5	12(174)
O_6P_4	B5	12(180)
O_7P_2 ----	B5	12(180)
O_8S_2 --	B5	12(172)
$O_{10}P_4$	B5	12(180)
P	B5	12(180)
P_2	B5	12(180)
P_2S_3	B5	12(182)

P_4	B5	12(180)
PB	B5	8(102)
S	B5	12(171)
S ----	B5	12(171)
SE	B5	12(174)
TE	B5	12(174)
TI	B5	3(16)
W	B5	8(102)
$AL\ BR_3$	B7	6(54)
$AL\ I_3$	B7	6(54)
AL N	B7	3(21)
$AL_4\ C_3$	B7	3(21)
$BE\ F_2$	B7	7(96)
$BE_2\ C$	B7	3(21)
$BE_3\ N_2$	B7	3(21)
BR LI	B7	6(54)
$BR_2\ MG$	B7	6(54)
C TI	B7	3(21)
$C_2\ LI_2$	B7	3(21)
$C_2\ MG$	B7	3(21)
$C_3\ MG_2$	B7	3(21)
$F_2\ PB$	B7	6(53)
I LI	B7	6(54)
$I_2\ MG$	B7	6(54)
$LI_3\ N$	B7	3(21)
$MG_3\ N_2$	B7	3(21)
$N\ NA_3$	B7	3(13)
AL	B9	2(2- 1)
AL	B9	4(B 1)
$AL\ CL_3$	B9	2(2- 6)
$AL\ CL_3$	B9	4(B 6)
$AL\ F_3$	B9	2(2- 5)
$AL\ F_3$	B9	4(B 5)
$AL\ F_6\ LI\ O$	B9	11(74)
$AL\ F_6\ LI_3$	B9	11(71)
$AL\ F_6\ LI_3$	B9	11(162)
$AL\ F_6\ NA_3$	B9	9(31)
$AL\ F_6\ NA_3$	B9	13(49)
$AL\ LI\ O_2$	B9	2(2-27)
$AL\ LI\ O_2$	B9	4(B27)
AL N	B9	3(22)
AL N	B9	3(2-31)
AL N	B9	4(B31)
$AL\ NA\ O_2$	B9	9(31)
$AL_2\ BE\ O_4$	B9	8(49)
$AL_2\ BE\ O_4$	B9	8(52)
$AL_2\ BE\ O_4$	B9	8(172)
$AL_2\ BE\ O_4$	B9	11(58)
$AL_2\ BE\ O_4$	B9	11(64)
$AL_2\ BE\ O_4$	B9	11(160)
$AL_2\ H_2\ O_4$	B9	2(2- 3)
$AL_2\ H_2\ O_4$	B9	4(B 3)
$AL_2\ H_6\ O_6$	B9	2(2- 4)
$AL_2\ H_6\ O_6$	B9	4(B 4)
$AL_2\ MG\ O_4$	B9	4(B20)
$AL_2\ MG\ O_4$	B9	2(2-20)
$AL_2\ O_3$	B9	2(2- 2)
$AL_2\ O_3$	B9	4(B 2)
$AL_2\ O_3\text{-}CA\ O$	B9	13(60)
$AL_2\ O_3\text{-}CA_3\ O_3$	B9	13(56)
$AL_2\ O_5\ SI$	B9	8(166)
$AL_2\ O_5\ SI$	B9	8(167)
$AL_2\ O_5\ SI$	B9	8(168)
$AL_2\ O_5\ TI$	B9	8(170)
$AL_4\ C_3$	B9	3(22)
$AL_4\ C_3$	B9	3(2-37)
$AL_4\ C_3$	B9	4(B37)
$AL_4\ C_3$	B9	7(118)
$AL_4\ C_3$	B9	8(135)
$AL_4\ C_3$	B9	11(40)
$AL_4\ C_3$	B9	11(42)
$AL_4\ C_3$	B9	11(43)
$AL_4\ O_3$	B9	11(44)
$AL_4\ O_6\text{-}CA\ O$	B9	13(62)
$AL_{14}O_{27}CA_{12}O_{12}$	B9	13(58)
B	B9	5(49)

B	B9	5(50)
B	B9	5(51)
$B\ H_3\ O_3$	B9	5(79)
$B\ H_4\ K$	B9	11(177)
$B\ H_4\ LI$	B9	11(164)
$B\ H_4\ NA$	B9	9(31)
$B\ H_4\ NA$	B9	11(169)
B N	B9	5(129)
$B\ NA\ O_2$	B9	9(31)
$B\ NA\ O_2$	B9	10(73)
$B_2\ MG$	B9	9(31)
$B_2\ MG$	B9	10(64)
$B_2\ O_3$	B9	5(62)
$B_4\ C$	B9	5(135)
$B_4\ MG$	B9	9(31)
$B_4\ MG$	B9	10(65)
$B_4\ NA_2\ O_7$	B9	9(31)
$B_4\ NA_2\ O_7$	B9	10(73)
$B_5\ H_8\ K\ O_{12}$	B9	6(266)
$B_5\ H_9$	B9	5(71)
$B_5\ H_{10}NA\ O_{13}$	B9	6(264)
$B_5\ H_{12}N\ O_{12}$	B9	6(268)
$B_{10}H_{14}$	B9	5(74)
BA O	B9	13(52)
BE	B9	2(2- 7)
BE	B9	4(B 7)
$BE\ F_2$	B9	7(117)
$BE\ F_2$	B9	11(158)
$BE\ F_4\ LI_2$	B9	11(78)
$BE\ F_4\ LI_2$	B9	11(163)
BE O	B9	2(2- 8)
BE O	B9	4(B 8)
$BE_2\ C$	B9	3(22)
$BE_2\ C$	B9	3(2-34)
$BE_2\ C$	B9	4(B34)
$BE_2\ O_4\ SI$	B9	8(169)
$BE_3\ N_2$	B9	3(22)
$BE_3\ N_2$	B9	3(2-29)
$BE_3\ N_2$	B9	4(B29)
$BE_3\ N_2$	B9	8(48)
$BE_3\ N_2$	B9	8(134)
$BR\ K\ O_3$	B9	9(32)
$BR\ K\ O_3$	B9	10(75)
BR_2	B9	11(175)
C	B9	3(2-39)
C	B9	4(B39)
C TI	B9	3(22)
C TI	B9	3(2-38)
C TI	B9	4(B38)
$C_2\ CA$	B9	13(54)
$C_2\ LI_2$	B9	3(22)
$C_2\ LI_2$	B9	4(B33)
$C_2\ MG$	B9	3(22)
$C_2\ MG$	B9	3(2-35)
$C_2\ MG$	B9	4(B35)
$C_2\ O_3\text{-}FE\ O$	B9	13(74)
$C_2\ TI_2$	B9	3(2-33)
$C_3\ MG_2$	B9	3(22)
$C_3\ MG_2$	B9	3(2-36)
$C_3\ MG_2$	B9	4(B36)
$CA\ O\text{--}AL_2\ O_3$	B9	13(60)
$CA\ O\text{--}AL_4\ O_6$	B9	13(62)
$CA\ O\text{--}FE_2\ O_3$	B9	13(69)
$CA_2\ O_2\text{-}FE_2\ O_3$	B9	13(71)
$CA_2\ O_2\text{-}O_2\ SI$ GAMMA	B9	13(65)
$CA_2\ O_2\text{-}O_2\ SI$ BETA	B9	13(67)
$CA_3\ O_3\text{-}AL_2\ O_3$	B9	13(56)
$CA_3\ O_3\text{-}O_4\ SI_2$	B9	13(64)
CL HG	B9	9(32)
CL K	B9	11(173)
$CL\ K\ O_3$	B9	9(32)
$CL\ K\ O_4$	B9	9(32)
$CL\ K\ O_4$	B9	10(74)
CL LI	B9	2(2-26)
CL LI	B9	4(B26)
CL LI	B9	5(229)
CL NA	B9	9(31)
CL NA	B9	11(167)
$CL_2\ H_2\ MG\ O$	B9	2(2-16)
$CL_2\ H_2\ MG\ O$	B9	4(B16)

$CL_2H_4MGO_2$	B9	4(B17)
$CL_2H_4MGO_4$	B9	2(2-17)
$CL_2H_8MGO_4$	B9	2(2-18)
$CL_2H_8MGO_4$	B9	4(B18)
$CL_2H_{12}MGO_6$	B9	2(2-19)
$CL_2H_{12}MGO_6$	B9	4(B19)
CL_2MG	B9	2(2-15)
CL_2MG	B9	4(B15)
CL_4ZR	B9	5(252)
$CO\ O\text{--}FE_2O_3$	B9	13(73)
CRK_2O_4	B9	13(78)
FH_4N	B9	9(32)
FH_4N	B9	10(79)
FH_6NO	B9	9(32)
FH_6NO	B9	10(80)
FK	B9	11(171)
FLI	B9	2(2-25)
FLI	B9	4(B24)
FNA	B9	9(31)
FNA	B9	11(165)
F_2HLI	B9	9(31)
F_2HNA	B9	9(31)
F_2HNA	B9	10(69)
F_2MG	B9	2(2-14)
F_2MG	B9	4(B14)
F_3N	B9	9(32)
$FE\ O\text{--}CO_2O_3$	B9	13(74)
FE_2O_3	B9	13(76)
$FE_2O_3\text{-}CA\ O$	B9	13(69)
$FE_2O_3\text{-}CA_2O_2$	B9	13(71)
$FE_2O_3\text{-}CO\ O$	B9	13(73)
$FE_2O_3\text{-}NI\ O$	B9	13(75)
HF_2LI	B9	10(63)
HLI O	B9	2(2-23)
HLI O	B9	4(B23)
HNO_3	B9	9(32)
HNO_3	B9	10(81)
HNA	B9	9(31)
HO NA	B9	9(31)
HZR	B9	11(156)
H --ZR	B9	5(243)
H --ZR	B9	5(244)
H --ZR	B9	5(245)
H --ZR	B9	5(246)
H --ZR	B9	5(247)
H --ZR	B9	11(154)
H --ZR	B9	11(156)
H --ZR	B9	11(157)
H_2MG	B9	2(2-12)
H_2MG	B9	4(B12)
H_2MGO_2	B9	2(2-13)
H_2MGO_2	B9	4(B13)
H_2NNA	B9	9(31)
H_2NNA	B9	10(68)
H_3LIO_2	B9	2(2-24)
H_3LIO_2	B9	4(B24)
H_3NO_4	B9	9(32)
H_3NO_4	B9	10(82)
$H_4N_2O_3$	B9	9(32)
H_5NO	B9	9(32)
H_5NO	B9	10(78)
H_7NO_6	B9	9(32)
H_7NO_6	B9	10(83)
H_8N_2O	B9	9(32)
H_8N_2O	B9	10(77)
HG	B9	9(32)
HG O	B9	9(32)
HG O	B9	10(84)
IKO_3	B9	10(76)
KNO_3	B9	9(32)
KNA_2	B9	9(31)
LI	B9	2(2-21)
LI	B9	4(B21)
LI	B9	5(227)
LI_2O	B9	2(2-22)
LI_2O	B9	4(B22)
LI_2O_3TI	B9	8(144)
LI_3N	B9	3(22)
LI_3N	B9	3(2-28)
LI_3N	B9	4(B28)
MG	B9	2(2- 9)
MG	B9	4(B 9)
MG O	B9	2(2-10)
MG O	B9	2(2-11)
MG O	B9	4(B10)
MG O	B9	4(B11)
MGO_3SI	B9	8(146)
MGO_4TI	B9	8(150)
MGO_4W	B9	8(143)
MGO_5TI_2	B9	8(152)
MG_2O_4SI	B9	8(148)
MG_2O_4TI	B9	8(154)
MG_3N_2	B9	3(22)
MG_3N_2	B9	3(2-30)
MG_3N_2	B9	4(B30)
$NNAO_3$	B9	9(31)
NTI	B9	3(22)
NTI	B9	3(2-32)
NTI	B9	4(B32)
NZR	B9	5(250)
NA	B9	9(31)
NAO_2	B9	9(31)
NAO_2	B9	10(67)
NA_2O	B9	9(31)
NA_2O_2	B9	9(31)
NA_2O_2	B9	10(66)
NA_2O_3SI	B9	9(31)
NA_2O_3TI	B9	9(31)
$NA_2O_5SI_2$	B9	9(31)
$NA_2O_5TI_2$	B9	9(31)
$NA_2O_7TI_3$	B9	9(31)
NA_4O_4SI	B9	9(31)
NA_4O_4SI	B9	13(51)
$NI\ O\text{--}FE_2O_3$	B9	13(75)
OPB	B9	8(158)
OPB	B9	8(160)
$O_2SI\text{--}CA_2O_2$ GAMMA	B9	13(65)
$O_2SI\text{--}CA_2O_2$ BETA	B9	13(67)
OTI	B9	5(231)
O_2PB	B9	8(161)
O_2TI	B9	5(237)
O_2TI	B9	5(239)
O_2W	B9	8(139)
O_2ZR	B9	5(248)
$O_3PB\ SI$	B9	8(164)
O_3PB_2	B9	8(162)
O_3TI_2	B9	5(233)
O_3W	B9	8(141)
O_4PB_2SI	B9	8(165)
O_4PB_3	B9	8(163)
$O_4SI_2\text{-}CA_3O_3$	B9	13(64)
O_5TI_3	B9	5(235)
PB	B9	8(156)
TI	B9	3(22)
TI	B9	3(2-40)
TI	B9	4(B40)
W	B9	8(137)
ZR	B9	5(241)
ZR	B9	11(154)
ZR--H	B9	5(243)
ZR--H	B9	5(244)
ZR--H	B9	5(245)
ZR--H	B9	5(246)
ZR--H	B9	5(247)
ZR--H	B9	11(154)
ZR--H	B9	11(156)
ZR--H	B9	11(157)
DF_2N	C1	8(125)
F_2HN	C1	8(125)
AG	C5	12(184)
AG CL	C5	12(184)
AG_2O	C5	12(184)
AG +	C5	12(184)
BR	C5	12(168)
BR +	C5	12(168)
BR -	C5	12(168)

BR CL	C5	12(169)
BR F_5	C5	12(169)
BR H	C5	12(169)
BR I	C5	12(171)
BR N O	C5	12(179)
BR O_2	C5	12(169)
BR_2	C5	12(168)
BR_2 +	C5	12(168)
BR_3 O P	C5	12(182)
BR_3 P S	C5	12(182)
C	C5	12(183)
C O	C5	12(183)
C O_2	C5	12(183)
CL	C5	12(167)
CL +	C5	12(167)
CL −	C5	12(167)
CL F	C5	12(168)
CL F O_3	C5	12(168)
CL F_4 H	C5	12(168)
CL F_5 S	C5	12(174)
CL H	C5	12(167)
CL I	C5	12(171)
CL K O_3	C5	12(184)
CL K O_4	C5	12(184)
CL N O	C5	12(178)
CL N O_2	C5	12(178)
CL O	C5	12(167)
CL O_3	C5	12(167)
CL_2	C5	12(167)
CL_2 +	C5	12(167)
CL_2 F_6	C5	12(168)
CL_2 O	C5	12(167)
CL_2 O S	C5	12(173)
CL_2 O_2 S	C5	12(174)
CL_2 O_5 S_2	C5	12(174)
CL_2 O_7	C5	12(167)
CL_2 PB	C5	12(184)
CL_2 S_2	C5	12(173)
CL_2 SE_2	C5	12(174)
CL_3 O P	C5	12(182)
CL_3 P	C5	12(182)
CL_3 P +	C5	12(182)
CL_3 P S	C5	12(182)
CL_5 P	C5	12(182)
D	C5	12(165)
D H O	C5	12(165)
D O	C5	12(165)
D_2	C5	12(165)
D_2 O	C5	12(165)
F	C5	12(166)
F +	C5	12(166)
F −	C5	12(166)
F H	C5	12(166)
F N O	C5	12(178)
F N O_2	C5	12(178)
F O	C5	12(166)
F_2	C5	12(166)
F_2 +	C5	12(166)
F_2 H N	C5	12(178)
F_2 N	C5	12(178)
F_2 N_2	C5	12(178)
F_2 O	C5	12(166)
F_2 O S	C5	12(173)
F_2 O_2	C5	12(166)
F_2 O_2 S	C5	12(173)
F_2 O_3	C5	12(166)
F_3 N	C5	12(178)
F_3 O P	C5	12(182)
F_3 P	C5	12(182)
F_4 N_2	C5	12(178)
F_4 S	C5	12(173)
F_5 I	C5	12(171)
F_5 P	C5	12(182)
F_6 S	C5	12(173)
F_6 SE	C5	12(174)
F_6 TE	C5	12(175)
F_7 I	C5	12(171)
H	C5	12(165)
H +	C5	12(165)
H −−	C5	12(165)
H D	C5	12(165)
H I	C5	12(170)
H K O	C5	12(184)
H N	C5	12(175)
H N O_2	C5	12(176)
H N_3	C5	12(176)
H N_3 +	C5	12(176)
H O	C5	12(165)
H O −	C5	12(165)
H O NA	C5	12(184)
H O_2	C5	12(165)
H O_2 +	C5	12(165)
H_2	C5	12(165)
H_2 +	C5	12(165)
H_2 N	C5	12(175)
H_2 O	C5	12(165)
H_2 O +	C5	12(165)
H_2 O_2	C5	12(165)
H_2 O_2 +	C5	12(166)
H_2 S	C5	12(172)
H_2 SE	C5	12(174)
H_2 TE	C5	12(175)
H_3 N	C5	12(175)
H_3 P	C5	12(180)
H_3 P +	C5	12(180)
H_4 N_2	C5	12(176)
H_4 P_2	C5	12(180)
H_6 N_2 O	C5	12(177)
I	C5	12(169)
I +	C5	12(169)
I −	C5	12(170)
I_2	C5	12(170)
I_2 O_5	C5	12(170)
I_3 P	C5	12(182)
K +	C5	12(184)
N	C5	12(175)
N +	C5	12(175)
N O	C5	12(175)
N O +	C5	12(175)
N O_2 +	C5	12(175)
N P	C5	12(183)
N_2	C5	12(175)
N_2 O	C5	12(175)
N_2 O_4	C5	12(175)
N_3 +	C5	12(175)
N_3 −	C5	12(175)
NA +	C5	12(184)
O	C5	12(165)
O +	C5	12(165)
O −	C5	12(165)
O S	C5	12(171)
O_2	C5	12(165)
O_2 +	C5	12(165)
O_2 S	C5	12(171)
O_3	C5	12(165)
O_3 S	C5	12(172)
S	C5	12(171)
S +	C5	12(171)
S −	C5	12(171)
S_2	C5	12(171)
S_3	C5	12(171)
S_4	C5	12(171)
S_5	C5	12(171)
S_6	C5	12(171)
S_7	C5	12(171)
S_8	C5	12(171)
SE_2	C5	12(174)
SE_6	C5	12(174)
TE_2	C5	12(175)
AL	C6	2(1-13)
AL	C6	4(A13)
AL +	C6	6(229)
AL BE O	C6	12(140)
AL CL	C6	1(125)
AL CL	C6	2(1-30)
AL CL	C6	4(A32)
AL CL F_2	C6	2(1-61)
AL CL F_2	C6	4(A65)

AL CL O	C6	2(1-58)
AL CL O	C6	4(A62)
AL CL_2	C6	2(1-63)
AL CL_2	C6	4(A67)
AL CL_2 F	C6	2(1-62)
AL CL_2 F	C6	4(A66)
AL CL_3	C6	2(1-64)
AL CL_3	C6	4(A68)
AL F	C6	1(123)
AL F	C6	2(1-29)
AL F	C6	4(A31)
AL F O	C6	2(1-57)
AL F O	C6	4(A61)
AL F_2	C6	2(1-59)
AL F_2	C6	4(A63)
AL F_3	C6	2(1-60)
AL F_3	C6	4(A64)
AL H	C6	4(A30)
AL H O	C6	2(1-55)
AL H O	C6	4(A59)
AL H O_2	C6	2(1-56)
AL H O_2	C6	4(A60)
AL O	C6	1(127)
AL O	C6	2(1-28)
AL O	C6	4(A29)
AL S	C6	4(A33)
AL_2	C6	4(A28)
AL_2 CL_6	C6	2(1-65)
AL_2 CL_6	C6	4(A69)
AL_2 O	C6	2(1-53)
AL_2 O	C6	4(A57)
AL_2 O	C6	11(144)
AL_2 O_2	C6	2(1-54)
AL_2 O_2	C6	4(A58)
AR	C6	2(1-18)
AR	C6	4(A18)
AR +	C6	6(239)
B	C6	2(1- 5)
B	C6	4(A 5)
B	C6	5(53)
B +	C6	6(213)
B BR	C6	2(1-42)
B BR	C6	4(A45)
B BR	C6	5(113)
B BR CL_2	C6	5(121)
B BR F_2	C6	5(117)
B BR_2 CL	C6	5(123)
B BR_2 F	C6	5(119)
B BR_3	C6	5(115)
B CL	C6	2(1-41)
B CL	C6	4(A44)
B CL	C6	5(95)
B CL F	C6	5(107)
B CL F_2	C6	5(109)
B CL O	C6	5(101)
B CL_2	C6	5(97)
B CL_2 F	C6	5(111)
B CL_3	C6	5(99)
B F	C6	2(1-40)
B F	C6	4(A43)
B F	C6	5(85)
B F O	C6	5(91)
B F_2	C6	5(87)
B F_3	C6	5(89)
B H	C6	2(1-39)
B H	C6	4(A42)
B H	C6	5(65)
B H O_2	C6	5(77)
B H_3	C6	5(67)
B H_3 O_3	C6	5(81)
B I_3	C6	5(125)
B N	C6	2(1-44)
B N	C6	4(A47)
B N	C6	5(131)
B O	C6	2(1-38)
B O	C6	4(A41)
B O	C6	5(57)
B S	C6	2(1-43)
B S	C6	4(A46)
B S	C6	5(127)

B_2	C6	2(1-37)
B_2	C6	4(A40)
B_2	C6	5(55)
B_2 CL_4	C6	5(101)
B_2 H_6	C6	5(69)
B_2 O_2	C6	5(59)
B_2 O_3	C6	5(61)
B_2 O_3	C6	5(63)
B_3 CL_3 O_3	C6	5(105)
B_3 F_3 O_3	C6	5(93)
B_3 H_2 N_3	C6	5(133)
B_3 H_3 O_6	C6	5(83)
B_5 H_9	C6	5(72)
B_{10} H_{14}	C6	5(75)
BA H	C6	12(158)
BE	C6	2(1- 4)
BE	C6	4(A 4)
BE +	C6	6(211)
BE CL	C6	1(113)
BE CL	C6	2(1-24)
BE CL	C6	4(A24)
BE CL F	C6	2(1-49)
BE CL F	C6	4(A53)
BE CL_2	C6	2(1-48)
BE CL_2	C6	4(A52)
BE F	C6	1(111)
BE F	C6	2(1-23)
BE F	C6	4(A23)
BE F_2	C6	2(1-47)
BE F_2	C6	4(A51)
BE F_2	C6	12(138)
BE O	C6	1(115)
BE O	C6	2(1-22)
BE O	C6	4(A22)
BE_2 F_2 O	C6	11(146)
BR +	C6	6(247)
C	C6	2(1- 6)
C	C6	4(A 6)
C +	C6	6(215)
CA H	C6	12(154)
CL	C6	2(1-17)
CL	C6	4(A17)
CL +	C6	6(237)
CL −	C6	12(130)
CL F	C6	1(133)
CL F	C6	2(1-36)
CL F	C6	4(A39)
CL F MG	C6	2(1-52)
CL F MG	C6	4(A56)
CL H	C6	2(1-34)
CL H	C6	4(A37)
CL LI	C6	1(109)
CL LI	C6	2(1-21)
CL LI	C6	4(A21)
CL MG	C6	1(119)
CL MG	C6	2(1-27)
CL MG	C6	4(A27)
CL O	C6	1(135)
CL O	C6	2(1-35)
CL O	C6	4(A38)
CL_2	C6	1(131)
CL_2	C6	2(1-33)
CL_2	C6	4(A36)
CL_2 LI_2	C6	2(1-46)
CL_2 LI_2	C6	4(A50)
CL_2 MG	C6	2(1-51)
CL_2 MG	C6	4(A55)
D F_2 N	C6	8(130)
E −	C6	7(109)
F	C6	2(1- 9)
F	C6	4(A 9)
F +	C6	6(221)
F −	C6	12(128)
F H	C6	2(1-32)
F H	C6	4(A35)
F LI	C6	1(107)
F LI	C6	2(1-20)
F LI	C6	4(A20)
F MG	C6	1(117)
F MG	C6	2(1-26)

F MG	C6	4(A26)
F_2	C6	1(129)
F_2	C6	2(1-31)
F_2	C6	4(A34)
F_2 H N	C6	8(128)
F_2 LI 2	C6	2(1-45)
F_2 LI_2	C6	4(A49)
F_2 MG	C6	2(1-5D)
F_2 MG	C6	4(A54)
F_2 N	C6	6(241)
F_4 N_2	C6	6(243)
H	C6	2(1- 1)
H	C6	4(A 1)
H +	C6	7(1D7)
H −	C6	12(124)
H BE	C6	12(144)
H LI	C6	12(142)
H N	C6	12(146)
H P	C6	12(15D)
H SR	C6	12(156)
H_2	C6	7(111)
H_2	C6	11(157)
HE	C6	2(1- 2)
HE	C6	4(A 2)
HE +	C6	6(2D7)
HG +	C6	6(261)
I +	C6	6(255)
K +	C6	6(257)
K H	C6	12(152)
LI	C6	2(1- 3)
LI	C6	4(A 3)
LI +	C6	6(2D9)
LI D	C6	12(16D)
LI_2	C6	1(1D5)
LI_2	C6	2(1-19)
LI_2	C6	4(A19)
LI_2 D	C6	11(148)
LI_2 D_2	C6	11(15D)
MG	C6	2(1-12)
MG	C6	4(A12)
MG +	C6	6(227)
MG D	C6	1(121)
MG D	C6	2(1-25)
MG O	C6	4(A25)
MD +	C6	6(253)
N	C6	2(1- 7)
N	C6	4(A 7)
N +	C6	6(217)
N D +	C6	12(136)
N_2	C6	3(1-66)
N_2	C6	4(A48)
N_2 P	C6	12(132)
NA	C6	2(1-11)
NA	C6	4(A11)
NA H	C6	12(148)
NA +	C6	6(225)
NE	C6	2(1-1D)
NE	C6	4(A1D)
NE +	C6	6(223)
D	C6	2(1- 8)
D	C6	4(A 8)
D +	C6	6(219)
D −	C6	12(126)
O_2	C6	7(113)
O_2 +	C6	12(134)
P	C6	2(1-15)
P	C6	4(A15)
P +	C6	6(233)
PB +	C6	6(259)
S	C6	2(1-16)
S	C6	4(A16)
S +	C6	6(235)
SI	C6	2(1-14)
SI	C6	4(A14)
SI +	C6	6(231)
TI +	C6	6(245)
W +	C6	6(249)
ZR +	C6	6(251)

H_2	C7	11(83)
AL F_3	D1	9(157)
AL_2 D_3	D1	8(61)
AL_2 O_3	D1	11(99)
AL_2 O_3	D1	12(81)
BE--F --O	D1	8(55)
F --BE--D	D1	8(55)
MG O	D1	12(83)
AL	D2	1(48)
AL--D	D2	1(5D)
AL--D	D2	2(61)
AL_2 O_3	D2	4(33)
BE	D2	1(48)
BE	D2	1(54)
BE--D	D2	2(63)
BE CL_2	D2	2(71)
BE F_2	D2	2(71)
BE F_2	D2	4(35)
BE D	D2	1(53)
BE D	D2	1(54)
BE D	D2	4(31)
BE_2 D_2	D2	1(54)
BE_3 D_3	D2	1(54)
BE_4 D_4	D2	1(54)
BE_5 D_5	D2	1(54)
BE_6 O_6	D2	1(54)
CL LI	D2	2(79)
F LI	D2	4(36)
LI	D2	1(48)
LI--O	D2	2(64)
MG	D2	1(48)
MG--D	D2	2(64)
D	D2	1(54)
D --AL	D2	1(5D)
O --AL	D2	2(61)
O --BE	D2	2(63)
D --LI	D2	2(64)
D --MG	D2	2(64)
D_2	D2	1(54)
AL CL	D3	8(114)
AL CL_2	D3	8(114)
AL F	D3	8(114)
AL F_3	D3	2(63)
AL N	D3	3(37)
AL N --AL_4 C_3	D3	3(34)
AL_2 CL_6	D3	2(66)
AL_2 F_6	D3	2(65)
AL_2 F_6	D3	9(157)
AL_2 D_3-AL_4 C_3	D3	3(4D)
AL_4 C_3	D3	3(32)
AL_4 C_3-AL N	D3	3(34)
AL_4 C_3-AL_2 D_3	D3	3(4D)
AL_5 C_3 N	D3	3(35)
BE F	D3	8(114)
BE F_2	D3	8(119)
BE F_2	D3	11(113)
BE--D	D3	2(63)
BE_2 C	D3	3(41)
BE_3 N_2	D3	3(43)
C TI	D3	3(47)
C_2 LI_2	D3	3(45)
C_2 MG	D3	3(43)
C_3 MG_2	D3	3(43)
CL_2 MG	D3	2(73)
F LI	D3	2(74)
F LI	D3	2(77)
F_2 LI_2	D3	2(74)
F_2 MG	D3	2(71)
F_2 MG	D3	2(72)
H --ZR	D3	5(181)
H --ZR	D3	11(94)
LI_3 N	D3	3(46)
MG_3 N_2	D3	3(45)
N TI	D3	3(49)

O --BE	O3	2(63)
ZR--H	O3	5(181)
ZR--H	D3	11(94)
AL F 3	D8	9(158)
AL F 3	D9	9(164)
AL F 3	D9	9(165)
AL H 3 ME6 N 4	D9	3(57)
AL H 3 ME6 N 4	O9	3(59)
AL2 O 3	O9	3(41)
AL2 O 3	O9	8(67)
AL4 C 3	O9	3(33)
AL4 C 3	D9	3(34)
C TI	O9	3(49)
AL B 10	E2	5(150)
AL B 12	E2	5(150)
AL2 BE O 4	E2	5(160)
AL2 H 2 O 4	E2	1(88)
AL2 H 6 O 6	E2	1(88)
AL2 MG O 4	E2	5(160)
AL2 O --O 2 TI	E2	5(160)
AL2 O 3	E2	1(88)
AL2 O 3	E2	5(160)
AL2 O 4 ZR	E2	5(160)
B BE2	E2	5(150)
B N	E2	5(150)
B TI	E2	5(150)
B ZR	E2	5(150)
B 2 TI	E2	5(150)
B 2 ZR	E2	5(150)
B 4 C	E2	5(150)
B 5 TI2	E2	5(150)
B 6 BE	E2	5(150)
B 12ZR	E2	5(150)
B 13C 2	E2	5(150)
BE O	E2	5(160)
LI2 O	E2	5(160)
MG O	E2	5(160)
MG O 3 TI	E2	5(160)
O 2 TI	E2	5(160)
O 2 TI--AL2 O 3	E2	5(160)
O 2 ZR	E2	5(160)
AL--B	F2	5(187)
AL--BE	F2	5(188)
AL--LI	F2	5(189)
AL--MG	F2	5(190)
AL--SI	F2	5(191)
AL--TI	F2	5(192)
AL--ZR	F2	5(193)
AL F 3-AL2 O 3-F LI	F2	5(156)
AL F 3-AL2 O 3-F LI	F2	5(206)
AL F 3-F K	F2	5(222)
AL F 3-F LI	F2	5(155)
AL F 3-F LI	F2	5(165)
AL F 3-F LI	F2	5(220)
AL F 3-F NA	F2	5(221)
AL2 O 3-AL F 3-F LI	F2	5(156)
AL2 O 3-AL F 3-F LI	F2	5(206)
AL2 O 3-BE O	F2	5(155)
AL2 O 3-BE O	F2	5(206)
AL2 O 3-BE O --MG O	F2	5(156)
AL2 O 3-BE O --MG O	F2	5(207)
AL2 O 3-BE O --O 2 TI	F2	5(156)
AL2 O 3-BE O --O 2 TI	F2	5(207)
AL2 O 3-BE O --O 2 ZR	F2	5(156)
AL2 O 3-BE O --O 2 ZR	F2	5(207)
AL2 O 3-MG O	F2	5(156)
AL2 O 3-MG O	F2	5(208)
AL2 O 3-MG O --O 2 TI	F2	5(156)
AL2 O 3-MG O --O 2 TI	F2	5(209)
AL2 O 3-O 2 TI	F2	5(156)
AL2 O 3-O 2 TI	F2	5(209)
AL2 O 3-O 2 TI--O 2 ZR	F2	5(157)
AL2 O 3-O 2 TI- O 2 ZR	F2	5(210)
B --AL	F2	5(187)
B --TI	F2	5(194)
B --ZR	F2	5(195)
B 2 O 3-LI2 O	F2	5(157)
B 2 O 3-LI2 O	F2	5(213)
B 2 O 3-MG O	F2	5(157)
B 2 O 3-MG O	F2	5(214)
BE--AL	F2	5(188)
BE--SI	F2	5(196)
BE--ZR	F2	5(197)
BE F 2-F LI	F2	5(163)
BE F 2-F LI	F2	5(218)
BE F 2-F 2 MG	F2	5(166)
BE F 2-F 2 MG	F2	5(224)
BE F 2-F 2 MG	F2	5(225)
BE O --AL2 O 3	F2	5(155)
BE O --AL2 O 3	F2	5(206)
BE O --AL2 O 3-MG O	F2	5(156)
BE O --AL2 O 3-MG O	F2	5(207)
BE O --AL2 O 3-O 2 ZR	F2	5(156)
BE O --AL2 O 3-O 2 TI	F2	5(156)
BE O --AL2 O 3-O 2 ZR	F2	5(207)
BE O --AL2 O 3-O 2 TI	F2	5(207)
BE O --MG O —O 2 ZR	F2	5(157)
BE O --MG O —O 2 ZR	F2	5(211)
BE O --O 2 TI	F2	5(157)
BE O --O 2 TI	F2	5(211)
BE O --O 2 TI—O 2 ZR	F2	5(157)
BE O --O 2 TI—O 2 ZR	F2	5(212)
CL LI--F LI	F2	5(163)
CL LI--F LI	F2	5(217)
F K --AL F 3	F2	5(222)
F LI--AL F 3	F2	5(155)
F LI--AL F 3	F2	5(165)
F LI--AL F 3	F2	5(220)
F LI--AL F 3-AL2 O 3	F2	5(156)
F LI--AL F 3-AL2 O 3	F2	5(206)
F LI--BE F 2	F2	5(163)
F LI--BE F 2	F2	5(218)
F LI--CL LI	F2	5(163)
F LI--CL LI	F2	5(217)
F LI--F 2 MG	F2	5(164)
F LI--F 2 MG	F2	5(219)
F LI--F 4 ZR	F2	5(166)
F LI--F 4 ZR	F2	5(223)
F NA--AL F 3	F2	5(221)
F 2 MG--F LI	F2	5(164)
F 2 MG--F LI	F2	5(219)
F 2 MG--BE F 2	F2	5(166)
F 2 MG--BE F 2	F2	5(224)
F 2 MG--BE F 2	F2	5(225)
F 2 MG--MG O	F2	5(158)
F 4 ZR--F LI	F2	5(166)
F 4 ZR--F LI	F2	5(223)
LI--AL	F2	5(189)
LI--MG	F2	5(198)
LI2 O --B 2 O 3	F2	5(157)
LI2 O --B 2 O 3	F2	5(213)
MG--AL	F2	5(190)
MG--LI	F2	5(198)
MG--SI	F2	5(199)
MG--TI	F2	5(200)
MG--ZR	F2	5(201)
MG O --AL2 O 3	F2	5(156)
MG O --AL2 O 3	F2	5(208)
MG O --AL2 O 3-BE O	F2	5(156)
MG O --AL2 O 3-BE O	F2	5(207)
MG O --AL2 O 3-O 2 TI	F2	5(156)
MG O --AL2 O 3-O 2 TI	F2	5(209)
MG O --B 2 O 3	F2	5(157)
MG O --B 2 O 3	F2	5(214)
MG O --BE O —O 2 ZR	F2	5(157)
MG O --BE O —O 2 ZR	F2	5(211)
MG O --F 2 MG	F2	5(158)
MG O --O 2 TI	F2	5(158)
MG O --O 2 TI	F2	5(214)
MG O --O 2 TI—O 2 ZR	F2	5(158)
MG O --O 2 TI—O 2 ZR	F2	5(216)
MG O --O 2 ZR	F2	5(158)

MG O --O$_2$ ZR	F2	5(215)
O$_2$ TI--AL$_2$ O$_3$	F2	5(156)
O$_2$ TI--AL$_2$ O$_3$	F2	5(209)
O$_2$ TI--AL$_2$ O$_3$-BE O	F2	5(156)
O$_2$ TI--AL$_2$ O$_3$-BE O	F2	5(207)
O$_2$ TI--AL$_2$ O$_3$-MG O	F2	5(156)
O$_2$ TI--AL$_2$ O$_3$-MG O	F2	5(209)
O$_2$ TI--AL$_2$ O$_3$-O$_2$ ZR	F2	5(157)
O$_2$ TI--AL$_2$ O$_3$-O$_2$ ZR	F2	5(210)
O$_2$ TI--BE O	F2	5(157)
O$_2$ TI--BE O	F2	5(211)
O$_2$ TI--BE O --O$_2$ ZR	F2	5(157)
O$_2$ TI--BE O --O$_2$ ZR	F2	5(212)
O$_2$ TI--MG O	F2	5(158)
O$_2$ TI--MG O	F2	5(214)
O$_2$ TI--MG O --O$_2$ ZR	F2	5(158)
O$_2$ TI--MG O --O$_2$ ZR	F2	5(216)
O$_2$ TI--O$_2$ ZR	F2	5(158)
O$_2$ TI--O$_2$ ZR	F2	5(216)
O$_2$ ZR--O$_2$ TI	F2	5(158)
O$_2$ ZR--O$_2$ TI	F2	5(216)
O$_2$ ZR--AL$_2$ O$_3$-BE O	F2	5(156)
O$_2$ ZR--AL$_2$ O$_3$-BE O	F2	5(207)
O$_2$ ZR--AL$_2$ O$_3$-O$_2$ TI	F2	5(157)
O$_2$ ZR--AL$_2$ O$_3$-O$_2$ TI	F2	5(210)
O$_2$ ZR--BE O --MG O	F2	5(157)
O$_2$ ZR--BE O --MG O	F2	5(211)
O$_2$ ZR--BE O --O$_2$ TI	F2	5(157)
O$_2$ ZR--BE O --O$_2$ TI	F2	5(212)
O$_2$ ZR--MG O	F2	5(158)
O$_2$ ZR--MG O	F2	5(215)
O$_2$ ZR--MG O --O$_2$ TI	F2	5(158)
O$_2$ ZR--MG O --O$_2$ TI	F2	5(216)
SI--AL	F2	5(191)
SI--BE	F2	5(196)
SI--MG	F2	5(199)
SI--TI	F2	5(202)
SI--ZR	F2	5(203)
TI--AL	F2	5(192)
TI--B	F2	5(194)
TI--MG	F2	5(200)
TI--SI	F2	5(202)
TI--ZR	F2	5(204)
ZR--AL	F2	5(193)
ZR--B	F2	5(195)
ZR--BE	F2	5(197)
ZR--MG	F2	5(201)
ZR--SI	F2	5(203)
ZR--TI	F2	5(204)
H --ZR	F3	5(205)
H --ZR	F3	11(95)
ZR--H	F3	5(205)
ZR--H	F3	11(95)
AL B$_3$ H$_{12}$	G1	13(8)
AL CL	G1	12(57)
AL F	G1	9(12)
AL F	G1	12(57)
AL$_2$ O	G1	11(119)
B$_2$ BE H$_8$	G1	13(8)
CL LI	G1	10(13)
CL LI	G1	10(18)
D F$_2$ N	G1	8(125)
F H	G1	4(46)
F$_2$ +	G1	13(24)
F$_2$ H N	G1	8(125)
F$_2$ MG	G1	13(24)
F$_2$ N	G1	6(33)
F$_4$ N$_2$	G1	2(36)
F$_4$ N$_2$	G1	6(33)
LI O	G1	11(118)
LI$_2$ O	G1	11(118)
LI$_2$ O$_2$	G1	11(118)
AL C	G2	4(43)
AL CL	G2	1(42)
AL CL	G2	4(43)
AL CL F$_2$	G2	1(44)
AL CL O	G2	1(44)
AL CL$_2$	G2	1(44)
AL CL$_2$ F	G2	1(44)
AL CL$_3$	G2	1(44)
AL F	G2	1(42)
AL F	G2	4(43)
AL F O	G2	1(44)
AL F$_2$	G2	1(44)
AL F$_3$	G2	1(44)
AL H	G2	4(43)
AL H O	G2	1(44)
AL H O$_2$	G2	1(44)
AL O	G2	1(42)
AL O	G2	4(45)
AL S	G2	4(45)
AL$_2$	G2	4(42)
BE CL	G2	1(42)
BE CL F	G2	1(43)
BE CL$_2$	G2	1(43)
BE F	G2	1(42)
BE F	G2	4(45)
BE F$_2$	G2	1(43)
BE O	G2	1(42)
CL F	G2	1(42)
CL F MG	G2	1(43)
CL LI	G2	1(42)
CL MG	G2	1(42)
CL O	G2	1(42)
CL$_2$	G2	1(42)
CL$_2$ LI$_2$	G2	1(43)
CL$_2$ MG	G2	1(43)
F H	G2	4(46)
F LI	G2	1(42)
F MG	G2	1(42)
F$_2$	G2	1(42)
F$_2$ LI$_2$	G2	1(43)
F$_2$ MG	G2	1(43)
F$_2$ N	G2	6(33)
F$_4$ N$_2$	G2	6(33)
LI$_2$	G2	1(42)
MG O	G2	1(42)
BE F	G3	8(109)
AL CL	G6	12(64)
AL CL	G6	12(65)
AL CL	G6	12(66)
AL F	G6	12(64)
AL F	G6	12(65)
AL BE O	G7	12(85)
BE F$_2$	G7	12(85)
BE$_2$ F$_2$ O	G7	11(119)
AL CL	G9	2(50)
AL CL F$_2$	G9	2(51)
AL CL O	G9	2(51)
AL CL$_2$	G9	2(51)
AL CL$_2$ F	G9	2(51)
AL CL$_3$	G9	2(51)
AL F	G9	2(50)
AL F	G9	4(47)
AL F	G9	9(14)
AL F O	G9	2(51)
AL F$_2$	G9	2(51)
AL F$_3$	G9	2(51)
AL H	G9	4(47)
AL H O	G9	2(51)
AL H O$_2$	G9	2(7)
AL O	G9	2(50)
AL S	G9	4(47)
AL$_2$	G9	4(47)
B BR	G9	5(43)
B BR CL$_2$	G9	5(47)

B BR F 2	G9	5(47)
B BR2	G9	5(47)
B BR2 CL	G9	5(47)
B BR2 F	G9	5(47)
B CL	G9	5(43)
B CL F	G9	5(46)
B CL O	G9	5(46)
B CL2	G9	5(46)
B CL2 F	G9	5(47)
B CL3	G9	5(46)
B F	G9	5(43)
B F O	G9	5(46)
B F 2	G9	5(46)
B F 3	G9	5(46)
B H	G9	5(43)
B H O 2	G9	5(45)
B H 3	G9	5(45)
B H 3 O 3	G9	5(46)
B I 3	G9	5(47)
B N	G9	5(43)
B O	G9	5(43)
B S	G9	5(43)
B 2	G9	5(43)
B 2 CL4	G9	5(46)
B 2 H 6	G9	5(45)
B 2 O 2	G9	5(45)
B 2 O 3	G9	5(45)
B 3 CL3 O 3	G9	5(46)
B 3 F 3 O 3	G9	5(46)
B 3 H 3 O 6	G9	5(46)
B 3 H 6 N 3	G9	5(47)
B 5 H 9	G9	5(45)
B 10H 14	G9	5(45)
BE O	G9	2(50)
BR CS	G9	10(19)
BR K	G9	10(19)
BR LI	G9	10(19)
BR NA	G9	10(19)
BR RB	G9	10(19)
BE CL	G9	2(50)
BE CL F	G9	2(51)
BE CL2	G9	2(51)
BE F	G9	2(50)
BE F	G9	4(47)
BE F 2	G9	2(51)
CL CS	G9	10(19)
CL F	G9	2(50)
CL F MG	G9	2(51)
CL K	G9	10(19)
CL LI	G9	2(50)
CL LI	G9	10(18)
CL LI	G9	10(19)
CL MG	G9	2(50)
CL NA	G9	10(19)
CL O	G9	2(50)
CL RB	G9	10(19)
CL2	G9	2(50)
CL2 LI2	G9	2(51)
CL2 MG	G9	2(51)
CS I	G9	10(19)
F CS	G9	10(19)
F H	G9	4(47)
F K	G9	10(19)
F LI	G9	2(50)
F LI	G9	10(19)
F MG	G9	2(50)
F NA	G9	10(19)
F RB	G9	10(19)
F 2	G9	2(50)
F 2 MG	G9	2(51)
F 4 N 2	G9	2(38)
F 4 N 2	G9	2(39)
I K	G9	10(19)
I LI	G9	10(19)
I NA	G9	10(19)
I RB	G9	10(19)
LI2	G9	2(50)
MG O	G9	2(50)

AL--O	H1	8(55)
AL2 O 3	H1	13(12)
F 4 N 2	H1	10(36)
O --AL	H1	8(55)
AL2 BE O 4	J1	12(83)
AL2 O 3	J1	13(12)
AL H	J2	1(99)
AL N	J2	4(26)
AL2 H 2 O 4	J2	1(90)
AL2 H 2 O 4	J2	1(91)
AL2 H 6 O 6	J2	1(90)
AL2 O 3	J2	1(91)
AL2 O 3	J2	1(92)
AL4 C 3	J2	4(22)
BE H 2	J2	1(100)
BE H 2 O 2	J2	1(94)
BE O	J2	1(94)
BE2 C	J2	4(20)
BE3 N 2	J2	4(25)
C 2 LI2	J2	4(18)
C 2 MG	J2	4(21)
C 3 MG2	J2	4(21)
H LI O	J2	1(97)
H 2 MG	J2	1(101)
H 2 MG O 2	J2	1(96)
H 3 LI O 2	J2	1(97)
H 3 LI O 3	J2	1(97)
LI2 O	J2	1(97)
LI3 N	J2	4(24)
MG O	J2	1(96)
MG3 N 2	J2	4(25)
BE F 2	J8	11(84)
BE F 2	J8	12(73)
BE H 2	J8	3(55)
AL	K1	12(26)
AL F 3	L1	8(13)
AL4 C 3	L1	11(23)
AL4 C 3	L1	11(26)
AL4 C 3	L8	11(1)
AL BE O	M1	13(25)
AL BE O +	M1	12(118)
AL2 BE O 4	M1	13(25)
AL2 O	M1	13(25)
AL2 O 3-BE O	M1	12(118)
AL2 O 3-BE O	M1	13(25)
BE--F --O	M1	8(55)
BE--F --O	M1	10(55)
BE F 2	M1	8(55)
BE F 2	M1	10(55)
BE F 2-BE O	M1	10(56)
BE F 2-BE O	M1	11(103)
BE O	M1	8(55)
BE O --AL2 O 3	M1	12(118)
BE O --AL2 O 3	M1	13(25)
BE O --BE F 2	M1	10(56)
BE O --BE F 2	M1	11(103)
F --BE--O	M1	8(55)
F --BE--O	M1	10(55)
O	M1	13(25)
O --BE--F	M1	8(55)
O --BE--F	M1	10(55)
AL--O	M8	8(56)
BE--F --O	M8	8(56)
F --BE--O	M8	8(56)
O --AL	M8	8(56)
O --BE--F	M8	8(56)
BE O --BE F 2	M9	11(110)
BE F 2	M9	10(57)
BE F 2-BE O	M9	11(109)
BE F 2-BE O	M9	11(110)
BE O --BE F 2	M9	11(109)

APPENDIX II

THERMODYNAMIC FUNCTIONS OF SOME SELECTED SUBSTANCES IN THE SOLID AND LIQUID STATES

by George T. Furukawa and Martin L. Reilly

(See Chapter B7 (pages 130-136) for discussion.)

TABLE B-134

THERMODYNAMIC FUNCTIONS FOR POTASSIUM NITRATE ($K N O_3$)
SOLID AND LIQUID PHASES

GRAM MOLECULAR WT.= 101.1069 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G^0_T-H^C_0)/T$	$(H^0_T-H^C_0)/T$	$(S_T-S^C_0)$	$(H^0_T-H^C_0)$	C^0_P	$-(G^0_T-H^C_0)$
DEG K	CAL DEG-MOLE	CAL DEG-MOLE	CAL DEG-MOLE	CAL MOLE	CAL DEG-MOLE	CAL MOLE
			SOLID PHASE (ALPHA)			
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.002	0.006	0.008	0.029	0.023	0.010
10.00	0.015	0.044	0.059	0.441	0.173	0.150
15.00	0.049	0.143	0.193	2.151	0.557	0.738
20.00	0.113	0.326	0.439	6.510	1.237	2.265
25.00	0.213	0.596	0.810	14.904	2.142	5.336
30.00	0.351	0.937	1.288	28.108	3.164	10.538
35.00	0.525	1.339	1.864	46.868	4.357	18.381
40.00	0.733	1.793	2.527	71.739	5.587	29.328
45.00	0.972	2.279	3.251	102.54	6.721	43.751
50.00	1.238	2.777	4.015	138.83	7.781	61.901
55.00	1.526	3.278	4.804	180.28	8.789	83.939
60.00	1.833	3.776	5.609	226.57	9.714	109.97
65.00	2.154	4.265	6.420	277.23	10.534	140.04
70.00	2.488	4.740	7.228	331.77	11.267	174.16
75.00	2.831	5.197	8.028	389.80	11.937	212.30
80.00	3.180	5.638	8.819	451.05	12.553	254.42
85.00	3.535	6.062	9.597	515.24	13.112	300.47
90.00	3.893	6.467	10.361	582.07	13.610	350.37
95.00	4.253	6.855	11.108	651.25	14.052	404.04
100.00	4.614	7.225	11.839	722.51	14.446	461.42
105.00	4.975	7.578	12.553	795.65	14.804	522.41
110.00	5.336	7.914	13.249	870.50	15.134	586.92
115.00	5.695	8.234	13.929	946.96	15.444	654.88
120.00	6.052	8.541	14.593	1024.9	15.736	726.19
125.00	6.406	8.834	15.241	1104.3	16.012	800.78
130.00	6.758	9.115	15.874	1185.0	16.272	878.57
135.00	7.107	9.385	16.492	1267.0	16.517	959.49
140.00	7.453	9.644	17.097	1350.2	16.749	1043.5
145.00	7.796	9.893	17.689	1434.5	16.968	1130.4
150.00	8.136	10.132	18.268	1519.8	17.178	1220.3
155.00	8.472	10.363	18.834	1606.2	17.380	1313.1
160.00	8.804	10.585	19.389	1693.6	17.576	1408.7
165.00	9.133	10.800	19.933	1782.0	17.769	1507.0
170.00	9.459	11.008	20.466	1871.3	17.960	1608.0
175.00	9.781	11.209	20.990	1961.6	18.149	1711.6
180.00	10.099	11.404	21.504	2052.8	18.338	1817.9
185.00	10.414	11.594	22.009	2145.0	18.527	1926.6
190.00	10.726	11.779	22.505	2238.1	18.715	2037.9
195.00	11.034	11.960	22.994	2332.1	18.903	2151.7
200.00	11.339	12.135	23.475	2427.1	19.091	2267.9
205.00	11.641	12.307	23.949	2523.0	19.280	2386.4
210.00	11.940	12.476	24.415	2619.9	19.468	2507.3
215.00	12.235	12.641	24.876	2717.7	19.658	2630.6
220.00	12.528	12.802	25.330	2816.5	19.848	2756.1
225.00	12.817	12.961	25.778	2916.2	20.039	2883.8
230.00	13.104	13.117	26.221	3016.9	20.231	3013.8
235.00	13.387	13.270	26.658	3118.5	20.423	3146.0
240.00	13.668	13.421	27.090	3221.1	20.616	3280.4
245.00	13.947	13.570	27.517	3324.7	20.810	3416.9
250.00	14.222	13.717	27.939	3429.2	21.003	3555.6
255.00	14.495	13.862	28.357	3534.7	21.195	3696.3
260.00	14.766	14.004	28.770	3641.1	21.386	3839.1
265.00	15.034	14.145	29.179	3748.5	21.576	3984.0
270.00	15.300	14.285	29.585	3856.9	21.764	4130.9
273.15	15.466	14.372	29.838	3925.6	21.881	4224.5
275.00	15.563	14.422	29.986	3966.2	21.950	4279.8
280.00	15.824	14.559	30.383	4076.4	22.133	4430.8
285.00	16.083	14.693	30.776	4187.5	22.313	4583.7
290.00	16.340	14.826	31.166	4299.5	22.491	4738.5
295.00	16.594	14.957	31.552	4412.4	22.667	4895.3
298.15	16.754	15.039	31.793	4484.0	22.776	4995.1
310.00	17.346	15.343	32.689	4756.3	23.179	5377.2

H^C_0 AND S^C_0 APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-134 (CONT.)

THERMODYNAMIC FUNCTIONS FOR POTASSIUM NITRATE ($K N O_3$)
SOLID AND LIQUID PHASES

GRAM MOLECULAR WT.= 101.1069 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / MOLE	CAL / DEG-MOLE	CAL / MOLE
			SOLID PHASE (ALPHA)			
300.00	16.847	15.087	31.934	4526.2	22.840	5054.0
320.00	17.837	15.593	33.430	4989.7	23.511	5707.8
330.00	18.320	15.838	34.158	5226.5	23.839	6045.7
340.00	18.797	16.078	34.875	5466.5	24.164	6390.9
350.00	19.266	16.314	35.580	5709.8	24.489	6743.2
360.00	19.729	16.545	36.274	5956.3	24.813	7102.4
370.00	20.185	16.773	36.959	6206.0	25.139	7468.6
373.15	20.328	16.844	37.172	6285.4	25.241	7585.4
380.00	20.636	16.997	37.633	6459.0	25.464	7841.6
390.00	21.080	17.219	38.299	6715.3	25.787	8221.3
400.00	21.519	17.437	38.956	6974.8	26.109	8607.5
401.00	21.562	17.458	39.021	7000.9	26.141	8646.5
			SOLID PHASE (BETA)			
401.00	21.562	20.958	42.520	8404.0	28.800	8646.5
401.00	21.562	20.958	42.520	8404.0	28.800	8646.5
425.00	22.794	21.400	44.194	9095.2	28.800	9687.3
450.00	24.029	21.812	45.840	9815.2	28.800	10813.
475.00	25.218	22.179	47.397	10535.	28.800	11979.
500.00	26.364	22.510	48.875	11255.	28.800	13182.
550.00	28.537	23.082	51.620	12695.	28.800	15696.
600.00	30.567	23.559	54.126	14135.	28.800	18340.
611.00	30.996	23.653	54.649	14452.	28.800	18938.
			LIQUID PHASE			
611.00	30.996	28.236	59.231	17252.	29.500	18938.
650.00	32.745	28.312	61.057	18402.	29.500	21284.
700.00	34.846	28.396	63.243	19877.	29.500	24392.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-135

THERMODYNAMIC FUCTIONS FOR SODIUM NITRATE ($NA\ N\ O_3$)
SOLID AND LIQUID PHASES

GRAM MOLECULAR WT.= 84.9947 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G^0_T-H^C_0)/T$	$(H^0_T-H^C_0)/T$	$(S_T-S^C_0)$	$(H^0_T-H^C_0)$	C^0_P	$-(G^0_T-H^C_0)$
DEG K	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / MOLE	CAL / DEG-MOLE	CAL / MOLE
			SOLID PHASE (ALPHA)			
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.001	0.003	0.004	0.017	0.013	0.006
10.00	0.009	0.027	0.035	0.266	0.106	0.089
15.00	0.030	0.090	0.120	1.346	0.359	0.449
20.00	0.071	0.212	0.283	4.239	0.839	1.417
25.00	0.137	0.403	0.540	10.072	1.518	3.435
30.00	0.232	0.653	0.886	19.603	2.309	6.966
35.00	0.355	0.951	1.306	33.291	3.173	12.417
40.00	0.503	1.283	1.786	51.333	4.045	20.126
45.00	0.675	1.639	2.314	73.747	4.923	30.358
50.00	0.866	2.012	2.879	100.61	5.824	43.324
55.00	1.076	2.399	3.476	131.95	6.706	59.199
60.00	1.302	2.793	4.095	167.56	7.528	78.117
65.00	1.541	3.187	4.728	207.12	8.288	100.17
70.00	1.792	3.577	5.368	250.37	9.005	125.41
75.00	2.051	3.962	6.013	297.12	9.690	153.86
80.00	2.319	4.340	6.659	347.21	10.338	185.54
85.00	2.594	4.711	7.304	400.42	10.936	220.45
90.00	2.873	5.072	7.945	456.47	11.476	258.58
95.00	3.157	5.422	8.579	515.09	11.966	299.89
100.00	3.444	5.761	9.204	576.06	12.418	344.35
105.00	3.733	6.088	9.820	639.23	12.842	391.92
110.00	4.023	6.404	10.427	704.44	13.242	442.54
115.00	4.315	6.710	11.024	771.61	13.620	496.17
120.00	4.606	7.005	11.611	840.60	13.975	552.76
125.00	4.898	7.291	12.189	911.33	14.312	612.27
130.00	5.190	7.567	12.757	983.70	14.634	674.64
135.00	5.480	7.834	13.315	1057.7	14.944	739.82
140.00	5.770	8.094	13.864	1133.1	15.242	807.77
145.00	6.058	8.345	14.403	1210.1	15.529	878.44
150.00	6.345	8.589	14.935	1288.4	15.804	951.79
155.00	6.631	8.826	15.457	1368.1	16.065	1027.8
160.00	6.915	9.056	15.971	1449.0	16.313	1106.3
165.00	7.197	9.280	16.477	1531.2	16.549	1187.5
170.00	7.477	9.497	16.974	1614.5	16.777	1271.1
175.00	7.755	9.708	17.464	1698.9	16.997	1357.2
180.00	8.032	9.914	17.945	1784.5	17.212	1445.7
185.00	8.306	10.114	18.420	1871.1	17.426	1536.6
190.00	8.578	10.309	18.888	1958.7	17.638	1629.9
195.00	8.849	10.500	19.348	2047.4	17.850	1725.5
200.00	9.117	10.686	19.803	2137.2	18.063	1823.4
205.00	9.383	10.869	20.252	2228.1	18.276	1923.5
210.00	9.647	11.047	20.695	2320.0	18.490	2025.9
215.00	9.909	11.223	21.132	2413.0	18.705	2130.5
220.00	10.169	11.396	21.565	2507.0	18.920	2237.2
225.00	10.427	11.565	21.992	2602.2	19.135	2346.1
230.00	10.683	11.732	22.415	2698.4	19.351	2457.1
235.00	10.937	11.896	22.834	2795.7	19.566	2570.2
240.00	11.189	12.058	23.248	2894.0	19.780	2685.4
245.00	11.440	12.218	23.658	2993.5	19.993	2802.7
250.00	11.688	12.376	24.064	3094.0	20.205	2922.0
255.00	11.935	12.531	24.466	3195.5	20.416	3043.3
260.00	12.180	12.685	24.865	3298.1	20.626	3166.7
265.00	12.423	12.837	25.259	3401.8	20.834	3292.0
270.00	12.664	12.987	25.651	3506.5	21.042	3419.3
273.15	12.815	13.081	25.896	3572.9	21.172	3500.4
275.00	12.904	13.135	26.039	3612.2	21.248	3548.5
280.00	13.142	13.282	26.424	3718.9	21.455	3679.6
285.00	13.378	13.427	26.805	3826.7	21.661	3812.7
290.00	13.613	13.571	27.184	3935.6	21.869	3947.7
295.00	13.846	13.713	27.559	4045.4	22.077	4084.5
298.15	13.992	13.802	27.794	4115.2	22.210	4171.7
300.00	14.078	13.854	27.932	4156.3	22.288	4223.3

H^C_0 AND S^C_0 APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-135 (CONT.)

THERMODYNAMIC FUCTIONS FOR SODIUM NITRATE ($NA\ N\ O_3$)
SOLID AND LIQUID PHASES

GRAM MOLECULAR WT.= 84.9947 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T DEG K	$-(G_T^0-H_0^C)/T$ CAL/DEG-MOLE	$(H_T^0-H_0^C)/T$ CAL/DEG-MOLE	$(S_T-S_0^C)$ CAL/DEG-MOLE	$(H_T^0-H_0^C)$ CAL/MOLE	C_P^0 CAL/DEG-MOLE	$-(G_T^0-H_0^C)$ CAL/MOLE
			SOLID PHASE (ALPHA)			
300.00	14.078	13.854	27.932	4156.3	22.288	4223.3
310.00	14.536	14.133	28.670	4381.3	22.716	4506.3
320.00	14.990	14.408	29.398	4610.7	23.156	4796.6
330.00	15.437	14.680	30.117	4844.5	23.608	5094.2
340.00	15.879	14.950	30.829	5082.9	24.071	5399.0
350.00	16.317	15.217	31.533	5325.9	24.543	5710.8
360.00	16.749	15.483	32.232	5573.8	25.021	6029.6
370.00	17.177	15.747	32.924	5826.4	25.501	6355.4
373.15	17.311	15.830	33.140	5906.9	25.652	6459.4
380.00	17.600	16.010	33.610	6083.8	25.981	6688.1
390.00	18.019	16.272	34.291	6346.0	26.459	7027.6
400.00	18.435	16.532	34.967	6612.9	26.935	7373.9
425.00	19.456	17.179	36.635	7301.1	28.115	8269.0
450.00	20.456	17.819	38.276	8018.7	29.295	9205.4
475.00	21.437	18.455	39.892	8766.0	30.491	10183.
500.00	22.400	19.087	41.487	9543.6	31.722	11200.
549.20	24.248	20.332	44.580	11167.	34.290	13317.
			SOLID PHASE (BETA)			
549.20	24.248	22.219	46.466	12203.	34.290	13317.
550.00	24.278	22.237	46.517	12230.	34.333	13353.
579.20	25.448	22.887	48.334	13256.	34.946	14739.
			LIQUID PHASE			
579.20	25.448	28.912	54.359	16746.	34.946	14739.
600.0	26.471	29.177	55.648	17506.	37.131	16122.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-136

THERMODYNAMIC FUNCTIONS FOR SODIUM ALUMINUM META-SILICATE (NA AL SI_2O_6)
(JADEITE)

GRAM MOLECULAR WT.= 202.1397 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
			SOLID PHASE			
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.000	0.001	0.002	0.002	0.001
10.00	0.002	0.006	0.007	0.057	0.027	0.016
15.00	0.007	0.025	0.032	0.376	0.114	0.103
20.00	0.019	0.066	0.085	1.320	0.275	0.383
25.00	0.040	0.129	0.169	3.224	0.496	1.006
30.00	0.071	0.212	0.283	6.361	0.768	2.125
35.00	0.111	0.315	0.426	11.010	1.103	3.883
40.00	0.161	0.438	0.599	17.526	1.517	6.431
45.00	0.221	0.585	0.806	26.334	2.022	9.928
50.00	0.291	0.758	1.049	37.910	2.625	14.550
55.00	0.372	0.959	1.331	52.743	3.322	20.485
60.00	0.466	1.188	1.653	71.256	4.094	27.931
65.00	0.570	1.443	2.013	93.768	4.919	37.080
70.00	0.687	1.722	2.409	120.51	5.784	48.121
75.00	0.816	2.022	2.838	151.65	6.677	61.226
80.00	0.957	2.341	3.298	187.31	7.590	76.555
85.00	1.109	2.677	3.786	227.58	8.519	94.256
90.00	1.272	3.028	4.300	272.52	9.461	114.46
95.00	1.445	3.392	4.837	322.20	10.412	137.29
100.00	1.629	3.767	5.395	376.66	11.372	162.86
105.00	1.822	4.152	5.973	435.92	12.333	191.28
110.00	2.024	4.545	6.569	499.99	13.293	222.63
115.00	2.235	4.946	7.181	568.84	14.245	257.00
120.00	2.454	5.353	7.807	642.42	15.185	294.46
125.00	2.681	5.765	8.446	720.67	16.111	335.09
130.00	2.915	6.181	9.096	803.50	17.020	378.94
135.00	3.156	6.599	9.755	890.84	17.912	426.06
140.00	3.404	7.019	10.422	982.59	18.788	476.50
145.00	3.657	7.439	11.096	1078.7	19.647	530.30
150.00	3.917	7.860	11.777	1179.0	20.490	587.48
155.00	4.181	8.281	12.462	1283.6	21.315	648.07
160.00	4.451	8.701	13.152	1392.2	22.121	712.11
165.00	4.725	9.120	13.844	1504.7	22.909	779.59
170.00	5.003	9.537	14.540	1621.2	23.677	850.55
175.00	5.286	9.951	15.237	1741.5	24.425	924.99
180.00	5.572	10.363	15.935	1865.4	25.153	1002.9
185.00	5.861	10.773	16.634	1993.0	25.862	1084.3
190.00	6.154	11.179	17.333	2124.0	26.554	1169.3
195.00	6.450	11.582	18.032	2258.5	27.229	1257.7
200.00	6.748	11.981	18.729	2396.3	27.888	1349.6
205.00	7.049	12.377	19.426	2537.3	28.532	1445.0
210.00	7.352	12.769	20.121	2681.6	29.162	1543.8
215.00	7.657	13.158	20.814	2828.9	29.779	1646.2
220.00	7.964	13.542	21.506	2979.3	30.383	1752.0
225.00	8.272	13.923	22.195	3132.7	30.976	1861.2
230.00	8.582	14.300	22.883	3289.1	31.556	1973.9
235.00	8.894	14.674	23.567	3448.3	32.124	2090.1
240.00	9.207	15.043	24.250	3610.3	32.680	2209.6
245.00	9.521	15.408	24.929	3775.1	33.223	2332.5
250.00	9.836	15.770	25.606	3942.5	33.753	2458.9
255.00	10.151	16.128	26.279	4112.6	34.269	2588.6
260.00	10.468	16.481	26.949	4285.2	34.772	2721.7
265.00	10.785	16.831	27.616	4460.3	35.260	2858.1
270.00	11.103	17.177	28.280	4637.7	35.734	2997.8
273.15	11.304	17.393	28.696	4750.8	36.026	3087.6
275.00	11.421	17.518	28.940	4817.6	36.195	3140.9
280.00	11.740	17.856	29.596	4999.7	36.641	3287.2
285.00	12.059	18.189	30.248	5184.0	37.075	3436.8
290.00	12.378	18.519	30.897	5370.4	37.496	3589.7
295.00	12.698	18.844	31.541	5558.9	37.905	3745.8
298.15	12.899	19.046	31.945	5678.7	38.158	3845.8
300.00	13.017	19.165	32.182	5749.4	38.304	3905.1

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-136 (CONT.)

THERMODYNAMIC FUNCTIONS FOR SODIUM ALUMINUM META-SILICATE (NA AL SI_2O_6)
(JADEITE)

GRAM MOLECULAR WT.= 202.1397 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
			SOLID PHASE			
300.00	13.017	19.165	32.182	5749.4	38.304	3905.1
310.00	13.656	19.795	33.450	6136.3	39.073	4233.3
320.00	14.294	20.409	34.703	6530.8	39.808	4574.1
330.00	14.931	21.007	35.938	6932.4	40.515	4927.3
340.00	15.567	21.591	37.158	7341.0	41.198	5292.8
350.00	16.201	22.161	38.362	7756.3	41.857	5670.4
360.00	16.833	22.717	39.550	8178.1	42.494	6060.0
370.00	17.463	23.260	40.723	8606.1	43.108	6461.3
373.15	17.661	23.428	41.089	8742.2	43.297	6590.2
380.00	18.090	23.790	41.880	9040.1	43.700	6874.4
390.00	18.715	24.308	43.023	9480.0	44.270	7298.9
400.00	19.337	24.814	44.151	9925.5	44.817	7734.8
425.00	20.878	26.028	46.906	11062.	46.089	8873.2
450.00	22.399	27.175	49.574	12229.	47.234	10079.
475.00	23.897	28.259	52.156	13423.	48.265	11351.
500.00	25.373	29.283	54.655	14641.	49.197	12686.
550.00	28.254	31.168	59.422	17143.	50.807	15540.
600.00	31.040	32.862	63.902	19717.	52.147	18624.
650.00	33.732	34.391	68.122	22354.	53.277	21926.
700.00	36.332	35.775	72.107	25042.	54.244	25432.
750.00	38.844	37.035	75.878	27776.	55.083	29133.
800.00	41.271	38.186	79.457	30549.	55.820	33017.
850.00	43.618	39.243	82.861	33357.	56.476	37075.
900.00	45.889	40.217	86.106	36195.	57.065	41300.
950.00	48.088	41.118	89.206	39062.	57.600	45684.
1000.00	50.219	41.955	92.173	41955.	58.091	50219.
1050.00	52.285	42.734	95.019	44871.	58.545	54899.
1100.00	54.290	43.462	97.752	47809.	58.967	59719.
1150.00	56.237	44.145	100.38	50767.	59.363	64672.
1200.00	58.129	44.787	102.92	53745.	59.736	69755.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-137

THERMODYNAMIC FUNCTIONS FOR SODIUM MONOTITANATE (NA_2TIO_3)
SOLID PHASE

GRAM MOLECULAR WT.= 141.8778 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T DEG K	$-(G_T^0-H_0^C)/T$ CAL DEG-MOLE	$(H_T^0-H_0^C)/T$ CAL DEG-MOLE	$(S_T-S_0^C)$ CAL DEG-MOLE	$(H_T^0-H_0^C)$ CAL MOLE	C_P^0 CAL DEG-MOLE	$-(G_T^0-H_0^C)$ CAL MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.001	0.001	0.006	0.004	0.002
10.00	0.003	0.009	0.012	0.088	0.035	0.029
15.00	0.010	0.030	0.040	0.446	0.119	0.149
20.00	0.023	0.070	0.094	1.406	0.280	0.470
25.00	0.046	0.136	0.182	3.402	0.535	1.143
30.00	0.078	0.231	0.309	6.930	0.893	2.354
35.00	0.123	0.357	0.480	12.505	1.354	4.310
40.00	0.181	0.516	0.697	20.640	1.915	7.234
45.00	0.252	0.707	0.959	31.805	2.564	11.355
50.00	0.338	0.928	1.266	46.396	3.282	16.899
55.00	0.438	1.177	1.614	64.713	4.052	24.083
60.00	0.552	1.450	2.001	86.972	4.858	33.107
65.00	0.679	1.744	2.423	113.34	5.695	44.154
70.00	0.820	2.057	2.876	143.96	6.554	57.390
75.00	0.973	2.385	3.358	178.90	7.420	72.965
80.00	1.138	2.727	3.864	218.15	8.279	91.012
85.00	1.313	3.078	4.392	261.66	9.126	111.65
90.00	1.500	3.438	4.937	309.39	9.963	134.96
95.00	1.695	3.803	5.498	361.27	10.789	161.04
100.00	1.900	4.173	6.072	417.27	11.605	189.96
105.00	2.112	4.546	6.658	477.30	12.406	221.78
110.00	2.332	4.921	7.253	541.29	13.189	256.56
115.00	2.559	5.297	7.856	609.16	13.953	294.33
120.00	2.793	5.673	8.466	680.79	14.696	335.13
125.00	3.032	6.049	9.081	756.08	15.416	379.00
130.00	3.277	6.422	9.699	834.91	16.112	425.95
135.00	3.526	6.794	10.320	917.16	16.785	475.99
140.00	3.780	7.162	10.942	1002.7	17.436	529.14
145.00	4.037	7.528	11.565	1091.5	18.066	585.41
150.00	4.299	7.889	12.188	1183.3	18.674	644.79
155.00	4.563	8.246	12.810	1278.2	19.262	707.28
160.00	4.831	8.600	13.430	1375.9	19.830	772.88
165.00	5.101	8.948	14.049	1476.5	20.379	841.58
170.00	5.373	9.292	14.665	1579.7	20.907	913.37
175.00	5.647	9.631	15.278	1685.5	21.418	988.23
180.00	5.923	9.966	15.889	1793.8	21.910	1066.1
185.00	6.201	10.295	16.496	1904.6	22.386	1147.1
190.00	6.479	10.619	17.099	2017.7	22.846	1231.1
195.00	6.759	10.939	17.698	2133.0	23.291	1318.1
200.00	7.040	11.253	18.293	2250.6	23.721	1408.1
205.00	7.322	11.562	18.884	2370.2	24.136	1501.0
210.00	7.604	11.866	19.470	2491.9	24.537	1596.9
215.00	7.887	12.165	20.052	2615.5	24.925	1695.7
220.00	8.170	12.460	20.630	2741.1	25.299	1797.4
225.00	8.453	12.749	21.202	2868.5	25.661	1902.0
230.00	8.737	13.034	21.770	2997.7	26.012	2009.4
235.00	9.020	13.313	22.333	3128.6	26.352	2119.7
240.00	9.303	13.588	22.892	3261.2	26.683	2232.8
245.00	9.586	13.859	23.445	3395.4	27.005	2348.6
250.00	9.869	14.125	23.994	3531.2	27.319	2467.2
255.00	10.151	14.387	24.538	3668.6	27.626	2588.5
260.00	10.433	14.644	25.077	3807.5	27.926	2712.6
265.00	10.714	14.898	25.612	3947.9	28.221	2839.3
270.00	10.995	15.147	26.142	4089.7	28.509	2968.7
273.15	11.172	15.302	26.474	4179.8	28.688	3051.6
275.00	11.275	15.393	26.668	4232.9	28.792	3100.7
280.00	11.555	15.634	27.189	4377.6	29.069	3235.4
285.00	11.834	15.872	27.706	4523.6	29.341	3372.6
290.00	12.112	16.107	28.219	4671.0	29.608	3512.4
295.00	12.389	16.338	28.727	4819.7	29.869	3654.8
298.15	12.563	16.482	29.045	4914.0	30.031	3745.8
300.00	12.666	16.566	29.231	4969.7	30.125	3799.7

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-138

THERMODYNAMIC FUNCTIONS FOR SODIUM DITITANATE ($NA_2TI_2O_5$)
SOLID PHASE

GRAM MOLECULAR WT.= 221.7766 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.001	0.003	0.004	0.014	0.011	0.005
10.00	0.007	0.022	0.029	0.219	0.087	0.073
15.00	0.025	0.073	0.098	1.101	0.291	0.368
20.00	0.058	0.170	0.228	3.401	0.655	1.155
25.00	0.110	0.316	0.426	7.892	1.162	2.761
30.00	0.184	0.506	0.691	15.193	1.774	5.527
35.00	0.279	0.737	1.016	25.798	2.485	9.769
40.00	0.395	1.006	1.400	40.225	3.302	15.786
45.00	0.530	1.311	1.841	58.977	4.214	23.867
50.00	0.686	1.650	2.336	82.505	5.210	34.287
55.00	0.860	2.022	2.882	111.20	6.277	47.311
60.00	1.053	2.423	3.476	145.36	7.394	63.186
65.00	1.264	2.849	4.113	185.19	8.544	82.140
70.00	1.491	3.298	4.789	230.83	9.715	104.38
75.00	1.734	3.765	5.499	282.35	10.892	130.08
80.00	1.993	4.247	6.239	339.74	12.059	159.42
85.00	2.265	4.740	7.005	402.91	13.208	192.52
90.00	2.550	5.242	7.792	471.79	14.341	229.51
95.00	2.847	5.751	8.598	546.30	15.461	270.47
100.00	3.155	6.264	9.419	626.38	16.566	315.51
105.00	3.473	6.780	10.253	711.93	17.652	364.68
110.00	3.801	7.299	11.099	802.86	18.715	418.06
115.00	4.136	7.818	11.954	899.03	19.750	475.69
120.00	4.480	8.336	12.816	1000.3	20.756	537.61
125.00	4.831	8.852	13.683	1106.5	21.732	603.86
130.00	5.188	9.366	14.554	1217.6	22.678	674.45
135.00	5.551	9.876	15.427	1333.3	23.595	749.41
140.00	5.919	10.382	16.302	1453.5	24.484	828.73
145.00	6.293	10.883	17.176	1578.1	25.345	912.42
150.00	6.670	11.379	18.049	1706.9	26.180	1000.5
155.00	7.051	11.870	18.921	1839.8	26.989	1092.9
160.00	7.436	12.355	19.790	1976.7	27.772	1189.7
165.00	7.823	12.833	20.656	2117.5	28.529	1290.8
170.00	8.213	13.306	21.519	2262.0	29.259	1396.2
175.00	8.606	13.772	22.377	2410.1	29.963	1506.0
180.00	9.000	14.231	23.231	2561.6	30.642	1620.0
185.00	9.396	14.683	24.080	2716.4	31.296	1738.3
190.00	9.794	15.129	24.923	2874.5	31.927	1860.8
195.00	10.192	15.567	25.760	3035.7	32.534	1987.5
200.00	10.592	15.999	26.591	3199.8	33.119	2118.4
205.00	10.992	16.424	27.416	3366.8	33.684	2253.4
210.00	11.393	16.841	28.234	3536.6	34.229	2392.5
215.00	11.794	17.252	29.046	3709.1	34.757	2535.7
220.00	12.195	17.655	29.851	3884.2	35.268	2683.0
225.00	12.597	18.052	30.649	4061.7	35.763	2834.2
230.00	12.998	18.442	31.440	4241.8	36.245	2989.5
235.00	13.398	18.826	32.225	4424.2	36.715	3148.6
240.00	13.799	19.204	33.002	4608.9	37.172	3311.7
245.00	14.199	19.575	33.773	4795.9	37.618	3478.6
250.00	14.598	19.940	34.538	4985.1	38.053	3649.4
255.00	14.996	20.300	35.296	5176.4	38.478	3824.0
260.00	15.394	20.653	36.047	5369.8	38.891	4002.4
265.00	15.790	21.001	36.791	5565.3	39.294	4184.5
270.00	16.186	21.343	37.530	5762.7	39.686	4370.3
273.15	16.435	21.556	37.991	5888.1	39.927	4489.2
275.00	16.581	21.680	38.261	5962.1	40.067	4559.7
280.00	16.975	22.012	38.987	6163.4	40.437	4752.9
285.00	17.367	22.338	39.706	6366.5	40.796	4949.6
290.00	17.758	22.660	40.418	6571.3	41.144	5149.9
295.00	18.148	22.976	41.124	6777.9	41.481	5353.8
298.15	18.393	23.173	41.566	6908.9	41.688	5484.0
300.00	18.537	23.287	41.824	6986.1	41.808	5561.1

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-139

THERMODYNAMIC FUNCTIONS FOR SODIUM TRITITANATE ($NA_2TI_3O_7$)
SOLID PHASE

GRAM MOLECULAR WT.= 301.6754 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.002	0.006	0.007	0.028	0.022	0.009
10.00	0.015	0.044	0.059	0.444	0.177	0.148
15.00	0.050	0.147	0.196	2.200	0.568	0.745
20.00	0.115	0.325	0.440	6.503	1.182	2.290
25.00	0.212	0.569	0.782	14.236	1.928	5.306
30.00	0.341	0.865	1.206	25.943	2.771	10.245
35.00	0.500	1.205	1.705	42.188	3.753	17.492
40.00	0.686	1.594	2.279	63.745	4.895	27.422
45.00	0.898	2.030	2.928	91.371	6.175	40.410
50.00	1.137	2.513	3.650	125.67	7.555	56.827
55.00	1.400	3.037	4.437	167.01	8.991	77.018
60.00	1.688	3.594	5.282	215.62	10.460	101.29
65.00	1.999	4.179	6.178	271.66	11.961	129.92
70.00	2.331	4.790	7.120	335.28	13.486	163.15
75.00	2.683	5.420	8.103	406.52	15.012	201.19
80.00	3.053	6.067	9.120	485.36	16.519	244.24
85.00	3.440	6.725	10.166	571.66	17.998	292.44
90.00	3.844	7.392	11.236	665.30	19.452	345.94
95.00	4.261	8.065	12.326	766.15	20.884	404.83
100.00	4.692	8.741	13.433	874.11	22.295	469.23
105.00	5.135	9.420	14.555	989.06	23.683	539.19
110.00	5.589	10.099	15.688	1110.9	25.042	614.79
115.00	6.053	10.778	16.831	1239.4	26.369	696.09
120.00	6.526	11.454	17.980	1374.5	27.660	783.11
125.00	7.007	12.128	19.135	1516.0	28.912	875.90
130.00	7.496	12.797	20.293	1663.6	30.125	974.46
135.00	7.991	13.460	21.452	1817.1	31.299	1078.8
140.00	8.493	14.118	22.611	1976.5	32.438	1189.0
145.00	9.000	14.769	23.768	2141.5	33.542	1304.9
150.00	9.511	15.412	24.924	2311.9	34.614	1426.7
155.00	10.027	16.049	26.076	2487.6	35.654	1554.2
160.00	10.546	16.677	27.224	2668.4	36.663	1687.4
165.00	11.069	17.298	28.367	2854.1	37.640	1826.4
170.00	11.595	17.910	29.505	3044.7	38.586	1971.1
175.00	12.122	18.514	30.636	3239.9	39.499	2121.4
180.00	12.652	19.109	31.761	3439.6	40.380	2277.4
185.00	13.184	19.696	32.879	3643.7	41.229	2439.0
190.00	13.717	20.273	33.990	3851.9	42.047	2606.2
195.00	14.251	20.842	35.092	4064.1	42.835	2778.9
200.00	14.786	21.401	36.186	4280.2	43.594	2957.1
205.00	15.321	21.951	37.272	4500.0	44.327	3140.8
210.00	15.856	22.492	38.349	4723.4	45.035	3329.8
215.00	16.392	23.025	39.416	4950.3	45.721	3524.2
220.00	16.927	23.548	40.475	5180.6	46.387	3724.0
225.00	17.462	24.063	41.525	5414.2	47.034	3929.0
230.00	17.997	24.569	42.566	5650.9	47.665	4139.2
235.00	18.530	25.067	43.597	5890.8	48.280	4354.6
240.00	19.063	25.557	44.620	6133.7	48.880	4575.2
245.00	19.595	26.039	45.634	6379.6	49.466	4800.8
250.00	20.126	26.513	46.639	6628.3	50.038	5031.5
255.00	20.656	26.980	47.636	6879.9	50.597	5267.2
260.00	21.184	27.439	48.623	7134.3	51.142	5507.8
265.00	21.711	27.892	49.603	7391.3	51.673	5753.4
270.00	22.236	28.337	50.573	7651.0	52.189	6003.8
273.15	22.567	28.614	51.181	7815.9	52.507	6164.1
275.00	22.760	28.775	51.536	7913.2	52.691	6259.1
280.00	23.283	29.207	52.489	8177.9	53.179	6519.2
285.00	23.803	29.631	53.435	8444.9	53.652	6784.0
290.00	24.322	30.049	54.372	8714.3	54.111	7053.5
295.00	24.840	30.461	55.301	8986.0	54.557	7327.7
298.15	25.165	30.717	55.882	9158.3	54.830	7502.8
300.00	25.355	30.866	56.221	9259.9	54.988	7606.5

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-140

THERMODYNAMIC FUNCTIONS FOR CESIUM PERCHLORATE (CS CL O_4)
SOLID PHASE

GRAM MOLECULAR WT.= 232.3556 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.013	0.037	0.051	0.187	0.140	0.066
10.00	0.088	0.234	0.322	2.340	0.825	0.885
15.00	0.252	0.632	0.883	9.477	2.134	3.775
20.00	0.511	1.225	1.736	24.506	3.917	10.211
25.00	0.860	1.945	2.805	48.634	5.709	21.496
30.00	1.282	2.709	3.991	81.281	7.322	38.455
35.00	1.757	3.477	5.235	121.71	8.830	61.502
40.00	2.271	4.233	6.504	169.32	10.183	90.844
45.00	2.812	4.958	7.770	223.12	11.304	126.54
50.00	3.370	5.641	9.011	282.04	12.234	168.50
55.00	3.938	6.277	10.215	345.22	13.017	216.58
60.00	4.510	6.867	11.377	412.02	13.684	270.58
65.00	5.081	7.414	12.495	481.90	14.252	330.28
70.00	5.649	7.920	13.570	554.40	14.734	395.46
75.00	6.212	8.388	14.601	629.12	15.147	465.90
80.00	6.767	8.822	15.590	705.79	15.515	541.39
85.00	7.315	9.226	16.541	784.24	15.859	621.74
90.00	7.853	9.604	17.457	864.36	16.187	706.75
95.00	8.382	9.959	18.340	946.08	16.500	796.25
100.00	8.901	10.293	19.194	1029.3	16.797	890.10
105.00	9.411	10.610	20.021	1114.0	17.081	988.15
110.00	9.912	10.910	20.822	1200.1	17.353	1090.3
115.00	10.403	11.196	21.599	1287.5	17.614	1196.3
120.00	10.885	11.469	22.354	1376.2	17.865	1306.2
125.00	11.359	11.729	23.088	1466.2	18.110	1419.8
130.00	11.824	11.980	23.803	1557.3	18.355	1537.1
135.00	12.280	12.220	24.501	1649.7	18.600	1657.8
140.00	12.729	12.452	25.181	1743.3	18.848	1782.0
145.00	13.170	12.677	25.847	1838.2	19.099	1909.6
150.00	13.603	12.896	26.499	1934.3	19.352	2040.5
155.00	14.030	13.108	27.138	2031.7	19.607	2174.6
160.00	14.449	13.315	27.764	2130.4	19.864	2311.9
165.00	14.862	13.517	28.379	2230.4	20.123	2452.2
170.00	15.268	13.716	28.984	2331.6	20.383	2595.6
175.00	15.669	13.910	29.579	2434.2	20.640	2742.0
180.00	16.063	14.100	30.164	2538.0	20.894	2891.4
185.00	16.452	14.287	30.740	2643.1	21.143	3043.7
190.00	16.836	14.471	31.307	2749.5	21.386	3198.8
195.00	17.214	14.651	31.865	2857.0	21.624	3356.7
200.00	17.587	14.828	32.416	2965.7	21.858	3517.4
205.00	17.955	15.003	32.958	3075.6	22.089	3680.9
210.00	18.319	15.174	33.493	3186.6	22.320	3847.0
215.00	18.678	15.343	34.021	3298.8	22.551	4015.8
220.00	19.033	15.510	34.542	3412.1	22.782	4187.2
225.00	19.383	15.674	35.057	3526.6	23.013	4361.2
230.00	19.729	15.836	35.565	3642.2	23.242	4537.7
235.00	20.072	15.996	36.067	3759.0	23.470	4716.8
240.00	20.410	16.154	36.564	3876.9	23.693	4898.4
245.00	20.745	16.310	37.055	3995.9	23.913	5082.5
250.00	21.076	16.464	37.540	4116.0	24.127	5268.9
255.00	21.403	16.616	38.020	4237.2	24.336	5457.8
260.00	21.727	16.767	38.494	4359.4	24.540	5649.1
265.00	22.048	16.915	38.964	4482.6	24.739	5842.8
270.00	22.366	17.062	39.428	4606.8	24.932	6038.8
273.15	22.564	17.154	39.718	4685.5	25.051	6163.4
275.00	22.680	17.207	39.887	4731.9	25.120	6237.1
280.00	22.992	17.350	40.341	4858.0	25.304	6437.6
285.00	23.300	17.491	40.791	4984.9	25.484	6640.5
290.00	23.605	17.630	41.236	5112.8	25.660	6845.5
295.00	23.908	17.768	41.676	5241.5	25.833	7052.8
298.15	24.097	17.854	41.951	5323.1	25.940	7184.5
300.00	24.208	17.904	42.111	5371.1	26.002	7262.3

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-141

THERMODYNAMIC FUNCTIONS FOR CALCIUM HYDROXIDE ($CA(OH)_2$)
SOLID PHASE

GRAM MOLECULAR WT.= 74.09474 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.001	0.001	0.004	0.003	0.001
10.00	0.002	0.007	0.009	0.066	0.026	0.022
15.00	0.007	0.022	0.030	0.335	0.089	0.112
20.00	0.018	0.053	0.070	1.057	0.210	0.353
25.00	0.034	0.102	0.137	2.561	0.404	0.859
30.00	0.059	0.174	0.233	5.221	0.672	1.771
35.00	0.093	0.269	0.362	9.418	1.015	3.244
40.00	0.136	0.385	0.521	15.401	1.383	5.439
45.00	0.189	0.518	0.706	23.294	1.782	8.497
50.00	0.251	0.667	0.918	33.331	2.241	12.546
55.00	0.322	0.832	1.154	45.777	2.742	17.716
60.00	0.402	1.013	1.415	60.788	3.265	24.130
65.00	0.491	1.207	1.697	78.430	3.793	31.904
70.00	0.588	1.410	1.998	98.715	4.323	41.135
75.00	0.692	1.622	2.315	121.69	4.869	51.909
80.00	0.804	1.843	2.647	147.45	5.441	64.307
85.00	0.922	2.072	2.994	176.12	6.029	78.404
90.00	1.047	2.308	3.356	207.75	6.622	94.274
95.00	1.179	2.551	3.730	242.34	7.211	111.98
100.00	1.316	2.798	4.114	279.84	7.789	131.59
105.00	1.458	3.050	4.508	320.20	8.354	153.14
110.00	1.606	3.303	4.909	363.35	8.904	176.68
115.00	1.759	3.558	5.317	409.22	9.439	202.25
120.00	1.916	3.814	5.730	457.72	9.961	229.86
125.00	2.076	4.070	6.147	508.81	10.471	259.55
130.00	2.241	4.326	6.567	562.41	10.968	291.34
135.00	2.409	4.581	6.990	618.46	11.451	325.23
140.00	2.580	4.835	7.415	676.90	11.919	361.24
145.00	2.754	5.087	7.841	737.63	12.371	399.38
150.00	2.931	5.337	8.268	800.58	12.807	439.66
155.00	3.110	5.585	8.695	865.67	13.227	482.07
160.00	3.291	5.830	9.121	932.83	13.632	526.61
165.00	3.474	6.073	9.547	1002.0	14.021	573.28
170.00	3.659	6.312	9.971	1073.0	14.395	622.07
175.00	3.846	6.548	10.394	1145.9	14.756	672.99
180.00	4.033	6.781	10.814	1220.5	15.103	726.01
185.00	4.222	7.010	11.233	1296.9	15.439	781.12
190.00	4.412	7.236	11.649	1374.9	15.764	838.33
195.00	4.603	7.459	12.062	1454.5	16.079	897.61
200.00	4.795	7.679	12.473	1535.7	16.385	958.95
205.00	4.987	7.894	12.881	1618.4	16.682	1022.3
210.00	5.180	8.107	13.287	1702.5	16.970	1087.8
215.00	5.373	8.317	13.690	1788.1	17.250	1155.2
220.00	5.567	8.523	14.089	1875.0	17.522	1224.6
225.00	5.760	8.726	14.486	1963.3	17.785	1296.1
230.00	5.954	8.925	14.880	2052.8	18.039	1369.5
235.00	6.148	9.122	15.270	2143.6	18.286	1444.9
240.00	6.343	9.315	15.658	2235.7	18.525	1522.2
245.00	6.537	9.506	16.042	2328.9	18.756	1601.5
250.00	6.730	9.693	16.423	2423.2	18.981	1682.6
255.00	6.924	9.877	16.801	2518.7	19.201	1765.7
260.00	7.118	10.059	17.176	2615.2	19.416	1850.6
265.00	7.311	10.237	17.548	2712.8	19.627	1937.4
270.00	7.504	10.413	17.917	2811.5	19.835	2026.1
273.15	7.626	10.522	18.148	2874.2	19.964	2082.9
275.00	7.697	10.586	18.283	2911.2	20.040	2116.6
280.00	7.889	10.757	18.646	3011.9	20.242	2208.9
285.00	8.081	10.925	19.006	3113.6	20.443	2303.1
290.00	8.272	11.091	19.363	3216.3	20.640	2399.0
295.00	8.463	11.254	19.718	3320.0	20.836	2496.7
298.15	8.583	11.356	19.940	3385.8	20.957	2559.1
300.00	8.654	11.416	20.069	3424.7	21.028	2596.2

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-141 (CONT.)

THERMODYNAMIC FUNCTIONS FOR CALCIUM HYDROXIDE ($CA(OH)_2$)
SOLID PHASE

GRAM MOLECULAR WT.= 74.09474 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / MOLE	CAL / DEG-MOLE	CAL / MOLE
300.00	8.654	11.416	20.069	3424.7	21.028	2596.2
310.00	9.033	11.732	20.765	3636.8	21.400	2800.3
320.00	9.411	12.039	21.450	3852.6	21.751	3011.4
330.00	9.786	12.339	22.124	4071.7	22.076	3229.3
340.00	10.158	12.629	22.788	4294.0	22.371	3453.9
350.00	10.529	12.912	23.440	4519.1	22.635	3685.0
360.00	10.896	13.185	24.081	4746.6	22.867	3922.6
370.00	11.261	13.449	24.711	4976.3	23.071	4166.6
373.15	11.375	13.531	24.906	5049.1	23.130	4244.7
380.00	11.623	13.705	25.328	5207.9	23.250	4416.8
390.00	11.982	13.952	25.934	5441.2	23.409	4673.1
400.00	12.339	14.190	26.529	5676.1	23.554	4935.5
425.00	13.216	14.751	27.967	6269.0	23.875	5616.8
450.00	14.074	15.266	29.340	6869.6	24.175	6333.2
475.00	14.912	15.743	30.655	7477.7	24.471	7083.3
500.00	15.731	16.186	31.917	8093.1	24.756	7865.5
550.00	17.312	16.989	34.301	9343.9	25.259	9521.7
600.00	18.821	17.695	36.516	10617.	25.636	11293.
650.00	20.263	18.316	38.579	11905.	25.877	13171.
700.00	21.641	18.860	40.501	13202.	25.976	15148.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-142

THERMODYNAMIC FUNCTIONS FOR CALCIUM FLUORIDE ($CA\ F_2$)
SOLID PHASE

GRAM MOLECULAR WT.= 78.0768 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / MOLE	CAL / DEG-MOLE	CAL / MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.000	0.001	0.002	0.002	0.001
10.00	0.001	0.004	0.005	0.040	0.016	0.013
15.00	0.004	0.013	0.018	0.201	0.054	0.067
20.00	0.011	0.032	0.042	0.636	0.127	0.212
25.00	0.021	0.062	0.083	1.550	0.247	0.517
30.00	0.036	0.107	0.142	3.196	0.420	1.071
35.00	0.056	0.167	0.224	5.848	0.650	1.976
40.00	0.084	0.245	0.328	9.784	0.933	3.346
45.00	0.118	0.339	0.457	15.257	1.264	5.298
50.00	0.159	0.450	0.609	22.494	1.639	7.953
55.00	0.208	0.577	0.785	31.741	2.068	11.427
60.00	0.264	0.721	0.985	43.267	2.549	15.842
65.00	0.328	0.882	1.209	57.299	3.068	21.319
70.00	0.400	1.057	1.457	73.982	3.608	27.975
75.00	0.479	1.245	1.724	93.398	4.159	35.918
80.00	0.566	1.445	2.010	115.57	4.711	45.247
85.00	0.659	1.653	2.312	140.50	5.260	56.047
90.00	0.760	1.868	2.628	168.16	5.802	68.394
95.00	0.867	2.090	2.956	198.50	6.334	82.351
100.00	0.980	2.315	3.295	231.48	6.854	97.974
105.00	1.098	2.543	3.641	267.02	7.359	115.31
110.00	1.222	2.773	3.995	305.05	7.848	134.40
115.00	1.350	3.004	4.354	345.47	8.320	155.27
120.00	1.483	3.235	4.718	388.21	8.772	177.95
125.00	1.620	3.465	5.085	433.16	9.205	202.45
130.00	1.760	3.694	5.454	480.23	9.617	228.80
135.00	1.904	3.921	5.824	529.30	10.009	257.00
140.00	2.050	4.145	6.195	580.29	10.382	287.05
145.00	2.200	4.366	6.566	633.09	10.736	318.95
150.00	2.351	4.584	6.935	687.62	11.072	352.70
155.00	2.505	4.799	7.304	743.79	11.392	388.30
160.00	2.661	5.009	7.670	801.52	11.696	425.74
165.00	2.818	5.216	8.035	860.72	11.983	465.00
170.00	2.977	5.420	8.396	921.32	12.254	506.08
175.00	3.137	5.619	8.755	983.24	12.510	548.96
180.00	3.298	5.813	9.111	1046.4	12.752	593.63
185.00	3.460	6.004	9.464	1110.7	12.980	640.07
190.00	3.622	6.190	9.813	1176.2	13.196	688.26
195.00	3.786	6.373	10.158	1242.7	13.402	738.19
200.00	3.949	6.551	10.500	1310.2	13.598	789.84
205.00	4.113	6.725	10.838	1378.7	13.786	843.19
210.00	4.277	6.895	11.173	1448.0	13.966	898.21
215.00	4.441	7.062	11.503	1518.3	14.139	954.91
220.00	4.606	7.225	11.830	1589.4	14.304	1013.2
225.00	4.770	7.384	12.153	1661.3	14.462	1073.2
230.00	4.934	7.539	12.473	1734.0	14.613	1134.8
235.00	5.098	7.691	12.789	1807.4	14.757	1197.9
240.00	5.261	7.840	13.101	1881.6	14.894	1262.7
245.00	5.424	7.985	13.409	1956.4	15.023	1328.9
250.00	5.587	8.127	13.714	2031.8	15.146	1396.7
255.00	5.749	8.266	14.015	2107.8	15.261	1466.1
260.00	5.911	8.402	14.313	2184.4	15.371	1536.9
265.00	6.072	8.534	14.606	2261.5	15.473	1609.2
270.00	6.233	8.663	14.897	2339.1	15.570	1682.9
273.15	6.334	8.743	15.077	2388.3	15.628	1730.2
275.00	6.393	8.790	15.183	2417.2	15.661	1758.1
280.00	6.553	8.913	15.466	2495.7	15.747	1834.8
285.00	6.712	9.034	15.745	2574.7	15.827	1912.8
290.00	6.870	9.152	16.021	2654.0	15.902	1992.2
295.00	7.027	9.267	16.294	2733.7	15.973	2073.0
298.15	7.126	9.338	16.464	2784.1	16.015	2124.6
300.00	7.184	9.379	16.563	2813.7	16.039	2155.1

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-143

THERMODYNAMIC FUNCTIONS FOR STRONTIUM OXIDE (SR O)
SOLID PHASE

GRAM MOLECULAR WT.= 103.6194 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / D5G MOL5	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.001	0.001	0.004	0.003	0.001
10.00	0.002	0.007	0.009	0.068	0.027	0.023
15.00	0.008	0.023	0.030	0.343	0.091	0.114
20.00	0.018	0.054	0.072	1.082	0.216	0.361
25.00	0.035	0.105	0.140	2.623	0.413	0.880
30.00	0.060	0.178	0.238	5.339	0.684	1.813
35.00	0.095	0.273	0.368	9.554	1.011	3.316
40.00	0.138	0.388	0.526	15.507	1.375	5.539
45.00	0.192	0.519	0.710	23.339	1.760	8.620
50.00	0.254	0.662	0.916	33.120	2.153	12.677
55.00	0.324	0.816	1.140	44.872	2.548	17.809
60.00	0.402	0.977	1.373	58.600	2.943	24.098
65.00	0.486	1.143	1.629	74.297	3.335	31.612
70.00	0.577	1.313	1.891	91.932	3.718	40.408
75.00	0.674	1.486	2.160	111.45	4.086	50.531
80.00	0.775	1.660	2.435	132.76	4.438	62.015
85.00	0.881	1.833	2.714	155.81	4.779	74.885
90.00	0.991	2.006	2.997	180.54	5.113	89.160
95.00	1.104	2.178	3.282	206.93	5.442	104.86
100.00	1.220	2.349	3.569	234.95	5.765	121.98
105.00	1.339	2.520	3.858	264.56	6.075	140.55
110.00	1.460	2.688	4.148	295.68	6.370	160.57
115.00	1.583	2.854	4.437	328.23	6.647	182.03
120.00	1.708	3.018	4.725	362.11	6.906	204.93
125.00	1.834	3.178	5.012	397.26	7.149	229.28
130.00	1.962	3.335	5.297	433.58	7.377	255.05
135.00	2.091	3.489	5.580	471.01	7.593	282.25
140.00	2.220	3.639	5.860	509.49	7.798	310.85
145.00	2.351	3.786	6.137	548.97	7.991	340.84
150.00	2.481	3.929	6.411	589.39	8.174	372.21
155.00	2.613	4.06	6.681	630.69	8.345	404.94
160.00	2.744	4.205	6.949	672.82	8.506	439.02
165.00	2.875	4.338	7.213	715.73	8.656	474.42
170.00	3.007	4.467	7.474	759.36	8.797	511.14
175.00	3.138	4.592	7.730	803.68	8.931	549.15
180.00	3.269	4.715	7.984	848.66	9.057	588.44
185.00	3.400	4.834	8.234	894.25	9.179	628.98
190.00	3.530	4.950	8.480	940.43	9.295	670.77
195.00	3.660	5.063	8.723	987.19	9.408	713.78
200.00	3.790	5.173	8.963	1034.5	9.517	757.99
205.00	3.919	5.280	9.199	1082.4	9.621	803.40
210.00	4.048	5.384	9.432	1130.7	9.721	849.98
215.00	4.175	5.486	9.662	1179.6	9.815	897.71
220.00	4.303	5.586	9.888	1228.9	9.905	946.59
225.00	4.429	5.683	10.112	1278.6	9.988	996.59
230.00	4.555	5.777	10.332	1328.7	10.066	1047.7
235.00	4.680	5.869	10.550	1379.2	10.139	1099.9
240.00	4.805	5.959	10.764	1430.1	10.206	1153.2
245.00	4.929	6.046	10.975	1481.3	10.268	1207.5
250.00	5.052	6.131	11.183	1532.8	10.326	1262.9
255.00	5.174	6.214	11.388	1584.5	10.380	1319.4
260.00	5.295	6.294	11.590	1636.6	10.431	1376.8
265.00	5.416	6.373	11.789	1688.8	10.479	1435.3
270.00	5.536	6.449	11.985	1741.4	10.525	1494.7
273.15	5.611	6.497	12.108	1774.6	10.554	1532.6
275.00	5.655	6.524	12.179	1794.1	10.570	1555.1
280.00	5.773	6.597	12.370	1847.1	10.613	1616.5
285.00	5.891	6.667	12.558	1900.2	10.654	1678.8
290.00	6.007	6.737	12.744	1953.6	10.695	1742.1
295.00	6.123	6.804	12.927	2007.2	10.734	1806.2
298.15	6.195	6.848	13.043	2041.0	10.759	1847.1
300.00	6.238	6.870	13.108	2060.9	10.773	1871.3

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-144

THERMODYNAMIC FUNCTIONS FOR BARIUM FLUORIDE (BaF_2)
SOLID PHASE

GRAM MOLECULAR WT.= 175.3368 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.001	0.003	0.004	0.016	0.013	0.006
10.00	0.009	0.025	0.034	0.253	0.098	0.086
15.00	0.028	0.078	0.106	1.174	0.286	0.416
20.00	0.061	0.166	0.227	3.314	0.597	1.227
25.00	0.112	0.297	0.409	7.437	1.073	2.789
30.00	0.181	0.473	0.654	14.200	1.647	5.422
35.00	0.269	0.687	0.957	24.062	2.306	9.427
40.00	0.377	0.932	1.308	37.267	2.977	15.072
45.00	0.502	1.196	1.697	53.805	3.638	22.573
50.00	0.642	1.473	2.115	73.675	4.312	32.093
55.00	0.796	1.763	2.559	96.961	5.005	43.768
60.00	0.962	2.063	3.025	123.76	5.715	57.718
65.00	1.139	2.371	3.510	154.12	6.431	74.047
70.00	1.326	2.686	4.013	188.04	7.132	92.849
75.00	1.523	3.005	4.528	225.38	7.795	114.20
80.00	1.727	3.324	5.051	265.91	8.411	138.14
85.00	1.938	3.640	5.578	309.42	8.985	164.71
90.00	2.155	3.952	6.107	355.70	9.525	193.92
95.00	2.377	4.259	6.636	404.62	10.038	225.78
100.00	2.603	4.560	7.163	456.05	10.527	260.28
105.00	2.832	4.856	7.688	509.85	10.992	297.41
110.00	3.065	5.145	8.210	565.92	11.430	337.15
115.00	3.300	5.427	8.727	624.11	11.840	379.50
120.00	3.537	5.702	9.239	684.28	12.223	424.41
125.00	3.775	5.970	9.745	746.29	12.577	471.88
130.00	4.014	6.231	10.245	810.00	12.904	521.86
135.00	4.254	6.484	10.738	875.28	13.204	574.32
140.00	4.494	6.729	11.223	942.01	13.481	629.22
145.00	4.735	6.966	11.701	1010.1	13.736	686.53
150.00	4.975	7.196	12.170	1079.3	13.973	746.22
155.00	5.214	7.418	12.632	1149.8	14.195	808.22
160.00	5.453	7.633	13.086	1221.3	14.403	872.52
165.00	5.691	7.841	13.532	1293.8	14.601	939.07
170.00	5.928	8.043	13.971	1367.3	14.790	1007.8
175.00	6.164	8.238	14.402	1441.7	14.969	1078.8
180.00	6.399	8.427	14.827	1516.9	15.140	1151.8
185.00	6.633	8.611	15.244	1593.0	15.302	1227.0
190.00	6.865	8.789	15.654	1669.9	15.454	1304.3
195.00	7.095	8.962	16.057	1747.6	15.598	1383.6
200.00	7.324	9.129	16.454	1825.9	15.732	1464.8
205.00	7.552	9.292	16.844	1904.9	15.856	1548.1
210.00	7.777	9.450	17.227	1984.4	15.970	1633.3
215.00	8.002	9.603	17.604	2064.6	16.075	1720.3
220.00	8.224	9.751	17.975	2145.2	16.171	1809.3
225.00	8.445	9.894	18.339	2226.3	16.260	1900.1
230.00	8.664	10.034	18.698	2307.8	16.341	1992.7
235.00	8.881	10.169	19.050	2389.7	16.417	2087.0
240.00	9.096	10.300	19.396	2471.9	16.490	2183.2
245.00	9.310	10.427	19.737	2554.6	16.561	2281.0
250.00	9.522	10.550	20.072	2637.5	16.631	2380.5
255.00	9.732	10.670	20.402	2720.9	16.703	2481.7
260.00	9.941	10.787	20.727	2804.6	16.776	2584.5
265.00	10.147	10.901	21.048	2888.6	16.853	2689.0
270.00	10.352	11.011	21.363	2973.1	16.932	2795.0
273.15	10.480	11.080	21.560	3026.5	16.983	2862.6
275.00	10.555	11.120	21.675	3058.0	17.014	2902.6
280.00	10.756	11.226	21.982	3143.2	17.099	3011.7
285.00	10.956	11.330	22.286	3229.0	17.186	3122.4
290.00	11.154	11.431	22.585	3315.1	17.274	3234.6
295.00	11.350	11.531	22.881	3401.7	17.362	3348.3
298.15	11.473	11.593	23.066	3456.5	17.417	3420.6
300.00	11.545	11.629	23.174	3488.7	17.449	3463.4

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-144 (CONT.)

THERMODYNAMIC FUNCTIONS FOR BARIUM FLUORIDE (BaF_2)
SOLID PHASE

GRAM MOLECULAR WT.= 175.3368 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
300.00	11.545	11.629	23.174	3488.7	17.449	3463.4
310.00	11.929	11.820	23.749	3664.1	17.620	3698.0
320.00	12.307	12.003	24.311	3841.1	17.783	3938.3
330.00	12.679	12.181	24.860	4019.7	17.934	4184.2
340.00	13.046	12.352	25.398	4199.7	18.074	4435.5
350.00	13.406	12.518	25.924	4381.1	18.204	4692.1
360.00	13.761	12.677	26.438	4563.8	18.325	4953.9
370.00	14.110	12.831	26.942	4747.6	18.439	5220.8
373.15	14.219	12.879	27.098	4805.8	18.473	5305.9
380.00	14.455	12.980	27.435	4932.5	18.546	5492.7
390.00	14.794	13.124	27.918	5118.5	18.647	5769.5
400.00	15.128	13.264	28.391	5305.5	18.744	6051.1
425.00	15.942	13.593	29.535	5776.9	18.968	6775.2
450.00	16.727	13.897	30.624	6253.7	19.170	7527.3
475.00	17.486	14.179	31.666	6735.3	19.354	8306.1
500.00	18.221	14.443	32.663	7221.3	19.525	9110.3
550.00	19.620	14.919	34.539	8205.5	19.839	10791.
600.00	20.936	15.341	36.278	9204.8	20.131	12562.
650.00	22.180	15.721	37.900	10218.	20.414	14417.
700.00	23.357	16.066	39.423	11246.	20.694	16350.
750.00	24.477	16.384	40.861	12288.	20.977	18358.
800.00	25.544	16.680	42.224	13344.	21.264	20435.
850.00	26.563	16.958	43.522	14414.	21.559	22579.
900.00	27.540	17.222	44.762	15500.	21.861	24786.
950.00	28.478	17.474	45.952	16601.	22.170	27054.
1000.00	29.381	17.717	47.098	17717.	22.487	29381.
1050.00	30.251	17.952	48.203	18849.	22.812	31763.
1100.00	31.091	18.180	49.272	19998.	23.144	34200.
1150.00	31.904	18.403	50.308	21164.	23.483	36690.
1200.00	32.692	18.622	51.314	22347.	23.829	39231.
1250.00	33.457	18.837	52.294	23547.	24.180	41821.
1300.00	34.200	19.050	53.250	24765.	24.538	44460.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-145

THERMODYNAMIC FUNCTIONS FOR SILICON (SI)
SOLID AND LIQUID PHASES

GRAM MOLECULAR WT.= 28.086 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
			SOLID PHASE			
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.000	0.000	0.000	0.000	0.000
10.00	0.000	0.000	0.001	0.005	0.002	0.001
15.00	0.001	0.002	0.002	0.025	0.007	0.008
20.00	0.001	0.005	0.006	0.094	0.023	0.027
25.00	0.003	0.011	0.014	0.284	0.057	0.076
30.00	0.006	0.023	0.030	0.704	0.115	0.182
35.00	0.011	0.042	0.053	1.474	0.196	0.386
40.00	0.018	0.067	0.086	2.696	0.295	0.729
45.00	0.028	0.099	0.127	4.450	0.407	1.256
50.00	0.040	0.136	0.176	6.782	0.527	2.010
55.00	0.055	0.177	0.232	9.720	0.649	3.026
60.00	0.072	0.221	0.293	13.273	0.773	4.337
65.00	0.092	0.268	0.360	17.446	0.896	5.969
70.00	0.114	0.318	0.431	22.234	1.018	7.946
75.00	0.137	0.368	0.506	27.629	1.140	10.286
80.00	0.163	0.420	0.583	33.631	1.261	13.006
85.00	0.190	0.473	0.663	40.240	1.382	16.120
90.00	0.218	0.527	0.745	47.453	1.503	19.640
95.00	0.248	0.582	0.830	55.264	1.622	23.578
100.00	0.279	0.637	0.916	63.668	1.740	27.942
105.00	0.312	0.692	1.004	72.659	1.857	32.742
110.00	0.345	0.748	1.093	82.235	1.974	37.983
115.00	0.380	0.803	1.183	92.394	2.090	43.673
120.00	0.415	0.859	1.275	103.13	2.205	49.816
125.00	0.451	0.916	1.367	114.44	2.319	56.420
130.00	0.488	0.972	1.460	126.32	2.431	63.487
135.00	0.526	1.028	1.554	138.75	2.542	71.021
140.00	0.564	1.084	1.648	151.73	2.650	79.026
145.00	0.603	1.140	1.743	165.24	2.756	87.504
150.00	0.643	1.195	1.838	179.28	2.859	96.457
155.00	0.683	1.251	1.934	193.83	2.960	105.89
160.00	0.724	1.306	2.029	208.88	3.058	115.79
165.00	0.765	1.360	2.125	224.41	3.153	126.18
170.00	0.806	1.414	2.220	240.40	3.245	137.04
175.00	0.848	1.468	2.316	256.85	3.333	148.38
180.00	0.890	1.521	2.411	273.73	3.419	160.20
185.00	0.932	1.573	2.506	291.04	3.502	172.49
190.00	0.975	1.625	2.600	308.75	3.582	185.25
195.00	1.018	1.676	2.694	326.85	3.660	198.49
200.00	1.061	1.727	2.788	345.34	3.735	212.19
205.00	1.104	1.777	2.881	364.20	3.807	226.36
210.00	1.148	1.826	2.973	383.41	3.877	241.00
215.00	1.191	1.874	3.065	402.96	3.945	256.10
220.00	1.235	1.922	3.157	422.85	4.010	271.65
225.00	1.279	1.969	3.248	443.06	4.073	287.66
230.00	1.322	2.016	3.338	463.58	4.134	304.13
235.00	1.366	2.061	3.427	484.39	4.193	321.04
240.00	1.410	2.106	3.516	505.50	4.250	338.40
245.00	1.454	2.151	3.604	526.89	4.305	356.20
250.00	1.498	2.194	3.692	548.55	4.358	374.44
255.00	1.542	2.237	3.779	570.47	4.410	393.12
260.00	1.586	2.279	3.865	592.65	4.459	412.23
265.00	1.629	2.321	3.950	615.06	4.506	431.77
270.00	1.673	2.362	4.035	637.71	4.552	451.73
273.15	1.701	2.387	4.088	652.09	4.580	464.53
275.00	1.717	2.402	4.119	660.57	4.596	472.12
280.00	1.760	2.442	4.202	683.66	4.637	492.92
285.00	1.804	2.481	4.285	706.95	4.678	514.14
290.00	1.847	2.519	4.366	730.43	4.717	535.76
295.00	1.891	2.556	4.447	754.11	4.754	557.80
298.15	1.918	2.580	4.498	769.12	4.777	571.89
300.00	1.934	2.593	4.527	777.97	4.790	580.23

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-145 (CONT.)

THERMODYNAMIC FUNCTIONS FOR SILICON (SI)
SOLID AND LIQUID PHASES

GRAM MOLECULAR WT.= 28.086 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
			SOLID PHASE			
300.00	1.934	2.593	4.527	777.97	4.790	580.23
310.00	2.020	2.665	4.686	826.21	4.858	626.30
320.00	2.106	2.735	4.841	875.12	4.922	673.93
330.00	2.191	2.802	4.993	924.65	4.983	723.11
340.00	2.276	2.867	5.143	974.77	5.041	773.79
350.00	2.360	2.930	5.290	1025.5	5.096	825.95
360.00	2.443	2.991	5.434	1076.7	5.148	879.58
370.00	2.526	3.050	5.576	1128.4	5.198	934.63
373.15	2.552	3.068	5.620	1144.8	5.213	952.26
380.00	2.608	3.107	5.715	1180.6	5.244	991.08
390.00	2.690	3.162	5.852	1233.3	5.288	1048.9
400.00	2.770	3.216	5.986	1286.4	5.329	1108.1
425.00	2.969	3.343	6.312	1420.8	5.422	1261.9
450.00	3.164	3.461	6.624	1557.4	5.502	1423.6
475.00	3.354	3.570	6.924	1695.8	5.572	1593.0
500.00	3.539	3.672	7.211	1835.9	5.634	1769.7
550.00	3.898	3.855	7.753	2120.4	5.741	2144.0
600.00	4.241	4.016	8.257	2409.7	5.831	2544.4
650.00	4.568	4.159	8.727	2703.3	5.909	2969.1
700.00	4.881	4.286	9.167	3000.5	5.978	3416.6
750.00	5.181	4.401	9.582	3300.9	6.040	3885.4
800.00	5.468	4.505	9.973	3604.4	6.098	4374.4
850.00	5.744	4.601	10.345	3910.6	6.151	4882.4
900.00	6.009	4.688	10.698	4219.4	6.202	5408.5
950.00	6.265	4.769	11.034	4530.7	6.250	5951.9
1000.00	6.512	4.844	11.356	4844.4	6.296	6511.7
1050.00	6.750	4.915	11.664	5160.3	6.341	7087.3
1100.00	6.980	4.980	11.960	5478.4	6.384	7677.9
1150.00	7.203	5.042	12.245	5798.7	6.426	8283.1
1200.00	7.419	5.101	12.519	6121.0	6.468	8902.3
1250.00	7.628	5.156	12.784	6445.5	6.508	9534.9
1300.00	7.831	5.209	13.040	6771.9	6.548	10181.
1350.00	8.029	5.259	13.288	7100.3	6.588	10839.
1400.00	8.220	5.308	13.528	7430.7	6.627	11508.
1450.00	8.407	5.354	13.761	7763.0	6.665	12191.
1500.00	8.590	5.398	13.988	8097.2	6.704	12885.
1550.00	8.767	5.441	14.208	8433.4	6.742	13589.
1600.00	8.941	5.482	14.423	8771.4	6.779	14305.
1650.00	9.110	5.522	14.632	9111.3	6.817	15032.
1685.00	9.226	5.549	14.775	9350.4	6.843	15546.
			LIQUID PHASE			
1685.00	9.226	12.730	21.956	21450.	6.100	15546.
1700.00	9.339	12.672	22.011	21542.	6.100	15876.
1750.00	9.703	12.484	22.187	21847.	6.100	16981.
1800.00	10.053	12.307	22.359	22152.	6.100	18095.
1850.00	10.387	12.139	22.526	22457.	6.100	19217.
1900.00	10.709	11.980	22.689	22762.	6.100	20347.
1950.00	11.018	11.829	22.847	23067.	6.100	21486.
2000.00	11.316	11.686	23.002	23372.	6.100	22632.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-146

THERMODYNAMIC FUNCTIONS FOR SILICON CARBIDE, HEXAGONAL (SI C)
SOLID PHASE

GRAM MOLECULAR WT.= 40.09715 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.000	0.000	0.000	0.000	0.000
10.00	0.000	0.000	0.000	0.002	0.001	0.001
15.00	0.000	0.001	0.001	0.011	0.003	0.004
20.00	0.001	0.002	0.002	0.036	0.007	0.012
25.00	0.001	0.004	0.005	0.089	0.014	0.030
30.00	0.002	0.006	0.008	0.184	0.024	0.061
35.00	0.003	0.010	0.013	0.340	0.039	0.113
40.00	0.005	0.015	0.019	0.581	0.058	0.194
45.00	0.007	0.021	0.028	0.933	0.083	0.310
50.00	0.009	0.029	0.038	1.426	0.115	0.473
55.00	0.013	0.038	0.051	2.102	0.157	0.694
60.00	0.016	0.050	0.067	3.017	0.212	0.987
65.00	0.021	0.065	0.086	4.240	0.280	1.368
70.00	0.027	0.083	0.110	5.831	0.359	1.856
75.00	0.033	0.105	0.138	7.842	0.447	2.473
80.00	0.040	0.129	0.169	10.314	0.543	3.238
85.00	0.049	0.156	0.205	13.289	0.648	4.174
90.00	0.059	0.187	0.246	16.803	0.759	5.300
95.00	0.070	0.220	0.290	20.893	0.877	6.636
100.00	0.082	0.256	0.338	25.587	1.001	8.204
105.00	0.095	0.294	0.390	30.913	1.130	10.022
110.00	0.110	0.335	0.445	36.893	1.263	12.109
115.00	0.126	0.379	0.505	43.547	1.399	14.482
120.00	0.143	0.424	0.567	50.892	1.539	17.160
125.00	0.161	0.472	0.633	58.941	1.681	20.159
130.00	0.181	0.521	0.702	67.706	1.825	23.493
135.00	0.201	0.572	0.773	77.195	1.971	27.179
140.00	0.223	0.624	0.847	87.416	2.118	31.229
145.00	0.246	0.678	0.924	98.375	2.266	35.658
150.00	0.270	0.734	1.004	110.07	2.414	40.477
155.00	0.295	0.790	1.085	122.52	2.563	45.698
160.00	0.321	0.848	1.169	135.71	2.713	51.333
165.00	0.348	0.907	1.255	149.64	2.862	57.392
170.00	0.376	0.967	1.342	164.32	3.010	63.884
175.00	0.405	1.027	1.432	179.74	3.158	70.819
180.00	0.434	1.088	1.523	195.91	3.306	78.205
185.00	0.465	1.150	1.615	212.80	3.452	86.050
190.00	0.497	1.213	1.709	230.42	3.597	94.361
195.00	0.529	1.276	1.805	248.77	3.742	103.15
200.00	0.562	1.339	1.901	267.84	3.885	112.41
205.00	0.596	1.403	1.999	287.62	4.027	122.16
210.00	0.630	1.467	2.098	308.11	4.168	132.40
215.00	0.666	1.532	2.197	329.30	4.308	143.14
220.00	0.702	1.596	2.298	351.19	4.447	154.38
225.00	0.738	1.661	2.399	373.76	4.584	166.12
230.00	0.776	1.726	2.502	397.02	4.719	178.37
235.00	0.813	1.791	2.605	420.95	4.853	191.14
240.00	0.852	1.856	2.708	445.55	4.985	204.42
245.00	0.891	1.922	2.812	470.80	5.115	218.22
250.00	0.930	1.987	2.917	496.70	5.244	232.54
255.00	0.970	2.052	3.022	523.24	5.370	247.39
260.00	1.011	2.117	3.128	550.40	5.495	262.77
265.00	1.052	2.182	3.233	578.18	5.618	278.67
270.00	1.093	2.247	3.340	606.58	5.739	295.10
273.15	1.119	2.287	3.407	624.77	5.814	305.73
275.00	1.135	2.311	3.446	635.57	5.858	312.06
280.00	1.177	2.376	3.553	665.15	5.975	329.56
285.00	1.220	2.440	3.659	695.32	6.091	347.59
290.00	1.263	2.504	3.766	726.06	6.204	366.15
295.00	1.306	2.567	3.873	757.36	6.316	385.25
298.15	1.333	2.607	3.941	777.36	6.385	397.56
300.00	1.350	2.631	3.980	789.21	6.426	404.89

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-146 (CONT.)

THERMODYNAMIC FUNCTIONS FOR SILICON CARBIDE, HEXAGONAL (SI C)
SOLID PHASE

GRAM MOLECULAR WT.= 40.09715 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
300.00	1.350	2.631	3.980	789.21	6.426	404.89
310.00	1.438	2.757	4.195	854.54	6.639	445.76
320.00	1.527	2.881	4.409	921.96	6.844	488.78
330.00	1.618	3.004	4.622	991.39	7.041	533.93
340.00	1.709	3.126	4.835	1062.8	7.230	581.22
350.00	1.802	3.246	5.047	1136.0	7.410	630.63
360.00	1.895	3.364	5.259	1210.9	7.583	682.16
370.00	1.989	3.480	5.469	1287.6	7.748	735.80
373.15	2.018	3.516	5.535	1312.1	7.798	753.13
380.00	2.083	3.594	5.677	1365.9	7.906	791.53
390.00	2.178	3.707	5.885	1445.7	8.057	849.34
400.00	2.273	3.817	6.090	1527.0	8.201	909.22
425.00	2.513	4.085	6.598	1736.3	8.537	1067.8
450.00	2.753	4.341	7.095	1953.5	8.839	1239.0
475.00	2.995	4.585	7.580	2178.0	9.112	1422.5
500.00	3.236	4.818	8.054	2408.9	9.358	1617.9
550.00	3.716	5.251	8.966	2887.8	9.783	2043.6
600.00	4.190	5.643	9.833	3386.0	10.134	2513.8
650.00	4.656	6.000	10.656	3900.2	10.427	3026.2
700.00	5.112	6.326	11.438	4427.9	10.673	3578.7
750.00	5.559	6.623	12.182	4966.9	10.882	4169.3
800.00	5.995	6.895	12.890	5515.6	11.062	4796.3
850.00	6.421	7.144	13.565	6072.7	11.217	5457.8
900.00	6.836	7.374	14.210	6637.0	11.352	6152.3
950.00	7.240	7.587	14.827	7207.7	11.473	6878.3
1000.00	7.635	7.784	15.419	7784.0	11.581	7634.6
1050.00	8.019	7.967	15.986	8365.6	11.679	8419.8
1100.00	8.393	8.138	16.531	8951.8	11.770	9232.8
1150.00	8.759	8.298	17.057	9542.5	11.856	10073.
1200.00	9.115	8.448	17.563	10137.	11.938	10938.
1250.00	9.463	8.589	18.052	10736.	12.017	11829.
1300.00	9.802	8.722	18.525	11339.	12.095	12743.
1350.00	10.134	8.849	18.983	11946.	12.172	13681.
1400.00	10.458	8.969	19.427	12556.	12.248	14641.
1450.00	10.775	9.083	19.858	13170.	12.327	15624.
1500.00	11.085	9.192	20.277	13789.	12.406	16627.
1550.00	11.388	9.297	20.686	14411.	12.489	17652.
1600.00	11.685	9.399	21.083	15038.	12.573	18696.
1650.00	11.976	9.496	21.472	15668.	12.661	19760.
1700.00	12.260	9.590	21.851	16304.	12.753	20843.
1750.00	12.540	9.682	22.222	16944.	12.849	21945.
1800.00	12.814	9.772	22.585	17589.	12.949	23065.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-147

THERMODYNAMIC FUNCTIONS FOR SILICON CARBIDE, CUBIC (SI C)
SOLID PHASE

GRAM MOLECULAR WT.= 40.09715 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T DEG K	$-(G_T^0-H_0^C)/T$ CAL/DEG-MOLE	$(H_T^0-H_0^C)/T$ CAL/DEG-MOLE	$(S_T-S_0^C)$ CAL/DEG-MOLE	$(H_T^0-H_0^C)$ CAL/MOLE	C_P^0 CAL/DEG-MOLE	$-(G_T^0-H_0^C)$ CAL/MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.000	0.000	0.000	0.000	0.000
10.00	0.000	0.000	0.000	0.002	0.001	0.001
15.00	0.000	0.001	0.001	0.012	0.003	0.004
20.00	0.001	0.002	0.003	0.039	0.008	0.013
25.00	0.001	0.004	0.005	0.096	0.015	0.032
30.00	0.002	0.007	0.009	0.199	0.027	0.066
35.00	0.004	0.011	0.014	0.369	0.042	0.123
40.00	0.005	0.016	0.021	0.629	0.063	0.210
45.00	0.007	0.022	0.030	1.007	0.089	0.336
50.00	0.010	0.031	0.041	1.532	0.122	0.512
55.00	0.014	0.041	0.054	2.242	0.164	0.749
60.00	0.018	0.053	0.071	3.192	0.219	1.060
65.00	0.023	0.069	0.091	4.453	0.288	1.464
70.00	0.028	0.087	0.115	6.091	0.369	1.978
75.00	0.035	0.109	0.144	8.157	0.459	2.623
80.00	0.043	0.134	0.176	10.694	0.557	3.422
85.00	0.052	0.162	0.213	13.740	0.663	4.395
90.00	0.062	0.193	0.254	17.331	0.775	5.562
95.00	0.073	0.226	0.299	21.498	0.893	6.945
100.00	0.086	0.263	0.348	26.270	1.017	8.563
105.00	0.099	0.302	0.401	31.672	1.145	10.435
110.00	0.114	0.343	0.457	37.729	1.278	12.579
115.00	0.131	0.387	0.517	44.462	1.415	15.014
120.00	0.148	0.432	0.580	51.887	1.555	17.756
125.00	0.167	0.480	0.647	60.016	1.697	20.823
130.00	0.186	0.530	0.716	68.857	1.840	24.228
135.00	0.207	0.581	0.788	78.417	1.984	27.988
140.00	0.229	0.634	0.863	88.702	2.130	32.115
145.00	0.253	0.688	0.940	99.717	2.276	36.622
150.00	0.277	0.743	1.020	111.47	2.424	41.521
155.00	0.302	0.800	1.102	123.96	2.572	46.825
160.00	0.328	0.857	1.186	137.19	2.721	52.543
165.00	0.356	0.916	1.272	151.16	2.870	58.686
170.00	0.384	0.976	1.360	165.89	3.019	65.264
175.00	0.413	1.036	1.449	181.35	3.167	72.286
180.00	0.443	1.098	1.541	197.55	3.314	79.761
185.00	0.474	1.159	1.633	214.49	3.461	87.695
190.00	0.506	1.222	1.728	232.16	3.607	96.097
195.00	0.538	1.285	1.823	250.56	3.752	104.97
200.00	0.572	1.348	1.920	269.68	3.896	114.33
205.00	0.606	1.412	2.018	289.52	4.039	124.18
210.00	0.641	1.477	2.117	310.07	4.181	134.51
215.00	0.676	1.541	2.217	331.33	4.322	145.35
220.00	0.712	1.606	2.318	353.29	4.462	156.69
225.00	0.749	1.671	2.420	375.95	4.600	168.53
230.00	0.786	1.736	2.523	399.29	4.737	180.89
235.00	0.825	1.801	2.626	423.32	4.873	193.76
240.00	0.863	1.867	2.730	448.02	5.007	207.15
245.00	0.902	1.932	2.834	473.38	5.139	221.06
250.00	0.942	1.998	2.940	499.40	5.269	235.49
255.00	0.982	2.063	3.045	526.06	5.397	250.45
260.00	1.023	2.128	3.151	553.37	5.523	265.94
265.00	1.064	2.194	3.258	581.30	5.648	281.97
270.00	1.106	2.259	3.364	609.84	5.770	298.52
273.15	1.132	2.300	3.432	628.14	5.846	309.22
275.00	1.148	2.324	3.471	638.99	5.890	315.61
280.00	1.190	2.388	3.578	668.74	6.008	333.23
285.00	1.233	2.453	3.686	699.07	6.124	351.39
290.00	1.276	2.517	3.793	729.98	6.238	370.09
295.00	1.320	2.581	3.901	761.45	6.350	389.33
298.15	1.347	2.621	3.969	781.56	6.419	401.72
300.00	1.364	2.645	4.009	793.48	6.460	409.10

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-147 (CONT.)

THERMODYNAMIC FUNCTIONS FOR SILICON CARBIDE, CUBIC (SI C)
SOLID PHASE

GRAM MOLECULAR WT.= 40.09715 GRAMS 1 CAL=4.1840 JOULES

T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
300.00	1.364	2.645	4.009	793.48	6.460	409.10
310.00	1.452	2.771	4.224	859.15	6.673	450.26
320.00	1.542	2.897	4.439	926.90	6.877	493.58
330.00	1.633	3.020	4.654	996.65	7.072	539.04
340.00	1.725	3.142	4.868	1068.3	7.259	586.65
350.00	1.818	3.262	5.081	1141.8	7.438	636.39
360.00	1.912	3.381	5.293	1217.0	7.609	688.26
370.00	2.006	3.497	5.503	1294.0	7.772	742.24
373.15	2.036	3.533	5.569	1318.5	7.822	759.68
380.00	2.101	3.612	5.713	1372.5	7.928	798.32
390.00	2.196	3.724	5.920	1452.5	8.078	856.48
400.00	2.292	3.835	6.127	1534.0	8.221	916.72
425.00	2.532	4.103	6.635	1743.7	8.552	1076.3
450.00	2.774	4.359	7.133	1961.3	8.850	1248.4
475.00	3.016	4.602	7.619	2186.0	9.118	1432.8
500.00	3.258	4.834	8.093	2417.0	9.360	1629.2
550.00	3.740	5.265	9.005	2895.8	9.776	2056.9
600.00	4.215	5.656	9.871	3393.4	10.117	2528.9
650.00	4.682	6.010	10.692	3906.6	10.401	3043.2
700.00	5.139	6.333	11.472	4432.8	10.639	3597.4
750.00	5.586	6.627	12.213	4969.9	10.841	4189.7
800.00	6.023	6.895	12.918	5516.4	11.014	4818.1
850.00	6.448	7.142	13.590	6070.9	11.163	5480.9
900.00	6.863	7.369	14.232	6632.4	11.295	6176.6
950.00	7.267	7.579	14.846	7200.1	11.411	6903.7
1000.00	7.661	7.773	15.434	7773.4	11.517	7660.8
1050.00	8.045	7.954	15.998	8351.7	11.614	8446.7
1100.00	8.418	8.122	16.541	8934.7	11.705	9260.3
1150.00	8.783	8.280	17.063	9522.1	11.791	10100.
1200.00	9.139	8.428	17.567	10114.	11.875	10966.
1250.00	9.485	8.568	18.053	10710.	11.958	11857.
1300.00	9.824	8.700	18.524	11310.	12.040	12771.
1350.00	10.155	8.825	18.980	11914.	12.123	13709.
1400.00	10.478	8.944	19.422	12522.	12.205	14669.
1450.00	10.794	9.058	19.852	13134.	12.291	15651.
1500.00	11.103	9.167	20.270	13751.	12.380	16654.
1550.00	11.405	9.273	20.677	14372.	12.472	17678.
1600.00	11.701	9.374	21.075	14998.	12.568	18721.
1650.00	11.991	9.472	21.463	15629.	12.668	19785.
1700.00	12.275	9.568	21.843	16265.	12.774	20868.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-148

THERMODYNAMIC FUNCTIONS FOR GERMANIUM (GE)
SOLID AND LIQUID PHASES

GRAM MOLECULAR WT.= 72.59 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / MOLE	CAL / DEG-MOLE	CAL / MOLE
			SOLID PHASE			
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.000	0.000	0.001	0.001	0.000
10.00	0.001	0.003	0.004	0.029	0.014	0.009
15.00	0.004	0.015	0.019	0.225	0.077	0.057
20.00	0.012	0.046	0.058	0.928	0.217	0.238
25.00	0.028	0.100	0.127	2.489	0.414	0.690
30.00	0.052	0.170	0.222	5.098	0.632	1.553
35.00	0.084	0.252	0.336	8.812	0.853	2.939
40.00	0.123	0.340	0.464	13.616	1.067	4.932
45.00	0.169	0.433	0.601	19.470	1.274	7.591
50.00	0.219	0.527	0.746	26.352	1.479	10.958
55.00	0.274	0.623	0.897	34.248	1.679	15.062
60.00	0.332	0.719	1.051	43.146	1.880	19.930
65.00	0.394	0.816	1.210	53.042	2.078	25.581
70.00	0.458	0.913	1.371	63.908	2.268	32.031
75.00	0.524	1.010	1.533	75.719	2.456	39.290
80.00	0.592	1.106	1.698	88.465	2.642	47.368
85.00	0.662	1.202	1.864	102.13	2.823	56.271
90.00	0.733	1.296	2.030	116.68	2.993	66.004
95.00	0.806	1.390	2.196	132.04	3.152	76.569
100.00	0.880	1.482	2.361	148.18	3.302	87.963
105.00	0.954	1.572	2.526	165.06	3.446	100.18
110.00	1.029	1.660	2.690	182.63	3.584	113.22
115.00	1.105	1.747	2.852	200.88	3.715	127.08
120.00	1.181	1.831	3.013	219.77	3.838	141.74
125.00	1.258	1.914	3.172	239.25	3.953	157.20
130.00	1.334	1.995	3.329	259.29	4.062	173.45
135.00	1.411	2.073	3.484	279.86	4.165	190.48
140.00	1.488	2.149	3.637	300.93	4.261	208.29
145.00	1.564	2.224	3.788	322.46	4.351	226.85
150.00	1.641	2.296	3.937	344.43	4.435	246.17
155.00	1.718	2.366	4.084	366.80	4.514	266.22
160.00	1.794	2.435	4.229	389.56	4.587	287.00
165.00	1.870	2.501	4.371	412.67	4.656	308.50
170.00	1.945	2.565	4.511	436.11	4.720	330.71
175.00	2.021	2.628	4.648	459.86	4.780	353.61
180.00	2.095	2.688	4.784	483.90	4.836	377.19
185.00	2.170	2.747	4.917	508.22	4.890	401.44
190.00	2.244	2.804	5.048	532.79	4.940	426.35
195.00	2.318	2.860	5.177	557.61	4.988	451.92
200.00	2.391	2.913	5.304	582.67	5.033	478.12
205.00	2.463	2.966	5.429	607.94	5.076	504.95
210.00	2.535	3.016	5.552	633.42	5.116	532.40
215.00	2.607	3.066	5.672	659.10	5.155	560.47
220.00	2.678	3.113	5.791	684.96	5.191	589.13
225.00	2.748	3.160	5.908	711.01	5.226	618.38
230.00	2.818	3.205	6.024	737.22	5.259	648.21
235.00	2.888	3.249	6.137	763.59	5.290	678.61
240.00	2.957	3.292	6.249	790.11	5.319	709.57
245.00	3.025	3.334	6.359	816.78	5.347	741.09
250.00	3.093	3.374	6.467	843.57	5.373	773.16
255.00	3.160	3.414	6.574	870.50	5.397	805.76
260.00	3.226	3.452	6.679	897.54	5.421	838.89
265.00	3.293	3.489	6.782	924.70	5.443	872.54
270.00	3.358	3.526	6.884	951.98	5.466	906.71
273.15	3.399	3.548	6.947	969.22	5.480	928.49
275.00	3.423	3.561	6.985	979.36	5.488	941.38
280.00	3.488	3.596	7.084	1006.9	5.510	976.55
285.00	3.552	3.630	7.181	1034.5	5.533	1012.2
290.00	3.615	3.663	7.278	1062.2	5.556	1048.4
295.00	3.678	3.695	7.373	1090.0	5.579	1085.0
298.15	3.717	3.715	7.432	1107.6	5.594	1108.3
300.00	3.740	3.727	7.467	1118.0	5.602	1122.1

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-148 (CONT.)

THERMODYNAMIC FUNCTIONS FOR GERMANIUM (GE)
SOLID AND LIQUID PHASES

GRAM MOLECULAR WT.= 72.59 GRAMS — 1 CAL=4.1840 JOULES

T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / MOLE	CAL / DEG-MOLE	CAL / MOLE
			SOLID PHASE			
300.00	3.740	3.727	7.467	1118.0	5.602	1122.1
310.00	3.863	3.788	7.651	1174.2	5.649	1197.7
320.00	3.985	3.847	7.831	1230.9	5.693	1275.1
330.00	4.104	3.903	8.007	1288.1	5.735	1354.3
340.00	4.221	3.958	8.179	1345.6	5.774	1435.2
350.00	4.337	4.010	8.347	1403.6	5.810	1517.9
360.00	4.450	4.061	8.511	1461.8	5.843	1602.2
370.00	4.562	4.109	8.672	1520.4	5.875	1688.1
373.15	4.597	4.124	8.721	1538.9	5.884	1715.5
380.00	4.673	4.156	8.829	1579.3	5.904	1775.6
390.00	4.781	4.201	8.982	1638.5	5.932	1864.6
400.00	4.888	4.245	9.133	1697.9	5.958	1955.2
425.00	5.149	4.347	9.496	1847.7	6.018	2188.1
450.00	5.400	4.442	9.841	1998.8	6.072	2429.9
475.00	5.642	4.529	10.171	2151.2	6.121	2680.1
500.00	5.877	4.610	10.486	2304.8	6.166	2938.3
550.00	6.323	4.755	11.078	2615.2	6.246	3477.6
600.00	6.742	4.882	11.624	2929.3	6.316	4045.3
650.00	7.138	4.995	12.132	3246.7	6.380	4639.4
700.00	7.511	5.096	12.608	3567.2	6.440	5258.0
750.00	7.866	5.188	13.054	3890.6	6.495	5899.7
800.00	8.204	5.271	13.475	4216.7	6.548	6563.0
850.00	8.526	5.348	13.873	4545.4	6.600	7246.8
900.00	8.833	5.419	14.252	4876.7	6.649	7950.0
950.00	9.128	5.485	14.613	5210.3	6.697	8671.6
1000.00	9.411	5.546	14.957	5546.3	6.744	9410.9
1050.00	9.683	5.604	15.287	5884.7	6.790	10167.
1100.00	9.945	5.659	15.604	6225.3	6.836	10939.
1150.00	10.197	5.711	15.909	6568.2	6.881	11727.
1200.00	10.442	5.761	16.203	6913.4	6.925	12530.
1210.40	10.491	5.771	16.262	6985.4	6.934	12699.
			LIQUID PHASE			
1210.40	10.491	12.050	22.541	14585.	7.000	12699.
1250.00	10.877	11.890	22.767	14863.	7.000	13596.
1300.00	11.339	11.702	23.041	15213.	7.000	14741.
1350.00	11.778	11.528	23.305	15563.	7.000	15900.
1400.00	12.194	11.366	23.560	15913.	7.000	17071.
1450.00	12.590	11.216	23.806	16263.	7.000	18256.
1500.00	12.968	11.075	24.043	16613.	7.000	19452.
1550.00	13.329	10.944	24.272	16963.	7.000	20660.
1600.00	13.674	10.820	24.495	17313.	7.000	21879.
1650.00	14.005	10.705	24.710	17663.	7.000	23109.
1700.00	14.323	10.596	24.919	18013.	7.000	24350.
1750.00	14.629	10.493	25.122	18363.	7.000	25601.
1800.00	14.923	10.396	25.319	18713.	7.000	26862.
1850.00	15.207	10.304	25.511	19063.	7.000	28133.
1900.00	15.480	10.217	25.698	19413.	7.000	29413.
1950.00	15.745	10.135	25.879	19763.	7.000	30702.
2000.00	16.000	10.056	26.057	20113.	7.000	32001.
2050.00	16.248	9.982	26.230	20463.	7.000	33308.
2100.00	16.487	9.911	26.398	20813.	7.000	34624.
2150.00	16.720	9.843	26.563	21163.	7.000	35948.
2200.00	16.945	9.778	26.724	21513.	7.000	37280.
2250.00	17.164	9.717	26.881	21863.	7.000	38620.
2300.00	17.377	9.658	27.035	22213.	7.000	39968.
2350.00	17.584	9.601	27.186	22563.	7.000	41324.
2400.00	17.786	9.547	27.333	22913.	7.000	42686.
2450.00	17.982	9.495	27.477	23263.	7.000	44057.
2500.00	18.174	9.445	27.619	23613.	7.000	45434.
2550.00	18.360	9.397	27.757	23963.	7.000	46819.
2600.00	18.542	9.351	27.893	24313.	7.000	48210.
2650.00	18.720	9.307	28.027	24663.	7.000	49608.
2700.00	18.894	9.264	28.157	25013.	7.000	51012.
2750.00	19.063	9.223	28.286	25363.	7.000	52424.
2800.00	19.229	9.183	28.412	25713.	7.000	53841.
2850.00	19.391	9.145	28.536	26063.	7.000	55265.
2900.00	19.550	9.108	28.658	26413.	7.000	56695.
2950.00	19.705	9.072	28.777	26763.	7.000	58130.
3000.00	19.857	9.038	28.895	27113.	7.000	59572.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-149

THERMODYNAMIC FUNCTIONS FOR LEAD ORTHOPHOSPHATE ($PB_3(PO_4)_2$)
SOLID PHASE

GRAM MOLECULAR WT.= 811.5128 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T DEG K	$-(G^0-H^C_0)/T$ CAL/DEG-MOLE	$(H^0-H^C_0)/T$ CAL/DEG-MOLE	$(S_T-S^C_0)$ CAL/DEG-MOLE	$(H^0-H^C_0)$ CAL/MOLE	C^0_P CAL/DEG-MOLE	$-(G^0-H^C_0)$ CAL/MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.022	0.061	0.083	0.305	0.227	0.109
10.00	0.143	0.375	0.518	3.749	1.307	1.433
15.00	0.401	0.977	1.378	14.659	3.142	6.008
20.00	0.789	1.788	2.576	35.753	5.350	15.773
25.00	1.288	2.750	4.038	68.752	7.901	32.208
30.00	1.884	3.835	5.719	115.04	10.614	56.522
35.00	2.562	4.999	7.560	174.95	13.337	89.663
40.00	3.308	6.202	9.510	248.10	15.883	132.31
45.00	4.108	7.406	11.514	333.27	18.141	184.85
50.00	4.949	8.581	13.530	429.03	20.125	247.46
55.00	5.821	9.713	15.534	534.23	21.935	320.13
60.00	6.713	10.805	17.518	648.29	23.675	402.77
65.00	7.620	11.860	19.480	770.88	25.348	495.27
70.00	8.536	12.880	21.416	901.60	26.923	597.52
75.00	9.459	13.866	23.325	1039.9	28.399	709.39
80.00	10.384	14.818	25.203	1185.5	29.797	830.72
85.00	11.310	15.739	27.049	1337.8	31.131	961.36
90.00	12.235	16.630	28.865	1496.7	32.402	1101.2
95.00	13.157	17.492	30.650	1661.7	33.611	1250.0
100.00	14.076	18.327	32.403	1832.7	34.760	1407.6
105.00	14.990	19.136	34.126	2009.2	35.856	1573.9
110.00	15.898	19.920	35.818	2191.2	36.907	1748.8
115.00	16.801	20.680	37.481	2378.2	37.921	1932.1
120.00	17.696	21.419	39.116	2570.3	38.904	2123.6
125.00	18.585	22.138	40.724	2767.2	39.860	2323.2
130.00	19.467	22.837	42.305	2968.9	40.789	2530.8
135.00	20.342	23.519	43.862	3175.1	41.692	2746.2
140.00	21.210	24.184	45.394	3385.7	42.567	2969.3
145.00	22.070	24.832	46.902	3600.7	43.416	3200.1
150.00	22.922	25.466	48.388	3819.9	44.242	3438.3
155.00	23.767	26.084	49.852	4043.1	45.048	3683.9
160.00	24.605	26.690	51.295	4270.3	45.839	3936.8
165.00	25.435	27.282	52.717	4501.5	46.618	4196.8
170.00	26.259	27.862	54.120	4736.5	47.385	4464.0
175.00	27.074	28.430	55.505	4975.3	48.141	4738.0
180.00	27.883	28.988	56.871	5217.9	48.882	5019.0
185.00	28.685	29.536	58.221	5464.1	49.607	5306.7
190.00	29.480	30.073	59.553	5713.9	50.313	5601.1
195.00	30.268	30.601	60.869	5967.2	50.998	5902.2
200.00	31.049	31.119	62.168	6223.8	51.662	6209.8
205.00	31.824	31.628	63.452	6483.8	52.304	6523.9
210.00	32.592	32.128	64.720	6746.8	52.925	6844.3
215.00	33.354	32.619	65.972	7013.0	53.527	7171.0
220.00	34.109	33.100	67.210	7282.1	54.111	7504.0
225.00	34.858	33.574	68.432	7554.1	54.678	7843.1
230.00	35.601	34.038	69.640	7828.8	55.230	8188.3
235.00	36.338	34.495	70.833	8106.3	55.769	8539.5
240.00	37.069	34.944	72.013	8386.5	56.294	8896.6
245.00	37.794	35.385	73.179	8669.3	56.806	9259.6
250.00	38.513	35.818	74.332	8954.5	57.306	9628.4
255.00	39.227	36.244	75.471	9242.3	57.792	10003.
260.00	39.935	36.663	76.598	9532.4	58.264	10383.
265.00	40.637	37.075	77.712	9824.9	58.723	10769.
270.00	41.334	37.480	78.814	10120.	59.168	11160.
273.15	41.770	37.732	79.502	10306.	59.440	11410.
275.00	42.025	37.878	79.904	10417.	59.598	11557.
280.00	42.711	38.270	80.981	10716.	60.013	11959.
285.00	43.392	38.655	82.047	11017.	60.413	12367.
290.00	44.068	39.033	83.101	11320.	60.799	12780.
295.00	44.738	39.406	84.144	11625.	61.170	13198.
298.15	45.158	39.637	84.794	11818.	61.397	13464.
300.00	45.404	39.771	85.175	11931.	61.527	13621.

H^C_0 AND S^C_0 APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-150

THERMODYNAMIC FUNCTIONS FOR VANADIUM MONOXIDE (V O)
SOLID PHASE

GRAM MOLECULAR WT.= 66.9414 GRAMS — 1 CAL=4.1840 JOULES

T DEG K = 273.15 + T DEG C

T DEG K	$-(G_T^0-H_0^C)/T$ CAL/DEG MOLE	$(H_T^0-H_0^C)/T$ CAL/DEG MOLE	$(S_T-S_0^C)$ CAL/DEG MOLE	$(H_T^0-H_0^C)$ CAL/MOLE	C_P^0 CAL/DEG MOLE	$-(G_T^0-H_0^C)$ CAL/MOLE
0.00	0.000	0.000	0.000	0.000	0.000	0.000
5.00	0.000	0.000	0.000	0.001	0.001	0.000
10.00	0.001	0.002	0.002	0.018	0.007	0.006
15.00	0.002	0.006	0.008	0.092	0.024	0.031
20.00	0.005	0.015	0.019	0.290	0.058	0.097
25.00	0.009	0.028	0.038	0.709	0.113	0.236
30.00	0.016	0.049	0.065	1.469	0.195	0.490
35.00	0.026	0.078	0.103	2.714	0.308	0.907
40.00	0.039	0.115	0.154	4.600	0.452	1.545
45.00	0.055	0.162	0.217	7.283	0.626	2.465
50.00	0.075	0.218	0.293	10.905	0.827	3.733
55.00	0.098	0.283	0.382	15.585	1.048	5.414
60.00	0.126	0.357	0.483	21.404	1.281	7.571
65.00	0.158	0.437	0.595	28.405	1.520	10.261
70.00	0.193	0.523	0.716	36.613	1.764	13.535
75.00	0.233	0.614	0.847	46.052	2.013	17.439
80.00	0.275	0.709	0.985	56.751	2.268	22.013
85.00	0.321	0.809	1.130	68.737	2.527	27.296
90.00	0.370	0.911	1.282	82.030	2.790	33.322
95.00	0.422	1.017	1.440	96.643	3.055	40.123
100.00	0.477	1.126	1.603	112.59	3.323	47.728
105.00	0.535	1.237	1.772	129.87	3.592	56.163
110.00	0.595	1.350	1.945	148.51	3.862	65.453
115.00	0.658	1.465	2.123	168.50	4.133	75.621
120.00	0.722	1.582	2.304	189.84	4.405	86.688
125.00	0.789	1.700	2.490	212.55	4.676	98.671
130.00	0.858	1.820	2.678	236.60	4.947	111.59
135.00	0.929	1.941	2.870	262.02	5.217	125.46
140.00	1.002	2.063	3.065	288.77	5.484	140.30
145.00	1.077	2.185	3.262	316.85	5.747	156.11
150.00	1.153	2.308	3.461	346.23	6.004	172.92
155.00	1.230	2.431	3.662	376.88	6.253	190.73
160.00	1.310	2.555	3.864	408.75	6.494	209.54
165.00	1.390	2.678	4.068	441.80	6.726	229.37
170.00	1.472	2.800	4.272	475.99	6.949	250.22
175.00	1.555	2.922	4.476	511.27	7.164	272.09
180.00	1.639	3.042	4.681	547.62	7.373	294.98
185.00	1.724	3.162	4.886	584.99	7.575	318.90
190.00	1.810	3.281	5.091	623.36	7.771	343.84
195.00	1.896	3.398	5.295	662.69	7.963	369.80
200.00	1.984	3.515	5.499	702.98	8.149	396.79
205.00	2.072	3.630	5.702	744.18	8.331	424.79
210.00	2.161	3.744	5.905	786.28	8.508	453.81
215.00	2.250	3.857	6.107	829.25	8.680	483.84
220.00	2.340	3.969	6.309	873.07	8.848	514.88
225.00	2.431	4.079	6.510	917.72	9.011	546.93
230.00	2.522	4.188	6.709	963.17	9.169	579.98
235.00	2.613	4.295	6.908	1009.4	9.322	614.02
240.00	2.704	4.402	7.106	1056.4	9.472	649.06
245.00	2.796	4.507	7.303	1104.1	9.617	685.08
250.00	2.888	4.610	7.499	1152.5	9.757	722.08
255.00	2.981	4.712	7.693	1201.7	9.893	760.06
260.00	3.073	4.813	7.886	1251.5	10.025	799.01
265.00	3.166	4.913	8.079	1301.9	10.151	838.93
270.00	3.259	5.011	8.270	1353.0	10.273	879.80
273.15	3.317	5.072	8.389	1385.5	10.346	906.03
275.00	3.351	5.108	8.459	1404.6	10.389	921.62
280.00	3.444	5.203	8.647	1456.9	10.499	964.39
285.00	3.537	5.297	8.834	1509.6	10.604	1008.1
290.00	3.630	5.389	9.019	1562.9	10.703	1052.7
295.00	3.723	5.480	9.203	1616.6	10.795	1098.3
298.15	3.781	5.537	9.318	1650.7	10.851	1127.5
300.00	3.816	5.569	9.385	1670.8	10.883	1144.8

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-150 (CONT.)

THERMODYNAMIC FUNCTIONS FOR VANADIUM MONOXIDE (V O)
SOLID PHASE

GRAM MOLECULAR WT.= 66.9414 GRAMS 1 CAL=4.1840 JOULES
T DEG K = 273.15 + T DEG C

T	$-(G_T^0-H_0^C)/T$	$(H_T^0-H_0^C)/T$	$(S_T-S_0^C)$	$(H_T^0-H_0^C)$	C_P^0	$-(G_T^0-H_0^C)$
DEG K	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / DEG-MOLE	CAL / MOLE	CAL / DEG-MOLE	CAL / MOLE
300.00	3.816	5.569	9.385	1670.8	10.883	1144.8
310.00	4.001	5.743	9.745	1780.5	11.041	1240.4
320.00	4.186	5.911	10.097	1891.6	11.179	1339.6
330.00	4.371	6.073	10.443	2004.0	11.300	1442.3
340.00	4.554	6.228	10.782	2117.5	11.407	1548.5
350.00	4.737	6.377	11.114	2232.1	11.502	1658.0
360.00	4.919	6.521	11.440	2347.5	11.589	1770.7
370.00	5.099	6.659	11.758	2463.8	11.669	1886.7
373.15	5.156	6.701	11.857	2500.6	11.692	1923.9
380.00	5.279	6.792	12.070	2580.9	11.743	2005.9
390.00	5.457	6.920	12.376	2698.7	11.812	2128.1
400.00	5.633	7.043	12.676	2817.1	11.878	2253.4
425.00	6.069	7.332	13.401	3116.0	12.028	2579.4
450.00	6.496	7.596	14.092	3418.4	12.162	2923.2
475.00	6.913	7.840	14.753	3724.0	12.284	3283.8
500.00	7.321	8.065	15.386	4032.5	12.396	3660.6
550.00	8.109	8.468	16.577	4657.5	12.603	4460.1
600.00	8.861	8.821	17.683	5292.6	12.802	5316.9
650.00	9.580	9.135	18.715	5937.7	13.000	6227.1
700.00	10.268	9.418	19.686	6592.6	13.195	7187.4
750.00	10.926	9.676	20.603	7257.2	13.391	8194.8
800.00	11.559	9.915	21.473	7931.9	13.599	9246.8
850.00	12.166	10.138	22.304	8617.3	13.822	10341.
900.00	12.752	10.349	23.101	9314.2	14.054	11477.
950.00	13.317	10.550	23.867	10023.	14.285	12651.
1000.00	13.863	10.743	24.605	10743.	14.507	13863.
1050.00	14.392	10.927	25.318	11473.	14.716	15111.
1100.00	14.904	11.103	26.007	12214.	14.910	16394.
1150.00	15.401	11.273	26.674	12964.	15.089	17712.
1200.00	15.885	11.435	27.320	13722.	15.252	19061.
1250.00	16.355	11.591	27.946	14489.	15.400	20443.
1300.00	16.812	11.740	28.552	15262.	15.534	21856.
1350.00	17.258	11.883	29.141	16042.	15.655	23298.
1400.00	17.693	12.019	29.712	16827.	15.764	24770.
1450.00	18.117	12.150	30.267	17618.	15.860	26269.
1500.00	18.531	12.275	30.806	18413.	15.956	27796.
1550.00	18.935	12.396	31.331	19213.	16.052	29350.
1600.00	19.331	12.511	31.842	20018.	16.148	30929.
1650.00	19.717	12.623	32.340	20828.	16.243	32534.
1700.00	20.096	12.731	32.827	21643.	16.338	34163.
1750.00	20.466	12.835	33.302	22462.	16.433	35816.
1800.00	20.829	12.937	33.766	23286.	16.527	37493.
1850.00	21.185	13.035	34.220	24114.	16.621	39193.
1900.00	21.534	13.130	34.665	24948.	16.716	40915.
1950.00	21.876	13.224	35.100	25786.	16.810	42659.
2000.00	22.212	13.314	35.527	26629.	16.903	44425.

H_0^C AND S_0^C APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

APPENDIX III

A LIST OF PUBLICATIONS SINCE 1957 BY THE STAFF OF THE NATIONAL BUREAU OF STANDARDS BEARING ON THE THERMODYNAMIC PROPERTIES OF LIGHT-ELEMENT AND SOME RELATED SUBSTANCES

A comprehensive interdivision program of research on the thermodynamic properties of light-element compounds and a few other classes of substances of interest in chemical propulsion has been sponsored at the National Bureau of Standards by the Advanced Research Projects Agency continuously since 1958, and is still in progress under the sponsorship of the Air Force Office of Scientific Research. The following list of publications (which is limited to unclassified ones) is designed to reflect not only the formal output of this program so far, but also that research during the same period of time and by the same staff members which, despite its sponsorship otherwise than by ARPA or AFOSR, logically belongs in the same subject category. The list thus omits work done by other NBS groups which may also contribute to light-element thermodynamics.

The publications listed are grouped into the following major categories, though some occasionally overlap (particularly V and VI with the other categories).

I. Heats of Formation, Reaction, and Solution by Calorimetry
II. Heat Capacities and Heats of Fusion (Solids and Liquids)
III. High-Temperature Equilibrium and Kinetic Studies
IV. Absorption and Emission Spectroscopy
V. Pertinent New Apparatus and Experimental and Computative Methods
VI. Bibliographies, Reviews, All-Theoretical Studies, etc.
VII. Preliminary Reports (Summary Technical Reports) on the Thermodynamic Properties of Light-Element and Some Related Compounds

In addition, each of the above groups is subdivided as follows:

Part A. Actual Publications: Material already published or accepted for publication, either formally (in journals, handbooks, monographs, etc.) or as reports, but excluding specific parts of the 14-semiannual Technical Summary Reports (some 2500 pages) issued as part of the ARPA-sponsored program since 1958. (These 14 reports are listed at the end.)

Part B. Projected Publications: Unpublished manuscripts which have at least reached the stage where their submission for publication can be scheduled for some fairly definite time in the near future. Since this criterion is necessarily a vague one, the coverage in Part B cannot be entirely consistent nor all-inclusive, but should help to bridge the time gap between completion of research and its actual publication.

I. Heats of Formation, Reaction, and Solution by Calorimetry

Part A. Actual Publications

Heat of Formation of Boron Trichloride
Walter H. Johnson, Richard G. Miller, and Edward J. Prosen
J. Research NBS 62, 213 (1959).

Heat of Formation of Beryllium Chloride
Walter H. Johnson and Alexis A. Gilliland
J. Research NBS 65A, 59 (1961).

Heat of Decomposition of Potassium Perchlorate
Walter H. Johnson and Alexis A. Gilliland
J. Research NBS 65A, 63 (1961).

Heats of Formation of Lithium Perchlorate, Ammonium Perchlorate, and Sodium Perchlorate
Alexis A. Gilliland and Walter H. Johnson
J. Research NBS 65A, 67 (1961).

Heat of Formation of N-Dimethylaminodiborane
Walter H. Johnson, Irving Jaffe, and Edward J. Prosen
J. Research NBS 65A, 71 (1961).

Heats of Hydrolysis and Formation of Potassium Borohydride
Walter H. Johnson, Richard H. Schumm, Isa H. Wilson, and Edward J. Prosen
J. Research NBS 65A, 97 (1961).

Heats of Combustion and Formation of Trimethylborane, Triethylborane, and Tri-n-butylborane
Walter H. Johnson, Marthada V. Kilday, and Edward J. Prosen
J. Research NBS 65A, 215 (1961).

Heats of Hydrolysis and Formation of Dimethoxychloroborane
Marthada V. Kilday, Walter H. Johnson, and Edward J. Prosen
J. Research NBS 65A, 435 (1961).

Heat of Formation of Nitronium Perchlorate
Alexis A. Gilliland
J. Research NBS 66A, 447 (1962).

Heats of Solution, Transition, and Formation of Three Crystalline Forms of Metaboric Acid
Marthada V. Kilday and Edward J. Prosen
J. Research NBS 68A, 127 (1964).

Heat of Formation of Nitrogen Trifluoride and the N-F Bond Energy
George T. Armstrong, Sidney Marantz, and C. F. Coyle
J. Am. Chem. Soc. 81, 3798 (1959).

Heats of Formation of Two Isomers of Difluorodiazine
George T. Armstrong and Sidney Marantz
J. Chem. Phys. 38, 169-172 (1963).

The Heat of Combustion of Dicyanoacetylene
George T. Armstrong and Sidney Marantz
J. Phys. Chem. 64, 1776 (1960).

The Heat of Combustion and Heat of Formation of Aluminum Carbide
R. C. King and G. T. Armstrong
J. Research Natl. Bur. Standards 68A, 661-668, Nov.-Dec. (1964).

Heat of Decomposition of Sodium and Potassium Chlorate
A. A. Gilliland and D. D. Wagman
J. Research Natl. Bur. Standards 69A, 1 (1965).

The Heat of Formation of Aluminum Fluoride by the Direct Combination of the Elements
E. S. Domalski and G. T. Armstrong
J. Research Natl. Bur. Standards 69A, 137-148 (1965).

Thermodynamic Studies of Substances of Interest in a Light Element Program. Part 1. Inorganic Compounds
George T. Armstrong
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the First Meeting, Nov. 1963, Vol. I, pp. 49-80. (Chemical Propulsion Information Agency Publ. No. 44 (U), Feb. 1964).

Calorimetric Investigation of Aluminum Borohydride
A. A. Gilliland and D. D. Wagman
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Second Meeting, June 1964, Vol. I, p. 53. (Chemical Propulsion Information Agency, Publ. No. 54 U, Aug. 1964).

Heat of Chlorination of Aluminum Borohydride
A. A. Gilliland and D. D. Wagman
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Third Meeting, Mar. 1965, Vol. I (In press) (Chemical Propulsion Information Agency).

Calorimetry of Beryllium Compounds
George T. Armstrong
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Second Meeting, June 1964, Vol. I, pp. 73-78. (Chemical Propulsion Information Agency Publ. No. 54 (U), Aug. 1964.)

Combustion and Reaction Calorimetry of Several Compounds of Interest in a Light Element Program
George T. Armstrong
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Third Meeting, Mar. 1965, Vol. I. (In press) (Chemical Propulsion Information Agency.)

Part B. Projected Publications

The Heats of Formation of Aluminum Diboride and Alpha Aluminum Dodecaboride
E. S. Domalski and G. T. Armstrong
J. Research Natl. Bur. Standards (To be submitted.)

The Heat of Formation of Beryllium Fluoride by Direct Combination of the Elements
K. L. Churney and G. T. Armstrong
J. Research Natl. Bur. Standards. (To be submitted)

Contribution to the Thermochemistry of Beryllium. A New Application of the Rotating Bomb Calorimeter.
G. T. Armstrong and C. F. Coyle
(To be submitted for Publication.)

II. Heat Capacities and Heats of Fusion (Solids and Liquids)

Part A. Actual Publications

The Heat Capacity of Sulfur from 25 to 456°, the Heats and Temperatures of Transition and Fusion
Estal D. West
J. Amer. Chem. Soc. 81, 29 (1959).

Calorimetric Properties of Some Alkali Pentaborate Hydrates from 15 to 370°K
G. T. Furukawa, M. L. Reilly, and J. H. Piccirelli
J. Res. Natl. Bur. Standards 68A, 381-389 (1964).

Heat Capacity of Potassium Borohydride (KBH_4) from 15 to 375°K. Thermodynamic Properties from 0 to 700°K.
G. T. Furukawa, M. L. Reilly, and J. H. Piccirelli
J. Res. Natl. Bur. Standards 68A, 651-659 (1964).

Heat Capacity and Thermodynamic Properties of Beryllium Aluminate (Chrysoberyl), $BeO \cdot Al_2O_3$, from 16 to 380°K
G. T. Furukawa and W. G. Saba
J. Res. Natl. Bur. Standards 69A, 13-18 (1965).

Calorimetric Determination of the Enthalpy of Graphite from 1200 to 2600°K
E. D. West and S. Ishihara
Paper in book "Advances in Thermophysical Properties at Extreme Temperatures and Pressures", Amer. Soc. Mech. Engin., New York, 1965.

Thermodynamic Properties of Magnesium Oxide and Beryllium Oxide from 298° to 1200°K
A. C. Victor and T. B. Douglas
J. Research Natl. Bur. Standards 67A, 325-329 (1963).

Heat Content of Sodium Borohydride and Potassium Borohydride from 0° to 400°C as Determined by the Drop Method
T. B. Douglas and A. W. Harman
J. Research Natl. Bur. Standards 60, 117-124 (1958).

Heat Content of Zirconium and of Five Compositions of Zirconium Hydride from 0° to 900°C
T. B. Douglas and A. C. Victor
J. Research Natl. Bur. Standards 61, 13-23 (1958).

The Relative Enthalpy of Polytetrafluoroethylene from 0 to 440°C
T. B. Douglas and A. W. Harman
J. Research Natl. Bur. Standards 69A, 149-157 (1965).

Heat Capacity and Enthalpy Measurements on Aluminum Carbide (Al_4C_3) from 15 to 1173°K. Thermodynamic Properties from 0 to 2000°K
G. T. Furukawa, T. B. Douglas, W. G. Saba, and A. C. Victor
J. Res. Natl. Bur. Standards 69A, Sept.-Oct. (1965).

Part B. Projected Publications

Heat Capacity and Thermodynamic Properties of Beryllium Nitride, Be_3N_2, from 16 to 370°K
G. T. Furukawa and M. L. Reilly
(Journal publication in near future.)

Heat Capacity and Thermodynamic Properties of Beryllium Aluminate, $BeO \cdot 3Al_2O_3$, from 16 to 380°K
G. T. Furukawa and W. G. Saba
(Journal publication in near future.)

Thermodynamic Properties of Beryllium Nitride (Be_3N_2) and Lithium Fluoroberyllate (Li_2BeF_4) Based on Enthalpy Measurements in the Interval 273 to 1173°K
T. B. Douglas and W. H. Payne
(To be submitted for journal publication.)

Thermodynamic Properties of Lithium Fluoroaluminate (Li_3AlF_6) and Crystalline Aluminum Fluoride (AlF_3) Based on Enthalpy Measurements from 273 to 1173°K
T. B. Douglas, D. A. Ditmars, and J. E. Neufer
(To be submitted for journal publication.)

Thermodynamic Properties of Two Aluminates of Beryllium ($BeAl_2O_4$ and $BeAl_6O_{10}$) Based on Enthalpy Measurements from 273 to 1173°K
D. A. Ditmars and T. B. Douglas
(To be submitted for journal publication.)

High-Temperature Thermodynamic Properties of the Condensed Phases of Potassium Chloride, Lithium Chloride, and their Eutectic Solution
T. B. Douglas and A. W. Harman
(To be submitted for journal publication.)

Heat Capacity and Thermodynamic Properties of Beryllium Oxide, BeO, from 15 to 380°K
G. T. Furukawa and M. L. Reilly
(Journal publication in near future.)

III. High-Temperature Equilibrium and Kinetic Studies

Part A. Actual Publications

Spectrophotometric Determination of the Rate of Dissociation of Tetrafluorohydrazine Behind a Shock Wave
Lawrence M. Brown and Basil deB. Darwent
J. Chem. Phys. 42, 2158-2165 (1965).

Apparent Temperatures at Melting Points of Some Metal Oxides in a Solar Furnace
J. J. Diamond and S. J. Schneider
J. Am. Ceram. Soc. 43, 1-3 (1960).

Solubility of Water Vapor in Molten Alumina
J. J. Diamond and A. L. Dragoo
"Thermal Imaging Techniques", Ed. by P. E. Glaser and R. F. Walker, Plenum Press 1964, pp. 225-228.

Part B. Projected Publications

Vapor Pressure and Heat of Sublimation of Aluminum Trifluoride as Determined by the Transpiration Method from 1230° to 1290°K
R. F. Krause, Jr., A. C. Victor, and T. B. Douglas
(To be submitted for journal publication.)

Mass Spectrometric Investigation of Vaporization and Reaction in the $BeO-BeF_2$ System
J. Efimenko
(To be submitted to J. Chem. Phys.)

Mass Spectrometric Investigation of Vaporization and Reaction in the $BeO-Al_2O_3$ System
J. Efimenko
(To be submitted to J. Chem. Phys.)

Preparation of Pure Polymorphs of BeF_2 by Phase Purifications at High-Temperatures
A. R. Glasgow, Jr.
(To be submitted to J. Research NBS, A. Physics and Chemistry.)

Hydrofluorothermal Growth of Crystalline BeF_2 Under HF Pressure
A. R. Glasgow, Jr.
(To be submitted for journal publication.)

Studies of Molten Alumina in the Arc-Image Furnace
J. J. Diamond and A. L. Dragoo

Vapor-Deposited Alumina and Its Transition to α-Alumina
A. L. Dragoo and J. J. Diamond

Effect of Silica on the Phase Transformation of Vapor-Deposited Alumina
A. L. Dragoo and J. J. Diamond

IV. Absorption and Emission Spectroscopy

Part A. Actual Publications

Infrared Emission Spectra of $B_2O_3(g)$ and $B_2O_2(g)$
David White, Patrick N. Walsh, and D. E. Mann
J. Chem. Phys. 28, 508 (1958).

Infrared Emission Spectra of Gaseous B_2O_3 and B_2O_2
David White, David E. Mann, Patrick N. Walsh, and Armin Sommer
J. Chem. Phys. 32, 481 (1960).

Infrared Emission Spectrum of Gaseous HBO_2
David White, David E. Mann, Patrick N. Walsh, and Armin Sommer
J. Chem. Phys. 32, 488 (1960).

The Infrared Absorption Spectra of B_2O_3, B_2O_2 and BO_2 in Solid Argon Matrices
D. E. Mann, A. Sommer, David White, and M. J. Linevsky
J. Chem. Phys. 38, 87 (1963).

The Infrared Spectra, Structures, and Thermodynamics of Gaseous LiO, Li_2O and Li_2O_2
D. E. Mann, David White, K. S. Seshadri, and D. F. Dever
J. Chem. Phys. 39, 2463 (1963).

Infrared Spectrum and Structure of Gaseous $A\ell_2O$
M. J. Linevsky, David White, and D. E. Mann
J. Chem. Phys. 41, 542 (1964).

Microwave Spectrum and Structure of N_2F_4
David R. Lide, Jr. and D. E. Mann
J. Chem. Phys. 31, 1129 (1959).

Microwave Spectrum of Aluminum Monofluoride
D. R. Lide, Jr.
J. Chem. Phys. 38, 2027 (1963).

Microwave Spectrum of Lithium Chloride
David R. Lide, Jr., P. Cahill, and L. P. Gold
J. Chem. Phys. 40, 156-159 (1964).

High Temperature Microwave Spectroscopy: $A\ell F$ and $A\ell C\ell$
D. R. Lide, Jr.
J. Chem. Phys. 42, 1013 (1965).

Spectroscopy of Fluorine Flames. I. Hydrogen-Fluorine Flame and the Vibration-Rotation Emission Spectrum of HF
D. E. Mann, B. A. Thrush, D. R. Lide, Jr., J. J. Ball, and N. Acquista
J. Chem. Phys. 34, 420 (1961).

Recent Microwave Spectra Studies of High Temperature Species
D. R. Lide, Jr.
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the First Meeting, Nov. 1963, Vol. I, pp. 1-2. (Chemical Propulsion Information Agency Publ. No. 44 (U), Feb. 1964).

High-Temperature Matrix Spectroscopy at the National Bureau of Standards
D. E. Mann
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Third Meeting, Mar. 1965, Vol. I. (In press)(Chemical Propulsion Information Agency).

Infrared Spectrum and Structure of the NF_2 Radical
M. D. Harmony, R. J. Meyers, L. J. Schoen, D. R. Lide, Jr., and D. E. Mann
J. Chem. Phys. 35, 1129 (1961).

Microwave Spectrum and Structure of Difluoramine
David R. Lide, Jr.
J. Chem. Phys. 38, 456 (1963).

Infrared Spectrum of Difluoroamine
J. J. Comeford, D. E. Mann, L. J. Schoen, and D. R. Lide, Jr.
J. Chem. Phys. 38, 461 (1963).

Microwave Spectrum of the SO Radical
F. X. Powell and D. R. Lide, Jr.
J. Chem. Phys. 41, 1413 (1964).

Part B. Projected Publications

Vibrational Matrix Spectra of Group II A Fluorides
D. E. Mann, et al.

Low Frequency Vibrational Matrix Spectra and Structure of B_2O_3
D. E. Mann, et al.

Low Frequency Vibrational Matrix Spectra and Structure of Li_2O
D. E. Mann, et al.

Improved Measurement of the Electric Dipole Moment of the Hydroxyl Radical
F. X. Powell and D. R. Lide, Jr.
(To be published in J. Chem. Phys.)

V. Pertinent New Apparatus and Experimental and Computative Methods

Part A. Actual Publications

Combustion Calorimetry with Fluorine. Constant Pressure Flame Calorimetry
George T. Armstrong and Ralph S. Jessup
J. Research Natl. Bur. Standards 64A, 49-59 (1960).

New Apparatus for the Precise Measurement of Heat Content and Heat Capacity from 0° to 1500°C
T. B. Douglas and W. H. Payne
NBS Handbook 77: Vol. II, 241-276 (1961).

Calorimetric Calibration of the Electrical Energy Measurement in an Exploding Wire Experiment
D. H. Tsai and J. H. Park
"Exploding Wires", Vol. II, ed. W. G. Chace and H. K. Moore, Plenum Press, New York, 1962.

A Fast-Opening, Large-Aperture Shutter for High-Speed Photography
E. C. Cassidy and D. H. Tsai
J. Research Natl. Bur. Standards 67C, Jan.-March 1963
Reprinted in J. of Soc. Mot. Picture and Television Engineers, 9 E. 41 St., New York (1963).

Versatile Stark Waveguide for Microwave Spectroscopy
D. R. Lide, Jr.
Rev. Sci. Inst. 35, 1226 (1964).

High-Speed Thermodynamic Measurements and Related Techniques
C. W. Beckett and A. Cezairliyan
Chapter of book "Experimental Thermodynamics, Vol. I. Calorimetry of Non-Reacting Systems" (to be published).

A High-Speed (milliseconds) Method for the Simultaneous Measurement of Enthalpy, Specific Heat, and Resistivity of Electrical Conductors at High Temperatures
A Cezairliyan
Advances in Thermophysical Properties at Extreme Temperatures and Pressures, p. 253, Amer. Soc. Mech. Eng., 345 East 47 St., New York (1965).

Light-Element Purification
A. R. Glasgow, Jr.
Manuscript prepared for inclusion in NBS Tech. Note ____, Analysis and Purification Section: Summary of Activities July 1964 to June 1965.

Hydrofluorothermal Growth of Crystalline BeF_2 under HF Pressure
A. R. Glasgow, Jr.
NBS Tech. Note 251, Sec. 2.8, p. 10-11, Oct. 1964;
and NBS Tech. Note 260, Sec. 2.25, p. 23-24, May 1965.

Apparatus for High-Temperature Preparation of Pure Crystalline Polymorphs
A. R. Glasgow, Jr.
NBS Tech. Note 251, Sec. 5.2, p. 53-54, Oct. 1964; and
NBS Tech. Note 260, Sec. 5.16, p. 75-79, May 1965.

Electrical Resistances of Wires of Low Temperature Coefficient of Resistance Useful in Calorimetry (10°-380°K)
G. T. Furukawa, M. L. Reilly, and W. G. Saba
Rev. Sci. Instr. 35, No. 1, 113-114 (1964).

Principles of Calorimetric Design
D. C. Ginnings and E. D. West
Chapter of book "Experimental Thermodynamics. Vol. I: Calorimetry of Non-Reacting Systems" (to be published).

High-Temperature Drop Calorimetry
Thomas B. Douglas and Edward G. King
Chapter of book "Experimental Thermodynamics. Vol. I: Calorimetry of Non-Reacting Systems" (to be published).

An Adiabatic Calorimeter for the Range 30 to 500°C
E. D. West and D. C. Ginnings
J. Research Natl. Bur. Standards 60, 309 (1958).

Techniques in Calorimetry. I. A Noble-Metal Thermocouple for Differential Use
E. D. West
Rev. Sci. Instr. 31, 896 (1960).

Heat Exchange in Adiabatic Calorimeters
E. D. West
J. Research Natl. Bur. Standards 67A, 331 (1963).

Heating Rate as a Test of Adiabatic Calorimeters, and the Heat Capacity of α-Alumina
E. D. West
Trans. Faraday Soc. 59, 2200 (1963).

Heat Lead Problem in Calorimetry
D. C. Ginnings and E. D. West
Rev. Sci. Instr. 35, 965 (1964).

Part B. Projected Publications

Debye Thermodynamic Functions in One, Two, and Three Dimensions
M. L. Reilly and G. T. Furukawa
(NBS Monograph, in near future.)

Adiabatic Low-Temperature Calorimetry
E. F. Westrum, Jr., J. P. McCullough, and G. T. Furukawa
Chapter of book "Experimental Thermodynamics. Vol. I: Calorimetry of Non-Reacting Systems".

Adiabatic Calorimetry from 300 to 800°K
Estal D. West and Edgar F. Westrum, Jr.
Chapter of book "Experimental Thermodynamics. Vol. I: Calorimetry of Non-Reacting Systems".

High-Temperature Valve for Use with Fluorides
A. R. Glasgow, Jr.
Anal. Chem. "Aids for the Analyst." (Manuscript in process of review for publication.)

Nickel-Monel Trap for Fluorides
A. R. Glasgow, Jr.
Anal. Chem. "Aids for the Analyst." (Manuscript in process of review for publication.)

Time-Resolved Electrical Measurements in High-Current Discharges
E. C. Cassidy, S. W. Zimmerman, and K. K. Neumann
Submitted for publication in Rev. Sci. Instr.

Rupture-Disc Ampoule for Anhydrous Addition of HF to a Closed Bomb
A. R. Glasgow, Jr.
Anal. Chem. Manuscript being prepared for publication.

Design of Automatically Controlled High-Temperature, Three-Zone Furnace
A. R. Glasgow, Jr.
J. Research NBS C (Eng. and Inst.). Manuscript to be prepared for publication.

Preparation of Pure Crystalline Solids by Phase Purifications at High Temperatures
A. R. Glasgow, Jr.
J. Research NBS A (Phys. and Chem.). Manuscript to be prepared for publication.

Photographic and Spectroscopic Studies of Exploding Wires in a Sealed Vessel
E. C. Cassidy and K. K. Neumann
Submitted for publication in Proc. 7th Int. Congress on High-Speed Photography, Zurich, Switzerland.

VI. Bibliographies, Reviews, All-Theoretical Studies, etc.

Part A. Actual Publications

LCAO-MO SCF Study of B_2
Alice A. Padgett and Virginia Griffing
J. Chem. Phys. 30, 1286-1291 (1959).

Fluorine Flame Calorimetry
George T. Armstrong
Chapter 7, "Experimental Thermochemistry", Vol. II, H. A. Skinner, Ed. (Interscience Publishers, New York, 1962).

Heats of Formation of Inorganic Fluorine Compounds - A Survey
George T. Armstrong and Leslie A. Krieger
Progress in International Research on Thermodynamic and Transport Properties, Joseph F. Masi and Donald H. Tsai, Editors, (ASME), Academic Press, 1962, pp. 8-78.

Rate of Vaporization of Refractory Substances
R. F. Walker, J. Efimenko, and N. L. Lofgren
Proceedings of the Conference on Physical Chemistry in Aerodynamics and Space Flight, A. L. Meyerson and A. C. Harrison, Ed. Pergamon Press, New York 1961, pp. 24-30.

Rate of Vaporization of Refractory Substances
J. J. Diamond, J. Efimenko, R. F. Hampson, and R. F. Walker
Proceedings of the Fourth International Symposium on the Reactivity of Solids, Elsevier Publ. Co., Amsterdam, 1961, pp. 725-34.

High Temperature Measurements and Standards: 1000-3000°C
R. F. Walker
"High Temperature Technology", supplement to Pure and Applied Chemistry, 7-38 (1964).

The Zirconium-Hydrogen System: Some Thermodynamic Properties from a Heat Content Study
T. B. Douglas
J. Am. Chem. Soc. 80, 5040-5046 (1958).

Current Thermodynamic Research on Light-Element Compounds at the National Bureau of Standards
T. B. Douglas
Proceedings of the Propellant Thermodynamics and Handling Conference, Ohio State Univ. Special Report 12, 111-126 (1960).

High-Temperature Thermodynamic Functions for Zirconium and Unsaturated Zirconium Hydrides
T. B. Douglas
J. Research Natl. Bur. Standards 67A, 403-426 (1963).

A Statistical Model for the Beta Zirconium Hydrides
T. B. Douglas
J. Chem. Phys. 40, 2248-2257 (1964).

The Calorimeter and Its Influence on the Development of Chemistry
George T. Armstrong
J. Chem. Educ. 41, 297-307 (1964).

Thermodynamic Data Compilation and Review at the National Bureau of Standards
G. T. Armstrong
Svensk Kemisk Tidskrift 76, 419-427 (1964).

Recent Studies of Thermodynamic Properties of Beryllium Species
T. B. Douglas
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the First Meeting, Nov. 1963, Vol. I, pp. 87-99. (Chemical Propulsion Information Agency, Publ. No. 44 (U), Feb. 1964).

A Survey of Certain Thermodynamic Data on Some Light-Element Mixed-Metal and Mixed-Nonmetal Compounds
T. B. Douglas
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the First Meeting, Nov. 1963, Vol. I, pp. 173-182. (Chemical Propulsion Information Agency, Publ. No. 44 (U), Feb. 1964).

Selected Values of Chemical Thermodynamic Properties
Donald D. Wagman
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Second Meeting, June 1964, Vol. I, pp. 13-34. (Chemical Propulsion Information Agency, Publ. No. 54 U, Aug. 1964).

Recent Studies of Thermodynamic Properties of Some Beryllium and Aluminum Species
Thomas B. Douglas
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Second Meeting, June 1964, Vol. I, pp. 67-72. (Chemical Propulsion Information Agency, Publ. No. 54 U, Aug. 1964).

Some Aspects of High-Temperature Matrix-Isolation Spectroscopy
D. E. Mann
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Second Meeting, June 1964, Vol. I, pp. 109-115. (Chemical Propulsion Information Agency, Publ. No. 54 U, Aug. 1964).

Status of Thermochemical Data on Some Heavy-Metal Oxides and Halides
Donald D. Wagman
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Third Meeting, Mar. 1965, Vol. I (In press) (Chemical Propulsion Information Agency).

A Survey of the Thermodynamic Data on Heavier Elements and Their Compounds: High-Temperature Enthalpy and Vaporization Equilibria
Thomas B. Douglas
Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry. Proceedings of the Third Meeting, Mar. 1965, Vol. I (In press) (Chemical Propulsion Information Agency).

VII. Preliminary Reports (Summary Technical Reports) on the Thermodynamic Properties of Light-Element and Some Related Compounds

NBS Report No.	Summary Technical Report No.	Date of Report
	Part A. Actual Publications	
6297	1	1 January 1959
6484	2	1 July 1959
6645	3	1 January 1960
6928	4	1 July 1960
7093	5	1 January 1961
7192	6	1 July 1961
7437	7	1 January 1962
7587	8	1 July 1962
7796	9	1 January 1963
8033	10	1 July 1963
8186	11	1 January 1964
8504	12	1 July 1964
8628	13	1 January 1965
8919	14	1 July 1965
	Part B. Projected Publications	
(?)	15	1 January 1966

APPENDIX IV.

SUBSTANCE-PROPERTY INDEX FOR 1964

by Rachel M. Dudley, Catherine Nelson,
Joyce J. Grimes, and Donald D. Wagman

This Section presents a comprehensive bibliography and index of abstracted and published papers on thermochemistry and chemical thermodynamics for the period 1 December 1963 to 31 December 1964. The Physical, Applied, and Organic Sections of Chemical Abstracts were carefully searched for references to articles containing thermodynamic data. In addition a number of journals were searched, issue by issue, for such data. A listing of these journals is given on page 82 of NBS Report 7796 (1 January, 1963).

The index provides a key to the properties and substances covered by the bibliography. It lists by formula, the inorganic and organometallic compounds arranged in the Standard Order of Arrangement based on that used for the revision of Circular 500 by the Chemical Thermodynamics Group at the National Bureau of Standards. (See Figure 1,) If the structural formula of the organic portion of a metal-organic compound is not clearly apparent, the name of the organic portion is listed below the formula.

The state of the substance is indicated in the column "state". (See Table I.) Listing of a particular substance is in the following order: (not identified), solid, liquid, gas, amorphous, aqueous, non-aqueous, adsorbed. The absence of a state designation implies that the state is the same as that immediately preceding. However, it must be noted that when the physical state cannot be determined from the abstracted document, it is listed first with no state designation.

A code letter or series of letters is used to designate the property, properties or types of measurement which have been made on the substance in the article indicated by the reference number in the last column. The properties to which the code letters refer are given in Table 1.

The numbers in the last column of the Index refer to the citations in the Bibliography. If the column entry is preceded by a letter, it refers to a summary of current work in progress at various laboratories, which has been published in the IUPAC Bulletin of Thermodynamics and Thermochemistry, Number 8, 1965. Information regarding this Bulletin may be obtained from Dr. Guy Waddington, Office of Critical Tables, National Academy of Sciences, Washington, D.C.

Table I

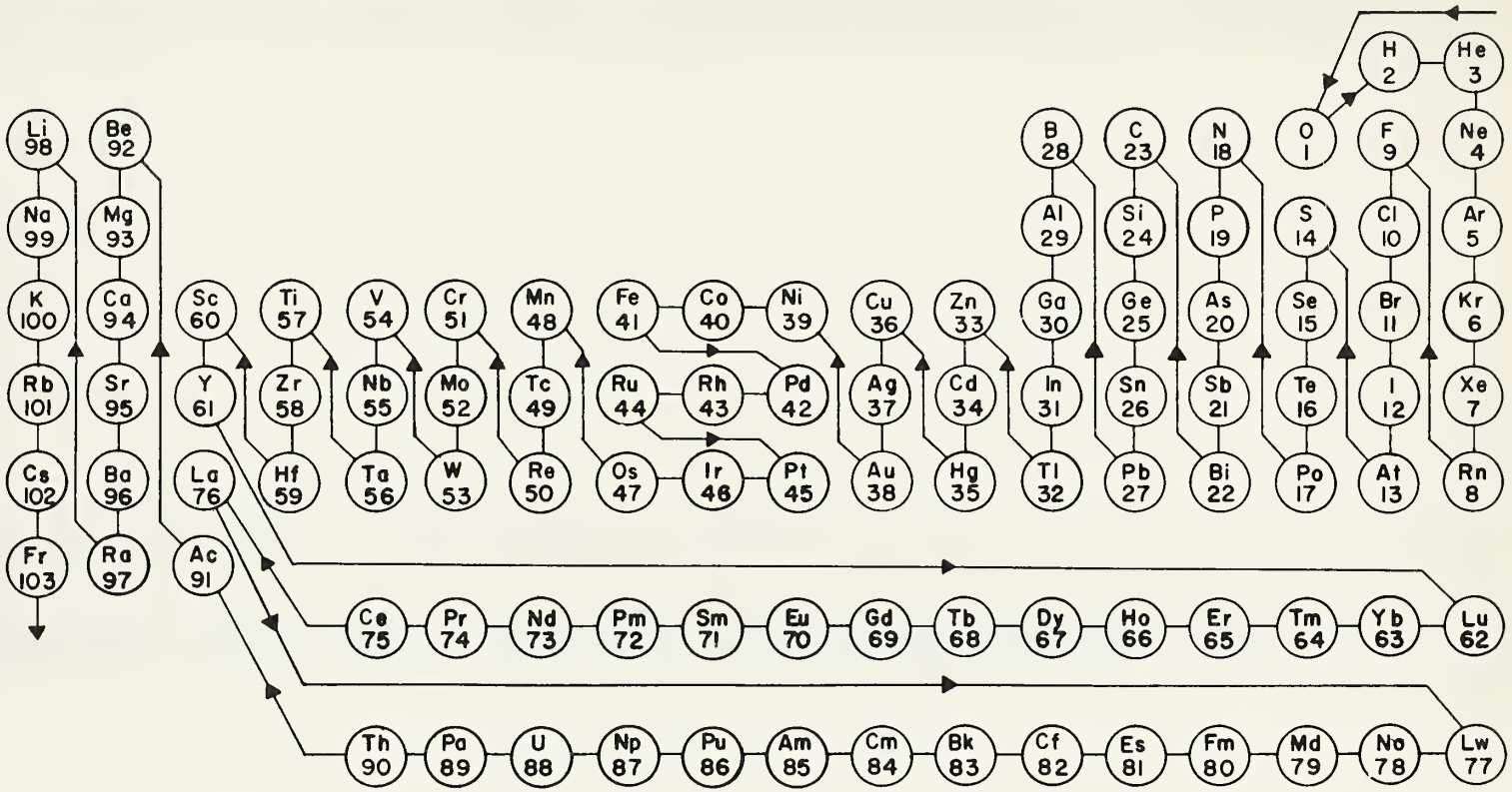
GLOSSARY OF SYMBOLS FOR SUBSTANCE-PROPERTY INDEX

Property Letter	Property Identification
a	Physical properties of pure substances: density, refractive index, boiling point, freezing or triple point.
b	Physical properties of condensed mixtures including phase diagrams.
h	Pressure effects on condensed phases: compressibility.
i	Critical state properties.
j	P-V-T data for gases including mixtures.
k	Equilibrium data for congruent phase changes: vapor pressures, sublimation pressures.
l	Equilibrium data for non-congruent phase changes: decomposition pressures.
m	Heat and entropy for phase changes: transition, fusion, vaporization.
n	Heats of chemical reactions.
p	Solution equilibria: activities, vapor pressures over solutions including alloys, solubility.
q	Heats of solution, mixing and dilution.
r	Chemical equilibria.
s	Electrochemical data.
t	Heat content data and derived functions.
v	Heat capacity data and derived functions.
w	Thermal functions from statistical and similar calculations.
y	Miscellaneous heat effects: adsorption, radioactive decay.
z	Reviews, compilations.

Physical States:

(c)crystal, solid	(aq)aqueous
(liq)liquid	(non-aq)non-aqueous, includes fused salts, solid solutions
(g)gas	
(amorph)amorphous	(ads)adsorbed

Listing of states is in order of thermal stability. Substance is listed first when the particular physical state cannot be determined from the abstracted document.



Standard Order of Arrangement of the Elements and Compounds
based on the
Periodic Classification of the Elements

Figure 1

Explanation: key "finding numbers" below the chemical symbol for each element.

SUBSTANCE-PROPERTY INDEX TO ABSTRACTS AND BIBLIOGRAPHY

SECTION II. INORGANIC SUBSTANCES

Substance	State	Prop.	Ref.
1 - Oxygen			
O	liq		C-24
		a	2462
			2552
		k	2323
	g	v	2153
		w	1166
O^+	g	w	1166
O_2		a	D-2
		j	D-64
		k	C-8
		m	B-35
		w	D-64
	liq	a	D-14
	g	w	1166
		w	2448
	aq	p	1057
	ads	v	2077
O_2^+	g	w	1166
O_2-H_2O	g	p	2336
O_2-Sea H_2O	g	p	2336
O_2-Kr		b	D-14
O_2-Xe		b	D-14
O_2-Pb	g	s	1201
O_2-Ag	ads	y	1577
O_2-Fe	g	p	1288
O_3		n	1931
	g	w	1870
2 - Hydrogen			
H	c	k	2333
	liq	a	2462
		a	2465
		ak	2158
		j	2325
		k	2323
		k	2464
H^+	aq	n	1063
H_2		a	D-2
		a	D-7
		a	D-64
		a	D-72
		j	D-2
		k	C-8
		n	A-50
		s	D-31
H_2		w	A-70
	c	a	1882
		hv	1633
		k	2035
		m	B-41
		p	1812
		v	1412
HD	c	v	1529
D_2	c	mv	1182
H_2	liq	a	1265
		a	2552
		m	C-8
	g	hw	2400
		j	1028
		j	1645
		j	2325
		jv	2463
		t	1710
		v	1875
		w	2406
	aq	r	1905
	ads	y	C-1
		y	1186
		y	1821
D_2	liq	k	2323
		v	1182
	ads	y	C-1
H_2-O	g	p	D-41
H_2-He	liq	l	1086
	g	l	1086
H_2-Ne		b	D-28
H_2-Ar	g	q	A-20
H_2-N_2		bp	D-54
		j	D-28
		y	C-30
	g	q	A-20
H_2-CO_2		bp	D-54
H_2-CH_4		j	D-64
		y	C-30
	g	q	A-20
H_2-C_6H_{12}		p	D-49
H_2-AgCl	non-aq	s	1643
H_2-Ni	liq	p	D-62
H_2-Fe	g	p	1702
H_2-Co	liq	p	D-62
H_2-Pd		y	D-13

Substance	State	Prop.	Ref.
D_2-Pd		y	D-13
H_2-Pd/Ag	g	p	1906
H_2-Noble metal alloys		p	D-62
HO	g	n	1441
		w	2448
HO_3		n	1931
H_2O		b	D-69
		n	A-46
		w	D-34
	c	am	1688
		k	2044
		n	1603
		w	1838
H_2O(sea)	c	v	1467
H_2O	liq	h	1277
		i	1442
		iv	1339
		j	2039
		k	1067
		k	1479
		k	1868
		k	2332
		n	2105
		v	1478
		v	2032
		v	2148
		iv	1343
		w	1838
		z	2192
	g	j	B-10
		a	2267
		v	1478
		w	2448
	ads	y	C-38
D_2O	c	k	2468
	g	t	2433
T_2O	liq	a	1058
H_2O-H_2O_2	liq	h	2264
H_2O-H_2SO_4	aq	q	1034
H_2O-C_2H_2	g	r	1934
H_2O-porous glass	c	mv	1948
H_2O_2	aq	p	2072
H_2O_2-HF	aq	q	1120
H_2O_2-NH_3-H_2O		b	2473
H_3O^+	g	w	2197

3 - Helium

Substance	State	Prop.	Ref.
He	c	a	1388
		v	2154
	liq	m	C-8
		k	2115
		k	2117
		v	2271
		k	2410
		k	2470
		v	2509
		k	2548
	g	bv	1869
		z	2116
		i	2470
He-H_2	liq	l	1086
	g	l	1086
He-Ar		h	D-67
He-F	g	v	1681
He-C_4H_{10}		hj	D-66
He-CF_4		h	D-67
He-$AlCl_3$	g	v	1681
He_2-Li	g	p	2319

4 - Neon

Substance	State	Prop.	Ref.
Ne		w	D-64
	c	k	2157
	liq	k	2157
		k	2323
Ne-H_2		b	D-28
Ne-D_2		b	D-28

5 - Argon

Substance	State	Prop.	Ref.
Ar		a	D-2
		w	D-46
		w	D-64
		z	2596
	c	v	2402
	liq	k	2323
	g	jt	1680
		v	1877
		w	2401
	aq	p	1057
Ar-H_2		j	D-28
	g	q	A-20
Ar-He		h	D-67
Ar-Kr	liq	n	D-18
Ar-N_2		j	D-28
		k	C-3
	g	q	A-20
Ar-CO_2		n	D-18

Substance	State	Prop.	Ref.
$Ar-CH_4$	g	q	A-20
		l	1098
$Ar-H_2O-C_2H_5OH$	g	p	2305

6 - Krypton

Substance	State	Prop.	Ref.
Kr		w	D-46
	liq	k	2323
	g	v	1877
$Kr-O_2$		b	D-14
$Kr-H_2O$	g	p	2156
Kr-Ar	liq	n	D-18

7 - Xenon

Substance	State	Prop.	Ref.
Xe		w	D-46
		y	D-13
	liq	k	2323
	g	t	2133
$Xe-O_2$		b	D-14
$Xe-H_2O$	g	p	2156
XeO_3	c	n	1756
	g	w	2427
	aq	r	1316
$XeHO_4^-$	aq	r	1316
$XeHO_6^{---}$	aq	r	1316
$XeH_2O_6^{--}$	aq	r	1316
$XeH_3O_6^-$	aq	r	1316

9 - Fluorine

Substance	State	Prop.	Ref.
F	c	km	2510
F-He	g	v	1681
F_2	g	n	1002
HF		j	D-16
	liq	k	2323
	g	h	1109
	aq	r	1159
		r	2307
$HF-H_2O$		q	A-11
	c	b	1395
	g	p	1513
$HF-H_2O_2$	aq	q	1120
$HF\cdot H_2O$	c	a	1395
HF_2^-	aq	v	1825
$2HF\cdot H_2O$	c	a	1395
$3HF\cdot H_2O$	c	a	1395
XeF_2	g	l	1199
XeF_2-H_2O	c	p	1317
XeF_4	g	l	1199
		w	2326
XeF_6	c	a	2149

10 - Chlorine

Substance	State	Prop.	Ref.
Cl	liq	k	2323
Cl_2	g	q	1631
ClO_2	c	n	1403
	liq	l	1760
	g	r	1760
ClO_2-H_2O	g	p	2478
$ClO_2-aqH_2SO_4$	g	p	2478
ClO_2-aqCH_3COOH	g	p	2478
ClO_2-CCl_4	g	p	2478
ClO_2^-	aq	v	1825
ClO_3^-	aq	v	1825
ClO_4	aq	n	1337
ClO_4^-	aq	v	1825
HCl		q	A-46
	liq	k	2323
	g	q	1631
		t	1710
	aq	n	2557
		pw	1648
		q	1087
		q	1120
		q	1949
		q	2172
		s	1940
$HCl-H_2O$	g	q	2493
$HCl-As_2O_5$	aq	n	2484
HCl-NaCl	aq	ps	D-70
HCl(g)-HBr(g)-MBr(liq)-M'Cl(liq) M,M' = (Li,Na,K,Mg,Ca)		p	A-22
DCl	aq	s	1178
$HClO_2$	liq	l	1760
$HClO_4$	c	amv	1022
	liq	amv	1022
		amw	1460
	aq	n	2492
$HClO_4-CH_3COOH$	liq	n	2062
HCl·Ar	g	r	2486

Substance	State	Prop.	Ref.
$HCl \cdot Xe$	g	r	2486
ClF_3	c	akn	2425
	g	akn	2425
11 - Bromine			
Br	liq	k	2323
Br_2	aq	q	1799
Br_2-$C_4H_8O_2$ (1,4-dioxane)	liq	q	1179
BrO_3^-	aq	v	1825
HBr	liq	k	2323
$HBr \cdot Ar$	g	r	2486
$HBr \cdot Xe$	g	r	2486
HBr-H_2O	g	q	2493
BrF_5	liq	k	1761
$BrF_5 \cdot UF_6$	g	h	1761
12 - Iodine			
I_2	g	t	1710
	aq	r	1097
I_2-H_2O	c	p	1591
I_2-H_2SO_4-H_2O	c	p	1591
I_2-$C_4H_8O_2$ (1,3-dioxane)	c	q	1179
I_2-$C_4H_8O_2$ (1,4-dioxane)	c	q	1179
I_2-C_6F_6		p	D-53
I_2-C_6H_5F		p	D-53
I_2-C_6F_5H		p	D-53
I_2-$(C_3H_7)_2S_2$		n	A-34
I_2-$(C_4H_9)_2S$		n	A-34
IO_3^-	aq	v	1825
HI	liq	k	2323
	g	t	1710
	aq	p	1567
IH_5O_6	c	nq	2084
	aq	n	2084
ICl		km	C-19
		v	B-23
	aq	r	1097
IBr_2^-	aq	r	1928
$I_2Br_2^-$	aq	r	1928

Substance	State	Prop.	Ref.
14 - Sulfur			
S	c	a	1464
		am	2412
		k	1599
		l	2550
	amorph	m	B-16
S-C_6H_6		bp	D-53
S-C_7H_8		bp	D-53
S-o-C_8H_{10}		bp	D-53
S-$C_{10}H_8$		bp	D-53
S-$(C_6H_5)_2$		bp	D-53
S-CCl_4		bp	D-53
S-CS_2		bp	D-53
S systems		b	D-69
S_2	g	l	1151
SO		n	A-56
SO_2	liq	k	2323
	aq	q	2285
SO_2-H_2O	g	p	1580
		p	2343
SO_2-$(C_2H_5)_2O$		j	D-36
SO_2 systems	liq	b	D-69
$SO_2 \cdot H_2O$	c	n	1403
SO_3	liq	k	2323
SO_3-CH_3COOH	liq	n	2062
SO_3^{--}	aq	v	1825
SO_4^{--}	aq	r	1073
		v	1825
S_2O		z	1988
H_2S	liq	k	2323
	g	r	1367
	aq	z	2192
H_2S-C_2H_4		p	D-71
H_2S-C_2H_6		p	D-71
H_2S-C_3H_6		p	D-71
HSO_4^-	aq	r	1613
		r	1657
H_2SO_4	aq	n	[illegible]280
		r	1735
H_2SO_4-HNO_3-H_2O	liq	b	[illegible]56
H_2SO_4-CH_3COOH	liq	n	2062
H_2SO_4 systems		b	D-69

Substance	State	Prop.	Ref.
SF_6	liq	k	2323
SF_6	g	n	A-36
		w	1758
S_2F_2	c	km	1135
	liq	km	1135
HSO_3F	liq	mnqv	1470
HSO_3F-CH_3COOH	liq	n	2062
SCl_2	g	w	1360
S_2Cl_2	g	w	1360
S_2Cl_2-$SbCl_2$		b	2209
HSO_3Cl	liq	k	1329
		m	1470

15 - Selenium

Substance	State	Prop.	Ref.
Se		l	C-14
	c	av	2177
		mv	2176
	liq	km	1152
	amorph	m	B-16
SeO_2	c	km	2391
SeO_2-Na_2O-H_2O	c	p	2205
SeO_3	c	km	2302
$(SeO_3)_4$	c	mn	2302
SeH_2	g	n	2273
SeH_2-TeH_2	c	n	1125
$SeHO_4^-$	aq	s	2310
SeH_2O_3-70%H_2SO_4	c	q	1140
SeF_6	g	n	A-36
Se_4N_4		n	A-69

16 - Tellurium

Substance	State	Prop.	Ref.
Te		v	B-34
		z	D-52
	c	a	1116
		a	1660
	liq	km	1152
	aq	s	1779
Te_2	g	l	1562
		l	1632
TeO_2	c	km	1788
		mn	1679
TeH_2	c	n	1125
	g	n	2273
TeH_2-SeH_2	c	n	1125
H_2TeO_3	c	n	1679
	g	lm	1788
$H_2TeO_3 \cdot H_2O$	c	n	1679
$Te(OH)_4$	c	n	1679
$[Te(OH)_6]^{--}$	c	n	1679

18 - Nitrogen

Substance	State	Prop.	Ref.
N	c	km	2510
	liq	k	2323
	g	t	1579
		v	2153
		w	1539
N-Fe/Si	g	p	1535
N-alloys	g	p	1541
N_2		a	D-2
		a	D-7
		k	C-8
		m	B-35
		w	A-70
	liq	a	D-14
	g	j	1325
		j	1645
		jw	2290
		z	2381
	aq	p	1057
N_2-H_2		bp	D-54
		j	D-28
		y	C-30
	g	q	A-20
N_2-H_2O	g	p	2480
N_2-Ar		j	D-28
		k	C-3
	g	q	A-20
N_2-CO_2		n	D-18
N_2-B		p	D-63
N_2-Ni	liq	p	D-62
N_2-Co	liq	p	D-62
N_2-Fe alloys		p	D-62
	g	p	1701
		p	2351
N_2-aq$MgSO_4$	g	p	2480
N_2-aq$CaCl_2$	g	p	2480
N_2-aqNaCl	g	p	2480
N_2-aqNa_2SO_4	g	p	2480
NO	liq	k	2323
	g	r	1051
		r	1062

Substance	State	Prop.	Ref.
NO-various salts-H_2O	g	p	1351
NO_2		j	D-16
	g	r	1051
		r	1062
NO_2^-	aq	v	1825
NO_3^-	aq	v	1825
N_2O	liq	k	2323
		r	1932
N_2O_3-H_2SO_4	c	p	1731
N_2O_4	liq	k	2323
N_2O_4-NOCl	liq	p	1733
NH_2	g	w	1169
NH_2^-	aq	v	1825
NH_3	liq	k	2323
		t	2275
	g	j	1189
		j	1645
		p	1522
		v	1877
		w	1169
		w	2007
NH_3	ads	y	C-38
NH_3-H_2O	g	r	1437
NH_3-H_2O_2-H_2O		b	2473
NH_3-KOH	liq	p	1335
NH_3 systems	liq	b	D-69
$NH_3 \cdot 2H_2O$	c	amv	1939
NH_4^+	aq	v	1825
N_2H_4	g	n	1554
		w	1169
HNO_2	g	r	1051
		r	1062
HNO_3	liq	k	2324
	g	v	2153
	aq	lp	1652
		r	1326
	non-aq	p	1827
HNO_3-H_2SO_4-H_2O	liq	b	1156
HNO_3-$C_3H_7(NO_2)$	liq	a	D-7
HNO_3-$Zn(NO_3)_2$-H_2O	liq	b	1732
HNO_3-$LiNO_3$	aq	p	1903
DNO_3	liq	k	2071
NH_4NO_3	c	am	2087
		nq	2074
	non-aq	am	2418
NH_4NO_3-$(CH_3)_2SO_2$		p	2476
NF_3	g	n	A-50
N_2F_4	liq	ak	2005
NH_4F	c	h	1054
NF_2H	g	w	1071
NOCl-N_2O_4	liq	p	1733
NH_4Cl	c	a	1383
		r	1996
NH_4Cl	aq	q	B-44
NH_4Cl-$GaCl_3$	non-aq	b	2538
NH_4ClO_4	c	a	1383
$NClF_4O$	c	ln	1923
$NBrO_2$	g	r	2175
NH_4Br	c	r	1996
S_4N_4		n	A-69
NSH_3O_3		nq	A-46
$NH_4 \cdot SO_3NH_2$-$(NH_4)_2SO_4$-aqNH_3		p	D-27
$(NH_4)_2SO_3$-NH_4HSO_3		p	2312
$(NH_4)_2SO_4$-H_2SO_4	c	p	1574
$(NH_4)_2SO_4$-$NH_4 \cdot SO_3NH_2$-aq NH_3		p	D-27
$(NH_4)_2S_2O_8$-H_2SO_4-H_2O	c	p	1161
NSF_7	liq	aik	2543
NSF_3O_2	liq	km	1967
$NS_2F_3O_4$	liq	km	1967
$HNF_2 \cdot SO_2$	c	l	2183

19 - Phosphorus

Substance	State	Prop.	Ref.
P(white)		n	A-68
PO_3^-	aq	r	1835
		v	1825
PO_4^{---}	aq	v	1825
P_2O_5-ZnO-BaO	c	b	1264
P_2O_5-CdO	c	b	2141
P_2O_5-MgO-BaO	c	b	1264
P_2O_5-CaO-H_2O		q	A-68
	liq	v	A-68
$P_2O_7^{----}$	aq	r	1835
		r	2038
		v	1825
PH_3	g	w	2007
PH_3-carboxylic acids		b	D-77

Substance	State	Prop.	Ref.
HPO_4^{--}	aq	r	1835
$H_2PO_4^{-}$	aq	r	1835
H_3PO_3	aq	n	2397
H_3PO_3-CH_3OH	liq	r	1699
H_3PO_3-Li_2HPO_3-H_2O	c	p	2045
H_3PO_3-Na_2HPO_3-H_2O	c	p	2214
H_3PO_4		n	A-6
		v	B-35
$HP_2O_7^{---}$	aq	r	1104
$HP_3O_{10}^{----}$	aq	r	1104
		r	2266
PF_3	g	n	2080
PF_5	g	n	A-36
		w	1572
PCl_3		mv	B-35
PCl_5		n	A-62
		mv	B-14
	g	w	1572
POCl	liq	n	A-68
$POCl_3$	c	a	2534
$POCl_3$-$AlCl_3$-$TiCl_4$	c	b	1155
$POCl_3$-$TaCl_5$-$TiCl_4$	c	b	1155
$POCl_3$-NbC_5-$TiCl_4$	c	b	1155
$PClF_2$	g	w	2007
PCl_2F	g	w	2007
PCl_3F_2	g	w	1572
$PBrF_2$	g	w	2007
PBr_2F	g	w	2007
$PBrCl_2$	g	w	2007
PBr_2Cl	g	w	2007
P_4S_{10}		v	B-9
$PSCl_3$	liq	n	1859
$(NH_4)H_2PO_4$	c	a	1383

20 - Arsenic

Substance	State	Prop.	Ref.
As	c	t	1710
As-Pd	c	b	1103
As_4	c	k	1052
	g	t	1710
AsO_4^{---}	aq	r	1835
As_2O_3		n	A-8
		v	B-46
	g	v	B-46
As_2O_3-Sb_2O_3	liq	r	1919
As_2O_5		n	A-8
As_2O_5-HCl	aq	n	2484
AsH_3	g	w	2007
$HAsO_4^{--}$	aq	n	1949
		r	1835
$H_2AsO_4^{-}$	aq	n	1949
		v	1825
H_3AsO_3	aq	n	1949
H_3AsO_4	aq	n	1949
AsF_3	liq	m	1784
$AsClF_2$	liq	r	1846
$AsCl_2F$	liq	r	1846
$AsBr_3$		n	A-8
AsS	c	v	2434

21 - Antimony

Substance	State	Prop.	Ref.
Sb	c	a	1598
		k	1330
Sb-In-Zn	c	p	1634
Sb-Cu	c	s	1719
Sb_2O_3		v	B-46
Sb_2O_3-As_2O_3	liq	r	1919
SbH_3	c	n	1124
	g	n	2273
$SbCl_2$-S_2Cl_2		b	2209
$SbCl_3$-$BiCl_3$-$PbCl_2$	non-aq	q	2503
$SbCl_5$-$C_3H_6O_2$		n	A-34
$SbCl_5$-$C_5NH_{11}O_2$		n	A-34
$SbCl_5$-$C_3NF_3H_6O$		n	A-34
$SbBr_3$	c	a	2522
Sb_2S_3	liq	s	1024
Sb_2Se_3	c	k	2469
Sb_2Te_3	non-aq	s	2449

22 - Bismuth

Substance	State	Prop.	Ref.
Bi		bs	D-10
		m	B-31

Substance	State	Prop.	Ref.
Bi	c	a	1278
		v	1410
Bi/Al	liq	q	1671
Bi_2O_3	c	a	1789
		m	1526
$BiCl_3$	liq	i	1902
	g	i	1902
Bi(III: halides	aq	r	1895
$(BiO)_2SeO_3$		nq	A-79
$Bi_2(SeO_3)_3$		nq	A-79
Bi/Te	liq	s	D-24
Bi_2Te_3		s	D-24
	non-aq	s	2449
Bi_2Te_3-Ag_2Te	c	b	1292
$Bi_2(TeO_3)_3$		nq	A-79
Bi/Sb	liq	s	2570

24 - Silicon

Substance	State	Prop.	Ref.
Si		m	B-33
		p	D-23
	c	b	2389
		n	1061
		n	2178
	g	l	1001
	amorph	p	1716
Si-MnSi	c	b	2138
Si_2	g	l	1001
SiO		rl	D-9
SiO-CuO-CuO_2	non-aq	b	1559
SiO_2	c	v	B-34
		lr	D-9
		a	1266
		a	1829
		n	1061
		n	2027
		v	1886
		y	2288
		z	1307
	non-aq	v	B-34
		s	1525
SiO_2-H_2O	c	p	2321
SiO_2-GeO_2	c	b	1596
SiO_2-PbO	non-aq	s	1213
		s	1597
SiO_2-B_2O_3-MgO	non-aq	b	1488
SiO_2-Al_2O_3	c	b	1602
SiO_2-Al_2O_3-$K_2O \cdot Al_2O_3 \cdot 4SiO_2$	non-aq	r	2159
SiO_2-MgO-Al_2O_3		p	D-61
SiO_2-CaO-MgO		p	D-61
SiO_3^{--}	c	v	1825
SiO_4^{----}	c	v	1825
SiH_4	liq	k	2378
	g	w	1776
Si_3H_8	c	n	1124
	g	n	2273
Si_4H_{10}	c	a	1427
		k	1850
Si_5H_{12}	c	a	1427
SiH_4O_4	aq	z	2192
Si_3H_8O	liq	km	1365
SiF	g	n	1890
SiF_2	g	n	1890
SiF_4	c	kmv	2293
		n	1683
	liq	a	2293
		k	2323
Si_2F_6		n	A-69
	g	n	1843
Si_3F_8		k	C-35
		n	A-69
Si_4F_{10}		k	C-35
$SiF_6H_2 \cdot 213H_2O$	aq	n	1061
$SiCl_4$	c	k	1500
		km	1128
		l	2344
	liq	km	1128
		r	1080
$SiCl_4$-$SiHCl_3$	g	r	2390
$SiCl_4$-BBr_3	c	bp	1115
$SiCl_4$-$TiCl_4$	liq	p	1262
Si_5Cl_{12}	c	ak	1650
$SiHCl_3$-$SiCl_4$	g	r	2390
$SiBr_4$	liq	n	2178
$SiBr_4$-$GeBr_4$	c	b	1115
$SiBr_4$-BBr_3	c	bp	1115
SiI_4	c	n	2178
SiS		l	C-20
SiN_3H_3	liq	akm	2102

Substance	State	Prop.	Ref.
$SiN_2F_6H_8$	c	mv	1056
	aq	q	1056
Si_2PH_7	liq	k	1969
Si/Bi		b	D-45
SiC		n	A-36
	c	tv	2057
	g	l	1001
SiC_2	g	w	1979
Si_2C	g	l	1001
		w	1979
CH_3SiH_3	g	w	1978
$Si(C_2H_5)_4$		n	A-77
$Si(C_2H_5)_6$		n	A-77
$Si(C_6H_5)_4$		n	A-77
$(CH_3)_2SiO$		v	B-46
$(CH_3)_2Si(OCH_3)$	c	r	1429
$(C_2H_5)_2SiO$		v	B-46
$(CH_3)_2Si(OCH_3)_2$	c	r	1429
$CH_3Si(OCH_3)_3$	c	r	1429
$Si(OCH_3)_4$	liq	r	1080
$(CH_3)_2Si(OC_2H_5)(OCH_3)$	c	r	1429
$CH_3Si(OC_2H_5)(OCH_3)_2$	c	r	1429
$(CH_3)_2Si(OC_2H_5)_2$	c	r	1429
$HSi(OC_2H_5)_3$	liq	n	2588
$CH_3Si(OC_2H_5)_2(OCH_3)$	c	r	1429
$CH_3Si(OC_2H_5)_3$	c	r	1429
$Si(OC_2H_5)_4$	liq	n	2588
		r	1080
$(CH_3)_3SiOSiH_3$	liq	km	1365
$(CH_3)_3SiOSi(CH_3)_3$		n	A-8
	liq	n	1061
$SiC_2F_5H_3$ (2,2-difluoroethyltrifluorosilane)	liq	km	1893
CH_3SiCl_3	c	r	1429
CH_3SiCl_3-$CH_3Si[N(CH_3)_2]_3$	c	n	1429
$(CH_3)_2SiCl_2$	c	r	1429
$(CH_3)_2SiCl_2$-$(CH_3)_2Si[N(CH_3)_2]$	c	n	1429
$(CH_3)_3SiCl$		n	A-8
	c	k	1500
$(CH_3)_2(CHCl_2)SiH$	liq	a	1983
$CH_3SiCl_2(OCH_3)$	c	r	1429
$(CH_3)_2SiCl(OCH_3)$	c	r	1429
$CH_3SiCl(OCH_3)_2$	c	r	1429
$(CH_3)_2(CH_2Br)SiH$	liq	a	1983
$(CH_3)_2Si[N(CH_3)_2]_2$	c	r	1429
$(CH_3)_2SiNH$		v	B-46
$(CH_3)_2Si[N(CH_3)_2]$	c	r	1429
$(CH_3)_2Si[N(CH_3)_2]$-$(CH_3)_2SiCl_2$	c	n	1429
$SiC_4N_2H_{14}$ (bisdimethylaminosilane)	liq	akm	2103
$(CH_3)_2Si[N(CH_3)_2]_2$	c	r	1429
$SiC_6N_3H_{19}$ (trisdimethylaminosilane)	liq	akm	2103
$CH_3Si[N(CH_3)_2]_3$	c	r	1429
$CH_3Si[N(CH_3)_2]_3$-CH_3SiCl_3	c	n	1429
$SiC_8N_4H_{24}$ (tetrakisdimethylaminosilane)	liq	akm	2103
		r	1080
$[(CH_3)_3Si]_2NH$		n	A-8
$(CH_3)_2Si(OCH_3)[N(CH_3)_2]$	c	r	1429
$CH_3Si(OCH_3)_2[N(CH_3)_2]$	c	r	1429
$CH_3Si(OCH_3)[N(CH_3)_2]_2$	c	r	1429
$CH_3SiCl_2[N(CH_3)_2]$	c	r	1429
$(CH_3)_2SiCl[N(CH_3)_2]$	c	r	1429
$CH_3SiCl[N(CH_3)_2]_2$	c	r	1429
$Si_2Cl_2 \cdot 2N(CH_3)_3$	c	l	1651
$Si_3C_8N_2Cl_2H_{24}$	c	r	2108

25 - Germanium

Substance	State	Prop.	Ref.
Ge		t	B-24
	c	b	2389
Ge-(H_2O_2-HF)	c	q	1120
GeO_2	c	n	1121
	amorph	v	B-2
GeO_2-H_2O	c	p	2500
GeO_2-(H_2O_2-HF)	c	q	1120
GeO_2-SiO_2	c	b	1596
GeO_2-NaOH-H_2O	c	p	1658
GeH_4	g	w	1369
		w	1776

Substance	State	Prop.	Ref.
Ge_3H_8	c	n	1124
	g	n	2273
$Ge(OH)_2$	c	r	2528
GeF	g	n	1890
GeF_2	g	n	1890
GeF_4		n	A-69
	g	n	A-7
$GeF_5 \cdot H_2O$	c	r	1475
GeF_6^-	aq	r	1798
$GeCl_4$	c	km	1128
	liq	km	1128
$GeCl_4$-BBr_3	c	b	1115
		p	1115
$GeBr_4$-$SiBr_4$	c	b	1115
$GeBr_4$-BBr_3	c	b	1115
GeH_3I	g	w	1369
GeH_2I_2	g	w	1369
GeS	c	v	2434
		z	1009
		z	2200
Ge/S	non-aq	b	1293
GeS_2	c	z	2200
GeSe	c	z	1009
GeTe	c	l	1068
		lm	1358
		z	1009
	g	lm	1358
$Ge(C_2O_4)_3^{--}$	aq	s	2384
$Ge(C_2H_5)_4$	liq	n	1121
		n	1958
$Ge(C_3H_7)_4$	liq	n	1958
$(C_2H_5)_3GeO$		n	A-77
Ge(II):$C_{20}H_{14}O_8$ (pyrogallolphthalein)	aq	r	2228
Ge(II):$C_{20}SH_{14}O_9$ (catecholsulfonaphthalein)	aq	r	2228
$GeSi_2H_8$	c	a	1427
$GeSi_3H_{10}$	c	a	1427
$GeSi_4H_{12}$	c	a	1427
Ge_2SiH_8	c	a	1427

Substance	State	Prop.	Ref.
26 - Tin			
Sn		k	C-31
		m	B-31
Sn/Te	liq	t	A-42
Sn/Al	liq	q	1671
Sn/Tl	liq	s	A-26
Sn/Cu	liq	q	1669
SnO	c	r	1301
		z	1009
SnO_2	c	s	2028
SnF_2	liq	km	2531
$SnCl_2$	liq	k	1616
	g	w	2327
	non-aq	s	1712
$SnCl_2$-TlCl	liq	s	A-26
$SnCl_2$-InCl	liq	s	A-26
$SnCl_4$		n	A-10
	liq	k	2323
$SnCl_6^{--}$	aq	v	1825
$Sn_2Cl_6 \cdot 2HCl$	c	k	1783
$SnBr_6^{--}$	aq	v	1825
SnS	c	a	1514
		z	1009
	g	r	1301
Sn/S	c	b	1514
SnSe	c	am	1361
		z	1009
SnTe	c	n	1361
		z	1009
	g	l	1632
		w	1358
Sn/Te		n	A-42
Sn/Bi	non-aq	b	1291
$Sn(CH_3)_4$		n	A-10
$Sn(C_2H_3)_4$		n	A-10
$Sn(C_2H_5)_4$		n	A-10
$Sn(C_3H_7)_4$	liq	n	A-10
$Sn(C_4H_9)_4$		n	A-10
$Sn(C_6H_5)_4$		n	A-77
	c	n	1959
$Sn(C_6H_5)_6$		n	A-77

Substance	State	Prop.	Ref.
$(CH_3)_2SnOH^+$	c	r	1183
$(CH_3)_2Sn(OH)_2$	c	r	1183
$[(CH_3)_2SnOH]_2^{++}$	c	r	1183
$[(CH_3)_2Sn]_2(OH)_3^+$	c	r	1183
$[(CH_3)_2Sn]_3(OH)_4^{++}$	c	r	1183
$[(CH_3)_2Sn]_4(OH)_6^{++}$	c	r	1183
CH_3SnCl_3		n	A-10
	c	a	1982
$Sn(CH_3)_2Cl_2$		n	A-10
	c	a	1982
$C_2H_5SnCl_3$		n	A-10
$(CH_3)_2SnCl$		n	A-10
$(C_2H_5)_2SnCl_2$		n	A-10
$(C_2H_5)_3SnCl$		n	A-10
$SnCl_4 \cdot (CH_3)_2CO$	c	r	1955
$SnCl_4 \cdot HCOOC_2H_5$	c	r	1955
$SnCl_4 \cdot ClCOOC_2H_5$	c	r	1955
$SnCl_4 \cdot C_4H_8O$ (tetrahydrofuran)	c	r	1955
$SnCl_4 \cdot CH_3COOC_2H_5$	c	r	1955
$SnCl_4 \cdot (C_2H_5)_2O$	c	r	1955
$SnCl_4 \cdot CH_3ClCOOC_2H_5$	c	r	1955
$SnCl_4 \cdot CHCl_2COOC_2H_5$	c	r	1955
$SnCl_4 \cdot CH_3CH_2COOC_2H_5$	c	r	1955
$SnCl_4 \cdot (C_2H_5)_2CO_3$	c	r	1955
$SnCl_4 \cdot C_6H_{12}O$ (dimethyltetrahydrofuran)	c	r	1955
CH_3SnBr_3	c	a	1982
$Sn(C_6H_5)_2Br_2$	c	n	1959
$Sn(C_6H_5)_3Br$	c	n	1959
$(C_6H_5N_2)_2SnCl_6$-HCl	c	p	1163
$(p\text{-}ClC_6H_4N_2)_2SnCl_6$-HCl	c	p	1163
$(\beta\text{-}C_{10}H_7N_2)_2SnCl_6$-HCl	c	p	1163
$SnCl_4 \cdot C_6N_2H_6O_2$ (2-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_6N_2H_6O_2$ (3-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_6N_2H_6O_2$ (4-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_6N_2ClH_5O_2$ (2-chloro-4-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_6N_2ClH_5O_2$ (4-chloro-2-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_6N_2ClH_5O_2$ (5-chloro-2-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_6N_2ClH_5O_2$ (6-chloro-2-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_6N_2Cl_2H_4O_2$ (2,5-dichloro-4-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_6N_2Cl_2H_4O_2$ (2,6-dichloro-4-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_7N_2H_8O_2$ (2-methyl-4-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_7N_2H_8O_2$ (4-methyl-2-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_7N_2H_8O_2$ (4-methyl-3-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_7N_2H_8O_2$ (6-methyl-2-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_7N_2H_8O_2$ (6-methyl-3-nitroaniline)	non-aq	r	2523
$SnCl_4 \cdot C_{12}N_2H_{10}O_2$ (2-nitro-N-phenylaniline)	non-aq	r	2523
$SnCl_4 \cdot C_{12}N_2H_{10}O_2$ (4-nitro-N-phenylaniline)	non-aq	r	2523
$(p\text{-}HOC_6H_4N_2)_2SnCl_6$-HCl	c	p	1163
$(p\text{-}O_2NC_6H_4N_2)_2SnCl_6$-HCl	c	p	1163
$(p\text{-}CH_3OC_6H_4N_2)_2SnCl_6$-HCl	c	p	1163
$(2\text{-}C_{14}H_7O_2N_2)_2SnCl_6$-HCl	c	p	1163
$(C_6H_5N_2)_2SnBr_6$-HBr	c	p	1163
$(\beta\text{-}C_{10}H_7N_2)_2SnBr_6$-HBr	c	p	1163
$SnBr_4 \cdot C_6N_2H_6O_2$ (3-nitroaniline)	non-aq	r	2520
$SnBr_4 \cdot C_6N_2H_6O_2$ (4-nitroaniline)	non-aq	r r	2520 2523
$SnBr_4 \cdot C_7N_2H_8O_2$ (2-methyl-4-nitroaniline)	non-aq	r r	2520 2523
$SnBr_4 \cdot C_7N_2H_8O_2$ (4-methyl-2-nitroaniline)	non-aq	r r	2520 2523
$SnBr_4 \cdot C_7N_2H_8O_2$ (4-methyl-3-nitroaniline)	non-aq	r	2520
$SnBr_4 \cdot C_7N_2H_8O_2$ (6-methyl-3-nitroaniline)	non-aq	r	2520
$(p\text{-}O_2NC_6H_4N_2)_2SnBr_6$-HBr	c	p	1163
$(p\text{-}CH_3OC_6H_4N_2)_2SnBr_6$-HBr	c	p	1163

Substance	State	Prop.	Ref.
$(2\text{-}C_{14}H_7O_2N_2)_2SnBr_6\text{-}HBr$	c	p	1163
$(p\text{-}ClC_6H_4N_2)_2SnBr_6\text{-}HCl$	c	p	1163
$SnBr_4 \cdot C_6N_2ClH_5O_2$ (3-chloro-4-nitroaniline)	non-aq	r	2520

27 - Lead

Substance	State	Prop.	Ref.
Pb		m	B-31
		v	B-5
	c	a	1278
		a	1494
		k	1029
		t	1220
Pb^{++}	non-aq	s	1836
		s	2549
Pb/SiO_2	non-aq	s	1213
Pb/Al	liq	q	1671
Pb/Mg	liq	bp	D-65
Pb/acid electrochem. storage cells	non-aq	n	1381
PbO	c	a	1209
		kmv	1469
		s	1201
		z	1009
Pb/O	c	s	1954
PbO/SiO_2	non-aq	s	1597
PbO/V_2O_5	c	q	1848
Pb_3O_4	c	s	1954
$Pb(II):OH^-$	aq	r	2459
PbF_2		s	D-44
$PbCl^+$	non-aq	p	1203
		s	1065
$Pb(II):Cl^-$	aq	r	2539
	non-aq	r	2097
$PbCl_2$	non-aq	r	1664
		s	1065
		s	1192
		s	2371
		s	2488
$PbCl_2\text{-}H_2O$	c	y	2297
$PbCl_2\text{-}TlCl\text{-}H_2O$	non-aq	p	1517
$PbCl_2\text{-}KCl$	c	b	2474
	non-aq	p	1385
$PbCl_2\text{-}RbCl$	c	b	2474
$PbCl_2\text{-}CsCl$	c	b	2474
$PbCl_4^{--}$	non-aq	r	1664
$Pb(ClO_4)_2$-alcohols	c	q	2568
$PbFCl\text{-}CH_3OH\text{-}H_2O$	c	p	2049
$PbFCl\text{-}C_2H_5OH\text{-}H_2O$	c	p	2049
$PbBr^+$		p	D-22
	non-aq	s	1065
$PbBr_2$	non-aq	s	1065
$PbFBr\text{-}CH_3OH\text{-}H_2O$	c	p	2049
$PbFBr\text{-}C_2H_5OH\text{-}H_2O$	c	p	2049
PbI_2	c	km	1035
$PbFI\text{-}CH_3OH\text{-}H_2O$	c	p	2049
$PbFI\text{-}C_2H_5OH\text{-}H_2O$	c	p	2049
$4PbF_2 \cdot PbI\text{-}CH_3OH\text{-}H_2O$	c	p	2049
$4PbF_2 \cdot PbI\text{-}C_2H_5OH\text{-}H_2O$	c	p	2049
Pb(II):halides	aq	r	1895
PbS	c	z	1009
$PbS\text{-}H_2S\text{-}H_2O$	c	p	1353
PbS-PbSe	c	b	1449
$PbSO_4$	c	z	1960
		z	2192
$PbSO_4\text{-}Rb_2SO_4$	c	b	1672
$PbSO_4\text{-}Rb_2SO_4\text{-}Cs_2SO_4$	c	b	1672
PbSe	c	p	1706
		z	1009
PbSe-PbS	c	b	1449
$PbSeO_3$	c	n	1247
PbTe		n	A-42
	c	k	1562
		p	1706
		z	1009
	g	w	1358
$PbTe\text{-}AgBiTe_2$	c	b	1292
$Pb(NO_3)_2$	aq	n	A-79
$PbHP_3O_{10}$	aq	r	1379
$Pb(II):P_2H_2O_5^{--}$	aq	r	2306
Pb/Bi	non-aq	a	1278
		p	2445
		s	1310
$Pb(CH_3)_2H_2$	liq	km	1600
$Pb(CH_3)_3H$	liq	km	1600
$Pb(CH_3)_4$		mv	B-20

Substance	State	Prop.	Ref.
$Pb(C_2H_5)_4$		mv	B-20
Pb(II):$C_2H_4O_2$ (acetic acid)	c	r	1974
	aq	r	1078
		r	2104
Pb(II):$C_4H_6O_5$ (diglycolic acid)	aq	r	1208
Pb(II):$C_2F_3HO_2$ (trifluoroacetic acid)	c	r	1842
Pb(II):$C_3F_5HO_2$ (pentafluoropropionic acid)	c	r	1842
Pb(II):$C_4F_7HO_2$ (heptafluorobutyric acid)	c	r	1842
Pb(II):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2269
Pb(II):$C_7NH_{11}O_5$ (aminoacetone-N,N-diacetic acid)	aq	r	1334
Pb(II):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetraacetic acid)	c	nr	1635
Pb(II):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
Pb(II):$C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N',-tetraacetic acid)	c	nr	1635
Pb(II):$(C_{10}N_2H_{16}O_8)(C_6NH_9O_3)$ (ethylenediaminetetracetic acid, nitrilotriacetic acid)	c	r	1802
$(p\text{-}ClC_6H_4N_2)_2PbCl_6\text{-}HCl$	c	p	1163
$(\beta\text{-}C_{10}H_7N_2)_2PbCl_6\text{-}HCl$	c	p	1163
$(p\text{-}O_2NC_6H_4N_2)_2PbCl_6\text{-}HCl$	c	p	1163
$(p\text{-}CH_3OC_6H_4N_2)_2PbCl_6\text{-}HCl$	c	p	1163
$PbC_5NS_2H_{11}\text{-}H_2O$		p	1416
Pb(II):$C_5N_5SH_5$-aq dioxane (2-amino-6 mercaptopurine)		r	2163
$(O_2CCH_2S(CH_2)_2N(CH_2CO_2)_2^{---})$	aq	r	1816
Pb/Sn	c	bt	2581
	non-aq	v	1717

28 - Boron

Substance	State	Prop.	Ref.
B		k	C-31
		z	D-52
	c	n	A-60
	g	l	1001
		l	1173
		l	1174
$B\text{-}N_2$		p	D-63
BO_2^-	c	v	1825
B_2O_3	c	v	1937
	liq	l	1081
		n	1198
		n	1670
		r	1096
		v	B-43
	g	l	1081
		w	1649
	amorph	l	1081
		n	A-7
		v	2160
		v	B-34
		v	B-43
$B_2O_3\text{-}H_2O$	c	p	1687
$B_2O_3\text{-}MgO\text{-}SiO_2$	non-aq	b	1488
$B_2O_3\text{-}RbBO_2$	liq	q	A-72
$B_2O_3\text{-}Cs_2O_3$	c	b	2475
$B_4O_7^{--}$	c	v	1825
BH_4^-	c	v	1825
B_2H_6 (diborane)		n	A-14
	g	l	1081
B_6H_{12}		n	A-43
	liq	ak	1966
		k	1072
$B_{10}H_{14}$	g	n	2273
$B_{10}H_{16}$		n	A-43
BHO_2	c	nq	1027
H_2BOH	g	ln	1911
$HB(OH)_2$	g	ln	1911
$B(OH)_3$	c	nq	1027
$B_2(OH)_4$	c	n	A-9
$B_3H_3O_3$ (boroxine)	c	l	1081
	g	l	1081
$(HOBO)_3$	g	n	1896
BF		kn	A-65
	g	nr	1899
BF_3		n	A-60
	c	n	1818
	g	n	A-36
		p	1040
	aq	n	1090
$BF_3\text{-}H_2O$	c	q	1644
$BF_3\text{-}HF\text{-}H_2O$	c	q	1644

Substance	State	Prop.	Ref.
$BF_4 \cdot nH_2O$	c	a	1395
BF_5	c	n	1818
BOF		ln	1198
$BF_4H_3O-H_2O$	c	b	1395
BCl3	c	k	2044
		r	1455
	g	n	1670
		l	1081
		r	1096
BClO	g	r	1096
$(BOCl)_3$	g	n	1670
$B_3Cl_3O_3$ (trichloroboroxine)	g	l	1081
$B_4Cl_4O_4$ (tetrachloroboroxine)	g	l	1081
$BHCl_2$	g	w	1968
$B_3ClH_2O_3$	g	l	1081
$B_3Cl_2HO_3$	g	l	1081
BBr_3	c	p	1115
	liq	p	1115
BBr_3-SiCl_4	c	b	1115
BBr_3-SiBr_4	c	b	1115
BBr_3-GeCl_4	c	b	1115
BBr_3-GeBr_4	c	b	1115
BI_3	c	n	A-9
		a	2253
B_2S_3	c	m	1930
		w	1649
BN		t	A-4
	c	n	A-36
$B_5NH_4O_8 \cdot 4H_2O$	c	v	2111
	liq	v	2111
NH_4BF_4	c	a	1383
$HNF_2 \cdot BF_3$	c	l	2183
BC	g	l	1001
BC_2	g	l	1001
B_2C	g	l	1001
B_4C		t	A-4
		v	B-35
	c	n	A-60
		l	1173
		l	1174
$(CH_3)_3B$		mv	B-35

Substance	State	Prop.	Ref.
$(C_2H_5)_3B$		mv	B-35
$BC_{18}H_{15}$ (triphenylboron)	c	r	1455
$B_9C_2H_{11}$	c	a	1929
$B_9C_3H_{13}$	c	a	1929
$B_9C_4H_{15}$	c	a	1929
$B_9C_8H_{15}$	c	a	1929
$(CH_3O)_3B$ (methyl borate)		nv	B-35
	c	k	2044
	liq	r	1455
$BC_{18}H_{15}O$	c	r	1455
$BF_3 \cdot CH_3F$	c	r	1947
$BF_3 \cdot CH_3OH$	c	a	2252
$BF_3 \cdot 2CH_3OH$	c	a	2252
$CH_3OH_2^+BF_4^-$	c	a	2252
$HBF_4 \cdot 2CH_3OH$	c	a	2252
$HBF_4 \cdot 3CH_3OH$	c	a	2252
$BC_4FH_{10}O$	liq	r	1040
$BC_2ClH_4O_2$	liq	n	2106
$BC_3ClH_6O_2$	liq	n	2106
$BC_4ClH_8O_2$	liq	n	2106
$BF_3 \cdot C_3H_7Cl$	liq	r	1947
$BF_3 \cdot C_4H_9Cl$	c	r	1947
$BC_2S_2H_5$	liq	km	1844
$BF_3 \cdot (C_2H_5)_2S$	liq	r	1040
	g	p	1040
$BH_3 \cdot (CH_3)_3N$		mv	B-20
	c	n	1090
$C_6H_{18}BN$		mv	B-20
$BC_6N_3H_{18}$	liq	r	1455
BC_9NH_{18} (1-aza-5-borotricyclo[3,3,3,0]undecane)	c	akm	2563
$B_2C_2N_2H_{14}$	liq	k	1105
$B_2C_3N_2H_{16}$	liq	k	1105
$B_2C_4N_2H_{18}$	liq	k	1105
$B_2C_5N_2H_{20}$	liq	k	1105
$B_2C_8N_2H_{20}$	c	k	1767
$B_2C_{12}N_2H_{28}$	c	k	1767

Substance	State	Prop.	Ref.
$B_{10}C_6N_2H_{26}$	c	a	1936
$B_{12}C_6N_2H_{28}$	c	a	1936
$B(OC_2H_4)_3N$		mv	B-14
(triethanolamine borate)	c	v	1021
		mv	1558
	liq	v	1558
$BC_6NF_3H_{15}$	liq	r	1040
$BCl_3C_{13}NH_{11}O$	non-aq	r	2139
(benzanilide)			
$BCl_3 \cdot C_{14}NH_{13}O$	non-aq	r	2139
(N,N-diphenylacetamide)			
$BCl_3 \cdot C_{18}NH_{20}O$	non-aq	r	2139
$B_{10}C_2NSH_{17}$	c	a	1936
$BC_2PNF_5H_6$	c	l	1892
BSi	g	l	1001
BSi_2	g	l	1001
Si_2BF_7		n	A-69
		k	C-35
Si_3BF_9		k	C-35
BSiC	g	l	1001

29 - Aluminum

Substance	State	Prop.	Ref.
Al		m	B-31
	c	a	1787
		q	1008
Al^{+++}	non-aq	s	2549
Al-Bi	liq	q	1671
Al-C-O		z	D-52
Al-Sn	c	q	1720
	liq	q	1671
	non-aq	s	2161
Al-Pb	liq	q	1671
$Al\text{-}Al_2T_6$	non-aq	b	2544
$Al\text{-}AlF_3$		l	C-31
$Al\text{-}Al_2Br_6$	non-aq	b	2544
Al-In	liq	q	1671
Al-Tl	liq	q	1671
Al-Zn	liq	q	1671
Al-Cd	liq	q	1671
Al-fused cryolite	c	q	1533
AlO_2^-	aq	v	1825
Al_2O_3		t	B-8
Al_2O_3		t	B-43
		v	B-34
	c	a	1290
		km	2472
		l	1414
		mq	2076
		s	2029
		tv	2341
		v	1754
		v	2240
	liq	n	1670
$Al_2O_3\text{-}H_2O$	c	ny	1448
$Al_2O_3\text{-}SiO_2$	c	b	1602
$Al_2O_3\text{-}SiO_2\text{-}K_2O \cdot Al_2O_3 \cdot 4SiO_2$	non-aq	r	2159
$Al_2O_3\text{-}9PbO \cdot 3CdO \cdot 4B_2O_3$	c	mq	1636
$Al_2O_3\text{-}CaO\text{-}Cu_2O$	c	b	1452
$Al_2O_3\text{-}Fe_2O_3$	c	v	1659
$Al_2O_3\text{-}Nb_2O_5$	c	b	1393
	non-aq	b	1489
$Al_2O_3\text{-}Ti_2O_3$	c	b	2050
$Al_2O_3\text{-}Sc_2O_3$	non-aq	b	1332
$Al_2O_3\text{-}La_2O_3$	c	b	2140
$Al_2O_3\text{-}MgO$	c	b	1602
$Al_2O_3\text{-}CaO$	c	b	1392
$Al_2O_3\text{-}CaF_2$	c	b	2409
$Al_2O_3\text{-}BaO\text{-}CaO$	non-aq	b	1331
$Al_2O_3\text{-}NaOH$	non-aq	p	1692
$Al_2O_3\text{-}H_2O$	c	l	2241
$Al_2O_3 \cdot 3H_2O$		n	A-7
$Al(OH)_3$	c	y	1876
$Al(OH)_3\text{-}H_2O$	c	p	2482
AlF_2	g	n	1935
AlF_3		k	C-28
		l	C-31
	c	n	A-36
$AlF_3\text{-}LiF$		l	C-31
AlF_6^{---}	aq	v	1825
$AlCl_3$	c	a	2534
		r	1775
$AlCl_3\text{-}He$	g	v	1681
$AlCl_3\text{-}POCl_3\text{-}TiCl_4$	c	b	1155
$AlCl_3\text{-}CH_3CN$	c	b	1430
AlOCl	g	n	1670
		n	1962

Substance	State	Prop.	Ref.
AlBr	g	n	A-7
$AlBr_3$	c	r	1775
Al_2Br_6	c	a	2544
Al_2Br_6-Al	non-aq	b	2544
Al_2I_6	c	a	2544
Al_2I_6-Al	non-aq	b	2544
$Al_2(SO_4)_3$	aq	h	1328
AlN		k	C-20
		t	B-40
$AlPO_4 \cdot 2H_2O$		v	B-38
$AlPCl_6$	c	m	1155
$AlCl_3 \cdot POCl_3$	c	a	1518
		a	2534
		m	1155
$2AlCl_3 \cdot 3POCl_3$	c	a	1518
AlAs	c	an	1370
AlSb		t	B-24
Al/Bi		b	D-45
Al_4C_3		l	C-29
		t	B-35
		v	B-35
	c	n	1553
		n	1668
		n	2112
$Al(C_2H_5)_3$	liq	r	1884
	g	r	1884
$Al(C_4H_9)_3$	c	kmn	2006
Al(III):$C_4H_6O_5$ (malic acid)	aq	r	2359
Al(III):$C_5H_8O_7$ (trihydroxyglutaric acid)	aq	r	2359
Al(III):$C_6H_6O_2$ (catechol)	aq	r	2168
Al(III):$C_6H_{12}O_7$ (gluconic acid)	aq	r	2359
Al(III):$C_7H_6O_3$ (salicylic acid)	aq	r	1075
$Al(C_5H_7O_2)_3$ (acetylacetonate)	g	n	A-6
Al(III):C_9NH_7O (8-quinolinol)	non-aq	r	2547
Al(III):$(C_{10}N_2H_{16}O_8)(C_6NH_9O_3)$ (ethylenediaminetetracetic acid, nitrilotriacetic acid)	c	r	1802
$AlCl_3 \cdot CH_3CN$	c	a	1430
$2AlCl_3 \cdot 3CH_3CN$	c	a	1430
$Al(NH_2CONH_2)_6(ClO_4)_3$	c	n	1819
$CH_3NH_3Al(SO_4)_2 \cdot 12H_2O$	c	v	2396
Al(III):$C_{16}N_2S_2H_{12}O_8$ (2-(phenylazo)-1,8-dihydroxy-3,6-naphthalenedisulfonic acid)	aq	r	2212
Al_2SiO_5		nb	A-51
	c	b	2056
		t	1089
		v	1886
$Al_6Si_2O_{13}$		bn	A-51
Al/Sn		q	A-4
$2Al_2O_3 \cdot B_2O_3$	c	n	A-7
$9Al_2O_3 \cdot 2B_2O_3$		n	A-7
$Al(BH_4)_3$	liq	n	A-62

30 - Gallium

Substance	State	Prop.	Ref.
Ga	c	km	2322
		m	1487
		t	1710
		v	1446
	liq	h	D-13
		m	2239
Ga-Sn	c	q	1720
Ga-Mg	liq	s	A-26
Ga^{+++}	non-aq	s	1615
$Ga(OH)_3$-H_2O	c	p	2482
GaCl	g	t	1710
$GaCl_3$	c	a	2538
		p	2482
	g	t	1710
$GaCl_3$-NH_4Cl	non-aq	b	2538
$GaCl_3$-TlCl	non-aq	b	2538
$GaCl_3$-KCl	non-aq	b	2538
$GaCl_3$-CsCl	non-aq	b	2538
$GaBr_3$-C_2H_5Br	c	r	1053
GaI	g	t	1710
GaI_3	g	t	1710
$GaSO_4$	c	p	2482
$Ga(OH)SO_4$	c	p	2482
Ga/Te	non-aq	s	2283
NH_4GaCl_4	c	a	2538

Substance	State	Prop.	Ref.
GaP	c	am	1520
		ln	1585
$GaPO_4$	c	p	1141
GaAs		t	B-24
GaSb		t	B-24
	c	n	2369
	non-aq	s	2130
Ga(III):$C_7H_6O_3$ (salicylic acid)	aq	r	1727
$Ga(CH_2CH_3)_3 \cdot S(CH_3)_2$	liq	n	1762
Ga(III):$C_7SH_6O_6$ (sulfosalicylic acid)	aq	r	1728
$Ga(CH{=}CH_2)_3 \cdot N(CH_3)_3$	liq	kmn	1762
$Ga(CH_2CH_3)_3 \cdot N(CH_3)_3$	liq	kmn	1762
Ga(III):C_9NH_7O (8-quinolinol)	non-aq	r	2547
Ga(III):CNS^-	aq	r	2096
Ga(III):$C_{16}N_2S_2H_{12}O_8$ (2-(phenylazo)-1,8-dihydroxy-3,6-naphthalene-disulfonic acid)	aq	r	2212
Ga garnets		v	B-26

31 - Indium

Substance	State	Prop.	Ref.
In	c	km	1505
		s	1778
		v	2394
In-Sb-Zn	c	p	1634
In-Sn	c	q	1720
In-Al	liq	q	1671
In-In_2O_3	c	b	1168
In-Tl	liq	bs	A-26
In-Zn-Cd	liq	ps	A-27
In-Cd	liq	ps	A-27
In-Mg	liq	s	A-26
In_2O_3	c	l	2069
In_2O_3-In	c	b	1168
In/Cl	c	km	1139
InCl-$SnCl_2$	liq	s	A-26
$InCl_2$	c	km	1139
$InCl_3$	c	km	1139
	liq	km	1139
In_2Cl_3	c	a	1258
In_4Cl_7	c	km	1139
In(III):halides	aq	r	1895
In_2S_3	c	a	1486
		l	1507
		l	1751
		l	2567
In_2S_3-$ZnSO_4$-H_2O	c	p	1164
In_2S_3-$CdSO_4$-H_2O	c	p	1164
In_2S_3-$CuSO_4$-H_2O	c	p	1164
InTe		m	B-33
In_2Te		n	A-56
In_2Te_3		m	B-33
In_2Te_5		n	A-56
InP	c	l	1999
		n	2001
$In_4(P_2O_7)_3$	c	p	1016
$InHP_2O_7$	c	p	1016
InAs		t	B-24
	c	s	2342
$InAs_3Se_3$	c	b	1462
In/Sb		s	D-23
InSb		t	B-24
	c	a	1465
		l	2471
In/Sb/Te	non-aq	b	1282
InBi		n	A-56
In/Bi		s	D-23
	non-aq	v	2429
In_2Bi		n	A-56
In(III):C_9NH_7O (8-quinolinol)	non-aq	r	2547
In(III):CNS^-	aq	r	2096
In/Sn	non-aq	b	1231
In/Sn/Sb	non-aq	b	1219
In(III):chrome azurol S	aq	r	2260

32 - Thallium

Substance	State	Prop.	Ref.
Tl	c	v	2244
Tl-Se	liq	s	A-26
Tl-Sn	liq	s	A-26
Tl-Al	liq	q	1671
Tl-In	liq	s	A-26
Tl_2O_3	c	l	2069

Substance	State	Prop.	Ref.
$Tl(III):OH^-$	aq	s	2383
TlCl		a	D-15
	c	a	1991
		a	2349
		km	1611
	non-aq	p	1203
$Tl(III):Cl^-$	aq	n	2483
		r	1972
$TlCl-SnCl_2$		s	A-26
$TlCl-aqPbCl_2$		p	1517
$TlCl-GaCl_3$	non-aq	b	2538
TlCl-KCl		b	D-15
TlCl-RbCl		b	D-15
TlCl-alkali nitrates		b	D-22
Tl_2Cl_2	g	ln	1611
Tl_2Cl_3	c	a	1991
TlBr		p	D-22
$Tl(III):Br^-$	aq	n	2483
TlBr-alkali nitrates		b	D-22
TlBr-NaBr		b	D-15
TlBr-RbBr		b	D-15
TlI		a	D-15
TlI-alkali nitrates		b	D-22
$Tl(IO_3)-H_2O$	c	p	2458
Tl(III):halides	aq	r	1895
$Tl_2S-CdSO_4-H_2O$	c	p	1164
$Tl_2S-CuSO_4-H_2O$	c	p	1164
$Tl(I):S_2O_3^{--}$	aq	r	2460
TlSe	c	k	2469
Tl/Se	liq	s	A-26
Tl_2Se	c	k	2469
Tl_2Se_3	c	k	2469
Tl/Sb	non-aq	s	1026
	liq	s	2119
Tl/Bi		b	D-32
$TlBi_2$		n	A-56
$(CH_3)_2TlClO_4 \cdot CH_3COCH_2COCH_3$	c	r	1306
$(C_2H_5)_2TlClO_4 \cdot CH_3COCH_2COCH_3$	c	r	1306
$(CH_3)_2TlClO_4 \cdot C_6H_5COCH_2COCH_3$	c	r	1306
$(CH_3)_2TlClO_4 \cdot CH_3(COCH_2)_2COC_6H_5$	c	r	1306
$(C_2H_5)_2TlClO_4 \cdot C_6H_5COCH_2COCH_3$	c	r	1306
$(C_2H_5)_2TlClO_4 \cdot CH_3(COCH_2)_2COC_6H_5$	c	r	1306
$(CH_3)_2TlClO_4 \cdot C_6H_5COCH_2COC_6H_5$	c	r	1306
$(C_2H_5)_2TlClO_4 \cdot CH_3COCH_2COCH_3$	c	r	1306
$C_6H_5(pCH_3C_6H_4)TlClO_4 \cdot (CH_3CO)_2CH_2$	c	r	1306
$(C_2H_5)_2TlClO_4 \cdot CH_2(COC_6H_5)_2$	c	r	1306
$(CH_3)_2TlClO_4 \cdot (C_6H_5COCH_2)_2CO$	c	r	1306
$(C_2H_5)_2TlClO_4 \cdot (C_6H_5COCH_2)_2CO$	c	r	1306
$(C_6H_5)_2TlClO_4 \cdot C_6H_5COCH_2COCH_3$	c	r	1306
$C_6H_5(pCH_3C_6H_4)TlClO_4 \cdot C_6H_5COCH_2COCH_3$	c	r	1306
$(C_6H_5)_2TlClO_4 \cdot CH_3(COCH_2)_2COC_6H_5$	c	r	1306
$C_6H_5(pCH_3C_6H_4)TlClO_4 \cdot C_6H_5(COCH_2)_2COCH_3$	c	r	1306
$(C_6H_5)_2TlClO_4 \cdot (C_6H_5CO)_2CH_2$	c	r	1306
$C_6H_5(pCH_3C_6H_4)TlClO_4 \cdot (COC_6H_5)_2$	c	r	1306
$(C_6H_5)_2TlClO_4 \cdot (C_6H_5COCH_2)_2CO$	c	r	1306
$C_6H_5(pCH_3C_6H_4)TlClO_4 \cdot (C_6H_5COCH_2)_2CO$	c	r	1306
TlCN (thallium cyanide)		mv	B-14
$Tl(I):C_9NH_7O$ (8-quinolinol)	non-aq	r	2547
$(C_2H_5)_2TlNO_3 \cdot CH_2(COCH_3)_2$	c	r	1306
$Tl(I):C_{10}N_2H_{16}O_8$ (ethylenediaminetetraacetic acid)	aq	r	2041
$(C_3H_7)_2TlNO_3 \cdot CH_2(COCH_3)_2$	c	r	1306
$(C_2H_5)_2TlNO_3 \cdot C_6H_5COCH_2COCH_3$	c	r	1306

Substance	State	Prop.	Ref.
$(C_2H_5)_2TlNO_3 \cdot CH_3CO(CH_2CO)_2C_6H_5$	c	r	1306
$(C_3H_7)_2TlNO_3 \cdot C_6H_5COCH_2COCH_3$	c	r	1306
$(C_3H_7)_2TlNO_3 \cdot CH_3CO(CH_2CO)_2C_6H_5$	c	r	1306
$(C_2H_5)_2TlNO_3 \cdot CH_2(COC_6H_5)_2$	c	r	1306
$(C_2H_5)_2TlNO_3 \cdot (C_6H_5CO)_2CH_2CO$	c	r	1306
$(C_3H_7)_2TlNO_3 \cdot (C_6H_5CO)_2CH_2$	c	r	1306
$(C_3H_7)_2TlNO_3 \cdot (C_6H_5COCH_2)_2CO$	c	r	1306
$Tl(I):SCN^-$	aq	r	2458
$Tl(OH):SCN^-$	aq	r	2458
$TlAlCl_4$	c	a	2349
$GaTlCl_4$	c	a	2538
Tl_3InCl_6	c	b	1458

33 - Zinc

Substance	State	Prop.	Ref.
Zn		m	B-31
	c	a	1598
		k	2314
		n	1002
		t	1220
	non-aq	s	2257
Zn-Pb		ps	D-62
Zn-Al	liq	q	1671
Zn-In-Sb	c	p	1634
Zn-In-Cd	liq	ps	A-28
Zn-Sn		ps	D-62
Zn-Ce		bp	D-60
Zn-Mg	liq	s	D-60
Zn^{++}	non-aq	s	2549
ZnO	c	l	1898
		l	1976
		l	2497
		p	1866
$ZnO-BaO-P_2O_5$	c	b	1264
$Zn(II):OH^-$	aq	r	2335
ZnF_2	c	n	1002
[redacted]$_2$-ZnS	non-aq	b	1242
$Zn(II):Cl^-$	aq	r	2315
$ZnCl_2$	c	mt	1055
	liq	k	1841
	g	klm	1049
		z	1528
	aq	n	2557
	non-aq	s	2237
		s	2276
$ZnCl_2-NH_3-H_2O$	c	p	1438
$ZnCl_2-KCl$	non-aq	s	2132
$ZnCl_2-RbCl$	non-aq	s	2132
$ZnCl_2O_6-H_2O$	c	b	1786
$ZnCl_2O_6 \cdot nH_2O$	c	a	1786
$ZnBr_2$	c	amt	1055
	g	klm	1049
		z	1528
Zn(II):halides	aq	r	1895
ZnS		t	B-21
	c	l	1029
		l	2550
$ZnS-H_2O$		r	1355
ZnS-HCl	c	nq	2126
$ZnS-ZnF_2$	non-aq	b	1242
$ZnSO_4$		n	A-39
		v	B-21
	c	l	1235
$ZnSO_4 \cdot nH_2O$	c	l	1987
$ZnO \cdot 2ZnSO_4$	c	l	1235
ZnSe	c	l	1029
		l	2567
$ZnSeO_3 \cdot H_2O$	c	n	1998
ZnTe	c	l	1029
		l	2567
$Zn(NO_3)_2-HNO_3-H_2O$	liq	b	1732
$Zn(II):NH_2O^-$	c	r	1255
$(NH_4)_2Zn(SO_4)_2$	c	l	1985
$(NH_4)_2Zn(SO_4)_2 \cdot 6H_2O$	c	l	1985
$Zn(II):P_3O_{10}^{-----}$	aq	r	2266
$Zn_2P_2O_7-H_2O$	c	p	2495
$Zn_2P_2O_7-Cd_2P_2O_7$	c	b	2141
$Zn_3(PO_4)_2-Cd_3(PO_4)_2$	c	b	1263
Zn/Bi		p	D-62

Substance	State	Prop.	Ref.
ZnC_2O_4-NaCl-H_2O	c	p	1423
ZnC_2O_4-K_2CO_4-H_2O	c	p	1423
$Zn(C_2H_5)_2$		w	D-25
Zn(II):$C_2H_4O_2$ (acetic acid)	aq	r	2104
Zn(II):$C_4H_6O_6$ (tartaric acid)	aq	r r	2216 2229
Zn(II):$C_5H_8O_2$ (acetylacetone)		ns	A-18
Zn(II):$C_6H_8O_7$ (citric acid)	c	r	1251
Zn(II):$C_6H_8O_6$ (tricarballylic acid)	c	r	1251
Zn(II):$C_7H_6O_2$ (salicylaldehyde)	aq	r	2167
Zn(II):$C_7H_6O_3$ (salicylic acid)	aq	r	2167
Zn(II):$C_7H_8O_2$ (salicylalcohol)	aq	r	2167
Zn(II):$C_9H_{10}O_3$ (ethylsalicylate)	aq	r	2167
$ZnC_{17}H_{16}O_6$-50%dioxane (2-hydroxy-2',4',4-trimethoxybenzil)		r	1725
$Zn(CN)_4^{--}$	aq	n n	1088 2492
Zn(II):$C_2N_2H_8$ (ethylenediamine)	c	r	1630
Zn(II):$C_4N_3H_{13}$ (diethylenetriamine)	c	r	1630
Zn(II):$C_6N_2H_8$ (2-picolylamine)	c	r	1630
Zn(II):$C_6N_4H_{18}$ (triethylenetetramine)	c	r	1630
Zn(II):$C_8N_5H_{23}$ (tetraethylenepentamine)	aq	r	2557
Zn(II):$C_9N_3H_{15}$ (N-aminoethyl-2-(2-aminoethyl)pyridine)	c	r	1630
Zn(II):$C_{10}N_6H_{28}$ (penten)	aq	n	2558
Zn(II):$C_{10}N_6H_{29}$ (penten H^+)	aq	n	2558
Zn(II):$C_3N_2H_4$ (imidazole)	aq	r	1083
Zn(II):$C_{14}N_4H_{18}$ (ethylenebis-α,α'-(2-aminoethyl)pyridine)	c	r	1630

Substance	State	Prop.	Ref.
Zn(II):$C_2NH_5O_2$ (glycine)	c	n	1764
Zn(II):$C_2N_4H_4O_2$ (urazine)	aq	r	1496
Zn(II):$C_3NH_7O_3$ (serine)	aq	r	2374
Zn(II):$C_3N_3H_5O_2$ (urazole)	aq	r	1496
Zn(II):$C_4NH_9O_3$ (α-amino-β-hydroxybutyric acid)	aq	r	1418
Zn(II):$C_5NH_{11}O_3$ (3-hydroxynorvaline)	aq	r	1418
Zn(II):$C_5NH_{11}O_3$ (3-hydroxyvaline)	aq	r	1418
Zn(II):$C_5N_3H_3O_6$ (5-nitrobrotic acid)	c	r	1228
$ZnC_6NH_6O_6^-$ (nitrilotriacetate)	aq	n	2553
Zn(II):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2269
Zn(II):$C_6NH_{13}O_3$ (3-hydroxyleucine)	aq	r	1418
Zn(II):$C_6NH_{13}O_3$ (3-hydroxynorleucine)	aq	r	1418
$Zn(C_3NH_6O_2^-)_2 \cdot nH_2O$ (α-alanine)	c	n	1764
Zn(II):$C_7NH_7O_2$ (salicylamide)	aq	r	2167
Zn(II):$C_7NH_{11}O_5$ (aminoacetone-N,N-diacetic acid)	aq	r	1334
Zn(II):$C_8N_2H_{12}O$ (N-hydroxyethyl-(2-aminoethyl)pyridine)	c	r	1630
$Zn(C_4NH_8O_2^-)_2 \cdot nH_2O$ (n-aminobutyrate)	c	n	1764
Zn(II):$C_9NH_{11}O_3$ (phenylserine)	aq	r	1418
Zn(II):$C_{10}NH_{17}O_4$ (hexylaminediacetic acid)	aq	r	2554
Zn(II):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
Zn(II):$C_{13}NH_{11}O_2$ (salicylanilide)	aq	r	2167
Zn(II):$C_{13}N_4H_{12}O$ (diphenylcarbazone)	non-aq	r	2593
Zn(II):$C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635

Substance	State	Prop.	Ref.
Zn(II):$C_{14}N_3H_{14}O_2$	aq dioxane	r	1840
Zn(II):$(C_{10}N_2H_{16}O_8)(C_6NH_9O_3)$ (ethylenediaminetetracetic acid, nitrilotriacetic acid)	c	r	1802
Zn(II):C_9NH_7O-H_2O (8-quinolinol)	c	p	1417
$ZnCl_2 \cdot C_6NCl_2H_5$ (2,3-dichloroaniline)	non-aq	r	2521
$ZnCl_2 \cdot C_6NCl_2H_5$ (2,4-dichloroaniline)	non-aq	r	2521
$ZnCl_2 \cdot C_6NCl_2H_5$ (2,5-dichloroaniline)	non-aq	r	2521
$[N(CH_3)_4]_2ZnCl_4$-H_2O	c	nq	1093
Zn(II):$C_{12}N_3ClH_{10}$ aq dioxane (3-hydroxy-3-(p-chlorophenyl)-1-phenyltriazene)		r	1839
$[N(C_2H_5)_4]_2ZnCl_4$-H_2O	c	nq	1093
$ZnCl_2 \cdot C_7N_2H_8O_2$ (2-methyl-4-nitroaniline)	non-aq	r	2521
Zn(II):$C_{12}N_3ClH_{10}O$ (3-hydroxy-3-phenyl-1-o-chlorophenyltriazene)	c	r	1975
$ZnBr_2 \cdot C_6NBrH_6$ (4-bromoaniline)	non-aq	r	2521
$[(CH_3)_4N]_2ZnBr_4$		q	A-15
$ZnC_{16}N_2Br_4H_{40}$		q	A-15
Zn(II):$C_5N_2BrH_3O_4$ (5-bromoorotic acid)	c	r	1228
$ZnBr_3 \cdot C_6N_2H_6O_2$ (3-nitroaniline)	non-aq	r	2521
$ZnBr_2 \cdot C_6N_2H_6O_2$ (4-nitroaniline)	non-aq	r	2521
$ZnBr_2 \cdot C_7N_2H_8O_2$ (4-methyl-3-nitroaniline)	non-aq	r	2521
$ZnCl_2 \cdot C_6NBrH_6$ (4-bromoaniline)	non-aq	r	2521
$ZnBr_2 \cdot C_6NCl_2H_5$ (2,5-dichloroaniline)	non-aq	r	2521
Zn(II):$C_5N_2IH_3O_4$ (5-iodoorotic acid)	c	r	1228
$ZnI_2 \cdot C_6N_2H_6O_2$ (4-nitroaniline)	non-aq	r	2521
$ZnI_2 \cdot C_7N_2H_8O_2$ (4-methyl-3-nitroaniline)	non-aq	r	2521
$Zn(CNS)_2$	aq	r	1389
$ZnC_5NS_2H_{11}$-H_2O		p	1416

Substance	State	Prop.	Ref.
Zn(II):$C_5N_5SH_5$ aq dioxane (2-amino-6-mercapto purine)		r	2163
Zn(II):$C_9N_3SH_8$ (o-(2-thiazolylazo)phenol)	aq	r	2134
Zn(II):$C_{13}N_4SH_{12}$ (dithizone)	non-aq	r	2593
Zn(II):$C_{15}N_4SH_{16}$ (di-o-tolylthiacarbazone)	non-aq	r	2593
Zn(II):$C_{15}N_4SH_{16}$ (di-p-tolylthiacarbazone)	non-aq	r	2593
Zn(II):$C_{17}N_4SH_{20}$ (di-m-xylylthiacarbazone)	non-aq	r	2593
Zn(II):$C_{21}N_4SH_{16}$ (di-1-naphthylthiacarbazone)	non-aq	r	2593
Zn(II):$C_{21}N_4SH_{16}$ (di-2-naphthylthiacarbazone)	non-aq	r	2593
Zn(II):$C_{12}N_3SH_{11}O_4$ (3-hydroxy-3-phenyl-1-(p-sulfophenyl)triazene)	aq	r	2121
Zn(II):$C_{16}N_2SH_{14}O_2$ (8-(p-toluenesulfonamide)quinoline)	aq	r	1745
Zn(II):$C_{10}AsH_{11}O_4$	aq	r	2554
Zn(II):subst. ethylenediamines		nr	A-15
Zn/Sn	liq	s	D-24
Zn/Pb	non-aq	qt	1220
Zn/Al	non-aq	p	2421
Zn/Tl/Sn	non-aq	p	1318
Zn/Tl/In	non-aq	p	1318

34 - Cadmium

Cd	c	a	1304
		k	2314
		m	1055
		v	1446
Cd^{++}	non-aq	s	2549
Cd-Al	liq	q	1671
Cd-In	liq	ps	A-27
Cd-In-Zn	liq	ps	A-27
CdO		q	A-71
		t	B-40
	c	r	1300
CdO-P_2O_5	c	b	2141
Cd(II):OH^-	aq	r	2377
CdF_2		l	C-35

Substance	State	Prop.	Ref.
CdCl	g	r	2551
$CdCl^+$	aq	p	2408
	non-aq	p	1203
		s	1065
$Cd(II):Cl^-$	non-aq	s	1435
$CdCl_2$	c	a	1795
	g	lmw	1003
		r	2551
		z	1528
	non-aq	s	1065
		r	1664
$CdCl_2-H_2O$		s	2165
		s	2517
$CdCl_2-CH_3OH$		s	2165
$CdCl_2-aqCH_3OH$		s	2165
		s	2517
$CdCl_2-C_2H_5OH$		s	2165
$CdCl_2-aqC_2H_5OH$		s	2517
		s	2165
$CdCl_2-NH_4NO_3-H_2O$	aq	s	1677
$CdCl_2-KCl$	liq	q	A-59
$CdCl_2-KCl-NaCl$	c	b	1831
	non-aq	bs	1498
$CdCl_4^{--}$	non-aq	r	1664
$CdBr^+$		p	D-22
	non-aq	s	1065
$Cd(II):Br^-$	non-aq	r	2098
$CdBr_2$	c	a	1795
		s	2284
	g	z	1528
	non-aq	s	1065
Cd/I	non-aq	s	1144
CdI_2	c	a	1794
		a	1980
		s	2000
		s	2284
Cd(II):halides	aq	r	1895
CdS		q	A-71
		t	B-40
	c	l	1029
		l	2550
		r	1300
CdS-HCl	c	nq	2126
$CdSO_4$		n	A-39
	aq	h	1328
		by	D-37
CdSe		l	C-14
	c	l	1029
		l	2567

Substance	State	Prop.	Ref.
CdTe		t	B-40
	c	l	1029
		l	2567
$Cd(PO_4)_2-Zn_3(PO_4)_2$	c	b	1263
$Cd(II):P_3O_{10}^{-----}$	aq	r	2266
$Cd_2P_2O_7-H_2O$	c	p	2495
$Cd_2P_2O_7-Zn_2P_2O_7$	c	b	2141
$Cd(II):PH_2O_2^-$	aq	r	2306
$Cd(II):P_2H_2O_5^{--}$	aq	r	2306
Cd_3As_2	c	l	1052
Cd-Bi		ps	D-62
$CdC_2O_4-NaCl-H_2O$	c	p	1429
$CdC_2O_4-K_2CO_4-H_2O$	c	p	1423
$Cd(II):C_2H_4O_2$	aq	r	2104
$Cd(II):C_3H_4O_4$	aq	r	2453
(malonic acid)		r	2455
$Cd(II):C_4H_6O_6$	aq	r	2216
(tartaric acid)		r	2229
$Cd(C_5H_7O_2)_2$(acetylacetonate)		ns	A-18
$Cd(II):C_6H_8O_7$	c	r	1251
(citric acid)			
$Cd(C_{17}H_{16}O_6)$-50% dioxane		r	1725
(2-hydroxy-2',4',4-trimethoxybenzil)			
$Cd(CN)_2-H_2O$	c	p	1888
$Cd(II):C_2N_2H_8$	c	r	1630
(ethylenediamine)			
$Cd(II):C_4N_3H_3$	c	r	1630
(diethylenetriamine)			
$Cd(II):C_6N_2H_8$	c	r	1630
(2-picolylamine)			
$Cd(II):C_6N_4H_{18}$	c	r	1630
(triethylenetetramine)			
$Cd(II):C_9N_3H_{15}$	c	r	1630
(N-aminoethyl-2-(2-aminoethyl)pyridine)			
$Cd(II):C_{14}N_4H_{18}$	c	r	1630
(ethylenebis-α,α'-(2-aminoethyl)pyridine)			
$Cd(II):C_5N_3H_3O_6$	c	r	1228
(5-nitrobrotic acid)			
$Cd(II):C_6NH_9O_6$	aq	r	2269
(nitrilotriacetic acid)			
$Cd(II):C_7NH_{11}O_5$	aq	r	1334
(aminoacetone-N,N-diacetic acid)			
$Cd(II):C_8N_2H_{12}O$	c	r	1630
(N-hydroxyethyl-(2-aminoethyl)pyridine)			

Substance	State	Prop.	Ref.
Cd(II):$C_{10}NH_{17}O_4$ ($C_6H_{11}N(CH_2COOH)_2$)	aq	r	2554
Cd(II):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
Cd(II):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
Cd(II):$C_{14}N_2H_{22}O_8$ (1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
Cd(II):$C_{10}N_2H_{16}O_8$)($C_6NH_9O_3$) (ethylenediaminetetracetic acid)(nitrilotriacetic acid)	c	r	1802
Cd(II):$C_5N_2BrH_3O_4$ (5-bromobrotic acid)	c	r	1228
Cd(II):$C_6N_2IH_3O_4$ (5-iodobrotic acid)	c	r	1228
Cd(II):SCN^-	aq	r	1748
$Cd(SCN)_2$-H_2O	c	p	1888
Cd(II):CNS^-	aq	r	2096
$Cd(CNS)_2$	aq	v	1389
Cd(II):CN_2SH_4 (thiourea)	aq	p	1146
Cd(II):$C_9N_3SH_8$ (o-(2-thiazolylazo)phenol)	aq	r	2134
Cd(II):$C_{10}AsH_{11}O_4$	aq	r	2554
$CdSiO_3$	c	a	1973
Cd_2SiO_4	c	a	1973
		a	2431
Cd/Sn	non-aq	ps	D-62
Cd/Pb	non-aq	ps	D-62
Cd/Tl	non-aq	p	2419
Cd/Zn	non-aq	p	2314
Cd/Zn/Pb	non-aq	bs	D-24

35 - Mercury

Substance	State	Prop.	Ref.
Hg	c	a	1878
		n	1485
		v	2244
	liq	h	D-13
		ik	1107
Hg(II)	non-aq	s	1134
		s	2549
Hg-Zn	c	s	1111
Hg-Cd	c	s	1111
Hg_2	non-aq	s	1836
Hg_2^{++}	aq	rs	1927
HgCl	aq	n	1041
$HgCl_2$	aq	n	1041
		n	2492
$HgCl_2$-systems		b	D-69
Hg_2Cl_2	c	s	2195
HgBr	aq	n	1041
$HgBr_2$	aq	n	1041
		n	2492
Hg_2Br_2	aq	s	1774
HgBrCl	c	r	1912
	g	w	1979
HgI	aq	n	1041
Hg(II):I^--$Na_2S_2O_3$	aq	r	2135
HgI_2	c	n	1041
	aq	n	1041
		n	2492
	non-aq	r	2286
HgICl	c	r	1912
HgIBr	c	r	1912
	g	w	1979
HgS		k	A-79
	c	l	1029
		l	2550
	aq	r	1352
HgS_2^{--}	aq	r	1352
HgS_2H^-	aq	r	1352
HgS_2H_2	aq	r	1352
$HgI_2 \cdot S_2O_3$	aq	r	2135
HgSe	g	k	A-79
	c	l	1029
		km	1445
HgTe	c	l	1029
		l	2566
		l	2567
$Hg(NH_3)_2^{++}$	aq	r	1924
Hg/Bi		bs	D-10
HgC_2O_4-NaCl-H_2O	c	p	1423
HgC_2O_4-K_2CO_4-H_2O	c	p	1423
$HgC_6H_5^+$	aq	r	1925
Hg(II)$C_2H_4O_2$ (acetic acid)	c	r	1974
Hg(II):$C_5H_8O_2$-CH_3OH-H_2O (acetylacetone)		ns	A-18

Substance	State	Prop.	Ref.
Hg(I):$C_8H_9O_2$ (s-methoxyanisole)	aq	r	1925
$Hg_2(CH_3COO)_2$	non-aq	s	2591
$Hg_2(C_2H_3O_2)_2$ (acetate)	c	s	1092
CH_3HgCl	aq	r	2301
CH_3HgBr	aq	r	2301
CH_3HgI	aq	r	2301
CH_3HgSO_3	aq	r	2301
HgCN	c	k	1176
Hg(II):CN^-	aq	r	1134
Hg(II):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
Hg(II):$[(H_2N)_2CNH]_2$	aq	r	1924
Hg(I):$C_6H_5NH_2$	aq	r	1926
Hg(II):$C_6H_5NH_2$	aq	r	1927
$Hg(CN)_2(C_6H_9N)_2$	c	pr	1319
Hg(II):$C_{10}NH_{11}O_4$	aq	r	2554
Hg(II):$C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
Hg(II):$(C_{10}N_2H_{16}O_8)(C_6NH_9O_3)$ (ethylenediaminetetracetic acid)(nitrilotriacetic acid)	c	r	1802
$Hg(CNO)_2(C_6H_7N)_2$	c	pr	1319
HgCNCl	aq	r	1684
	non-aq	r	1601
HgCNBr	aq	r	1684
	non-aq	r	1601
HgCNI	aq	r	1684
	non-aq	r	1601
CH_3HgSCN	aq	r	2301
$Hg(SCN)_2(C_6H_7N)_2$	c	pr	1319
$HgC_4N_2SH_4O_2 \cdot 2H_2O$ (thiobarbiturate)	aq	r	1823
Hg(II):$C_{10}AsH_{11}O_4$ ($C_6H_5As(CH_2COOH)_2$	aq	r	2554
$HgGa_2Cl_8$	c	a	2268
Hg/In	non-aq	s	1778
		b	2352
Hg/Cd-Hg/Au		q	A-23
Hg/Zn-Hg/Cu		q	A-23
Hg/Zn-Hg/Au		q	A-23

36 - Copper

Substance	State	Prop.	Ref.
Cu		p	C-13
	c	a	2345
		v	1446
		v	1633
		v	1834
		v	1851
	liq	km	1994
Cu-H_2O	c	b	1807
Cu-Sb	c	s	1719
Cu-Bi/Pb		b	D-45
Cu-Sn	liq	q	1669
Cu-Ni		q	A-56
	liq	q	1669
Cu-Fe		q	A-56
Cu^+	non-aq	s	1836
		s	2549
Cu^{++}	non-aq	s	2549
CuO	c	l	1559
CuO-CuO_2-SiO_2	non-aq	b	1559
CuO-Cu_2O-Al_2O_3	c	b	1452
CuO-MgO	non-aq	b	1485
CuO_2-CuO-SiO_2	non-aq	b	1559
Cu_2O	c	l	1200
Cu_2O-CuO-Al_2O_2	c	b	1452
Cu(II):OH^-	aq	r	2208
Cu(II):H_2O	c	r	1363
$Cu(OH)_2$	c	n	1889
$Cu(OH)_2$-H_2O	c	p	2452
		p	2482
$Cu(OH)_2 \cdot H_2O$-H_2O	c	p	2452
CuCl	c	z	1806
	liq	n	A-58
Cu(II):Cl^-	aq	r	1205
$CuCl^+$	non-aq	r	1824
$CuCl_2$	c	l	2078
	aq	n	2557
$CuCl_2$-HCl-H_2O	c	p	1354
$CuCl_2$-TlCl	c	b	1673
$CuCl_2$-AgCl	c	b	1673
$CuCl_3^-$	non-aq	r	1824
Cu_3Cl_3	c	l	2078

Substance	State	Prop.	Ref.
$Cu(ClO_3)_2$	aq	r	1568
$Cu(ClO_4)_2$-$HClO_4$-H_2O	c	p	1354
$Cu(OH)_{1.5}(ClO_3)_{0.5}$-$H_2O$	c	p	1568
$3Cu(OH)_2 \cdot CuCl_2$	c	z	1806
CuBr	aq	r	1736
$CuBr_2$	c	l	1070
		l	2499
	aq	r	1736
$Cu(BrO_3)_2$	aq	r	1589
$Cu_2(OH)_3BrO_3$	c	p	1589
CuI	c	m	2585
		v	2586
CuI-AgI	c	m	2585
		v	2586
CuI_2	non-aq	r	2286
CuS	c	l	1599
$CuSO_4$		n	A-39
		v	B-21
	aq	r	1436
$CuSO_4 \cdot nH_2O$	c	l	1986
$CuSO_4 \cdot 2Cu(OH)_2$	c	p	2452
Cu_2Se	c	p	1706
$CuSeO_4 \cdot 5H_2O$	aq	nq	1386
Cu_2Te	c	p	1706
$Cu(NO_3)_2 \cdot 3H_2O$	c	n	1889
$Cu(II):NH_3$	aq	r	2231
$Cu(II):NH_2O^-$	c	r	1255
$Cu(NH_4)_2Cl_4 \cdot 2H_2O$	c	ar	1191
		v	2428
$(NH_4)_2Cu(SO_4)_2 \cdot nH_2O$	c	l	1985
$Cu(II):P_3O_{10}^{-----}$	aq	r	2266
$CuHPO_3$-H_2O	c	p	1734
$CuHPO_3 \cdot 2H_2O$-H_2O	c	p	1703
$Cu(II):PH_2O_2^-$	aq	r	2306
$Cu(II):P_2H_2O_5^{--}$	aq	r	2306
$Cu(HPO_3)_2^{--}$	aq	r	1734
$CuHPO_3 \cdot 3NH_3$	c	l	1808
$Cu(NH_4)_4HPO_3$	c	l	1808
$Cu(HCO_2)_2$		v	B-25
$Cu(HCO_2)_2 \cdot 4H_2O$	c	r	1476
$Cu(II):C_2H_4O_2$ (acetic acid)	aq	r	2104
		r	2173

Substance	State	Prop.	Ref.
$Cu(II):C_2H_4O_3$ (glycolic acid)	aq	r	2173
$Cu(II):CH_3COCO_2H$	aq	r	2362
$Cu(II):C_2H_5CO_2H$	aq	r	2362
$Cu(II):CH_3CH(OH)CO_2H$	aq	r	2362
$Cu(II):C_4H_6O_6$ (tartaric acid)	aq	r	2173
$Cu(II):C_4H_9COOH$	aq	r	2362
$Cu(II):C_6H_8O_6$ (tricarballylic acid)	c	r	1251
$Cu(II):C_6H_8O_7$ (citric acid)	c	r	1251
$Cu(II):C_7H_6O_2$ (salicyladehyde)	aq	r	2167
$Cu(II):C_7H_6O_3$ (salicylic acid)	aq	r	2167
$Cu(II):C_7H_8O_2$ (salicylalcohol)	aq	r	2167
$CuC_7H_{10}O^{++}$ (methacryloylacetone)	non-aq	p	1810
$Cu(II):C_9H_{10}O_3$ (ethylsalicylate)	aq	r	2167
$Cu(II):C_{17}H_{16}O_6$ aq dioxane (2-hydroxy-2',4',4-trimethoxybenzil)		r	1725
$Cu_2(II):C_6H_8O_7$ (tricarballylic acid)	c	r	1251
$Cu_2(II):C_6H_8O_7$ (citric acid)	c	r	1251
$Cu(II):C_2N_2H_8$ (ethylenediamine)	c	r	1630
$Cu(II):C_3N_2H_4$ (imidazole)	aq	r	1083
$Cu(II):C_3N_2H_4$ (pyrazole)	aq	r	2506
$Cu(II):C_3N_2H_8$ (1,3-diaminopropane)	c	r	1630
$Cu(II):C_4N_2H_6$ (N-methylimidazole)	aq	r	2506
$Cu(II):C_4N_2H_{12}$	aq	r	2485
$Cu(II):C_4N_3H_{13}$ (diethylenetriamine)	c	r	1630
$Cu(II):C_5NH_5$ (pyridine)	aq	r	2174
$Cu(II):C_5N_3H_9$ (histamine)	c	r	1314
	aq	r	2506

Substance	State	Prop.	Ref.
Cu(II):$C_6N_2H_8$ (o-phenylenediamine)	aq	r	1590
Cu(II):$C_6N_2H_8$ (2-picolylamine)	c	r	1630
	aq	r	2127
Cu(II):$C_6N_2H_{16}$ (N,N-diethylenediamine)	aq	r	1593
		r	2226
		r	2227
Cu(II):$C_6N_4H_{18}$ (triethylenetetramine)	c	r	1630
Cu(II):$C_7N_2H_{10}$ (2-(2-aminoethyl)pyridine)	c	r	1630
Cu(II):$C_8N_5H_{23}$ (tetraethylenepentamine)	aq	r	2557
Cu(II):$C_9N_3H_{15}$ (N-aminoethyl-2-(2-aminoethyl)-pyridine)	c	r	1630
$CuC_{10}N_6H_{28}^{++}$ (penten)	aq	n	2558
$CuC_{10}N_6H_{29}^{+++}$ (penten H^+)	aq	r	2558
$CuCN(C_6H_7N)_2$ (picoline)	c	pr	1319
Cu(II):$C_{14}N_4H_{18}$ (ethylenebis-α,α'-(2-aminoethyl)-pyridine)	c	r	1630
Cu(II):$C_2NH_5O_2$ (glycine)	aq	nr	2187
Cu(II):C_2NH_7O (ethanolamine)	aq	r	1356
Cu(II):$C_3NH_7O_2$ (sarcosine)	aq	nr	2187
Cu(II):$C_3NH_7O_3$ (serine)	aq	r	2374
Cu(II):$(C_2H_4O_3)(C_2NH_5O_2)$ (glycollic acid)(glycine)	aq	r	1690
Cu(II):$C_4NH_9O_2$ (α-aminoisobutyric acid)	aq	nr	2187
Cu(II):$C_4NH_9O_3$ (threonine)	aq	nr	2187
		r	1418
Cu(II):$C_4N_2H_8O_3$ (glycylglycine)	c	r	1314
Cu$(C_2NH_4O_2)_2 \cdot nH_2O$ (glycinate)	c	n	1764
Cu(II):$C_5NH_{11}O_3$ (3-hydroxyvaline)	aq	r	1418
Cu(II):$C_5NH_{11}O_3$ (3-hydroxynorvaline)	aq	r	1418
Cu(II):$C_5NH_{11}O_3$ (2-methylthreonine)	aq	r	1418

Substance	State	Prop.	Ref.
Cu(II):$(C_3N_2H_4)(C_2H_4O_2)$ (imidazole)(acetic acid)	aq	r	2506
Cu(II):$(C_2NH_5O_2)(C_3NH_7O_2)$ (glycine)(alanine)	aq	r	1678
Cu(II):$C_5N_2H_{14}O$ (N-(β-hydroxyethyl)1,3-diaminopropane)	aq	r	2224
Cu(II):$(C_5N_3H_9)(OH^-)$ (histamine)	c	r	1314
$CuC_6NH_6O_6^-$ (nitrilotriacetate)	aq	n	2553
Cu(II):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2269
Cu$(C_3NH_6O_2)_2 \cdot nH_2O$ (β-alanine)	c	n	1764
Cu(II):$C_6NH_{13}O_3$ (3-hydroxyleucine)	aq	r	1418
Cu(II):$C_6NH_{13}O_3$ (3-hydroxynorleucine)	aq	r	1418
Cu(II):$C_6NH_{13}O_7$ (D-glucosaminic acid)	aq	r	2248
Cu$(C_3NH_6O_2)_2 \cdot nH_2O$ (α-alanine)	c	n	1764
$[Cu(OH)(C_6N_2H_{16})]_n$ (N,N'-diethylenediamine)	aq	r	1593
Cu(II):$C_6N_3H_9O_2$ (histidine)	c	r	1314
	aq	r	2506
Cu(II):C_7NH_5O (salicylnitrile)	aq	r	2167
Cu(II):C_7NH_7O (salicylald oxime	aq	r	2167
Cu(II):$C_7NH_7O_2$ (salicylamide)	aq	r	2167
Cu(II):$C_7NH_7O_3$ (salicylhydroxamic acid)	aq	r	2167
Cu(II):C_7NH_9O (salicylamine)	aq	r	2167
Cu(II):$C_7NH_{11}O_5$ (aminoacetone-N,N-diacetic acid)	aq	r	1334
Cu(II):$C_7NH_{14}O_3$ (2-methyl-3-hydroxyleucine)	aq	r	1418
Cu(II):$C_7N_2H_8O$ (salicylaldazone)	aq	r	2167
Cu(II):$C_7N_2H_8O$ (salicylamidoxime)	aq	r	2167
Cu(II):$C_7N_2H_8O_2$ (salicyloylhydrazide)	aq	r	2167

Substance	State	Prop.	Ref.
$CuC_8NH_7O_3$-13 organic solvents (resacetophenone oxime)	p		1826
Cu(II):C_8NH_9O (N-methyliminesalicylaldehyde)	aq	r	2167
Cu(II):$C_8N_2H_{12}O$ (N-hydroxyethyl-(2-aminoethyl)-pyridine)	c	r	1630
$Cu(C_4NH_8O_2)_2$ (α-aminobutyrate)	c	n	1764
$Cu(C_4NH_8O_2)_2 \cdot nH_2O$ (β-aminobutyrate)	c	n	1764
Cu(II)$(C_2N_2H_8)(C_6NH_9O_6)$ (ethylenediamine)(nitrilotriacetic acid)	aq	r	1695
Cu(II):$C_9NH_{11}O_3$ (phenylserine)	aq	r	1418
Cu(II):$C_{10}NH_{17}O_4$ (hexylamine-N,N-diacetic acid)	aq	r	2554
Cu(II):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
$[Cu(C_5N_2H_{12}O)_2\text{-}H]^+$ (2-amino-2-methyl-3-butanone oxime)	aq	n	1904
Cu(II):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$Cu(C_6NH_6O_6)_2^{----}$ (nitrilotriacetate)	aq	n	2553
Cu(II):$(C_2N_2H_8)(C_{10}N_2H_{16}O_8)$ (ethylenetiamine)(ethylenediaminetetraacetic acid)	aq	r	1695
$[Cu(C_6N_2H_{14}O)_2\text{-}H]^+$ (2-methylamino-2-methyl-3-butanone oxime)	aq	n	1904
Cu(II):$C_{12}N_6H_{16}O_3$ (histydihistidine)	c	r	1314
Cu(II):$C_{13}NH_{11}O$ (salicylanil)	aq	r	2167
Cu(II):$C_{13}NH_{11}O_2$ (salicylanilide)	aq	r	2167
Cu(II):$C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
Cu(II):$C_{14}N_3H_{14}O_2$ aq dioxane (3-hydroxy-3-phenyl-1-(p-acetylphenyl)-triazene)		r	1840
Cu(II):$(C_6NH_7)_2(CNO)_2$ (picoline)	c	pr	1319
Cu(II):$(C_{10}N_2H_{16}O_8)(C_6NH_9O_3)$ (ethylenediaminetetracetic acid)(nitrilotriacetic acid)	c	r	1802

Substance	State	Prop.	Ref.
$Cu(C_9NH_6O)_2\text{-}H_2O$ (8-quinolinol)	c	p	1417
Cu(II):$C_{18}N_4H_{30}O_{12}$ (triethylenetetraminehexaacetic acid)	aq	r	2218
$Cu(C_{10}NH_{10}O)_2\text{-}H_2O$ (2-methyl-8-quinolinol)	c	p	1417
$Cu(C_{16}NH_{12}O)_2\text{-}H_2O$ (5-benzyl-8-quinolinol)	c	p	1417
Cu_2(II):$(C_5N_3H_9)_2(OH^-)_2$ (histamine)	c	r	1314
$[N(CH_3)_4]_2CuCl_4\text{-}H_2O$	c	nq	1093
$[N(C_2H_5)_4]_2CuCl_4\text{-}H_2O$	c	nq	1093
Cu(II):$C_{12}N_3ClH_9O$ aq dioxane (3-hydroxy-3-(p-chlorophenyl)-1-phenyltriazene)		r	1839
Cu(II):$C_{12}N_3ClH_{10}O$ (3-hydroxy-3-phenyl-1-o-chlorophenyltriazene)	c	r	1975
$[(C_2H_5)_4N]_2CuBr_4$		q	A-15
Cu(II):$C_5N_2BrH_3O_4$ (5-bromobrotic acid)	c	r	1228
$CuI_2 \cdot C_{12}N_2H_{12}$ (benzidine)	c	p	2363
$CuI_2 \cdot 2(C_{12}N_2H_{12})$ (benzidine)	c	p	2363
Cu(II):$C_5N_2IH_3O_4$ (5-iodobrotic acid)	c	r	1228
$Cu(CNS)_2$	aq	r	1389
$CuC_5\text{-}NS_2H_{11}H_2O$ (diethyldithiocarbamate)	c	p	1416
Cu(II):$C_9N_3SH_8$ (o-(2-thiazolylazo)phenol)	aq	r	2134
$Cu(SCN)_2 \cdot C_7NH_9$ (toluidine)	c	p	2363
$CuSCN(C_6H_7N)_2$ (picoline)	c	pr	1319
$Cu(SCN)_2 \cdot C_{12}N_2H_{12}$ (benzidine)	c	p	2363
$Cu(SCN)_2 \cdot C_{12}N_2H_{12}$ (m,m'-diaminobiphenyl)	c	p	2363
$Cu(SCN)_2 \cdot C_{13}N_2H_{12}$ (diaminofluorene)	c	p	2363
$Cu(SCN)_2 \cdot 2(C_7NH_9)$ (toluidine)	c	p	2363
$Cu(SCN)_2 \cdot 2(C_{12}N_2H_{12})$ (benzidine)	c	p	2363

Substance	State	Prop.	Ref.
$Cu(SCN)_2 \cdot 2(C_{12}N_2H_{12})$ (o-o'-diaminobiphenyl)	c	p	2363
$Cu(II):(C_2NH_5O_2)(C_7SH_6O_6)$ (glycine)(5-sulfosalicylic acid)	aq	r	1378
$Cu(II):HO_2CCH_2S(CH_2)_2N(CH_2COOH)_2$	aq	r	1816
$Cu(II):C_{10}NS_2H_7O_3$ (3-(p-carboxyphenyl)-rhodanine)	aq	r	1588
$Cu(II):C_{12}N_3SH_{11}O_4$ (3-hydroxy-3-phenyl-1-(p-sulfophenyl)-triazene)	aq	r	2121
$Cu(I):C_{10}AsH_{11}O_4$ $(C_6H_5As(CH_2COOH)_2)$	aq	r	2554
$Cu(II):C_{10}AsH_{11}O_4$ $(C_6H_5As(CH_2COOH)_2)$	aq	r	2554
$CuC_{38}As_2Cl_4H_{36}$	aq	q	1046
$Cu(II):C_{12}AsClH_{14}O_4$ $(p\text{-}ClC_6H_4As(CH_2CH_2COOH)_2)$	aq	r	2554
Cu(II):subst. ethylenediamines		mr	A-15
Cu/Sn	c	ps	1855
	non-aq	b	1280
Cu/Sn/S	non-aq	b	1516
Cu/Pb/Bi		b	D-45
$4TlCl \cdot CuCl_2$	c	a	1673
$3TlCl \cdot 2CuCl_2$	c	a	1673
Cu/Hg-Zn/Hg		q	A-23

37 - Silver

Substance	State	Prop.	Ref.
Ag		bp	D-23
		k	C-31
	c	a	1598
		a	2334
		a	2345
		k	2020
		k	2414
		km	1610
	liq	km	1994
		km	2166
$Ag\text{-}Bi_2Te_3$	c	p	1718
Ag-Sn	liq	q	A-37
Ag-Pb	liq	n	A-42
Ag-AgCl	non-aq	s	1642
Ag-Mn	liq	p	D-61
$Ag\text{-}Na_2O\text{-}B_2O_3\text{-}NaCl$		p	D-74
Ag^+	non-aq	s	1836
		s	2549
AgO_2	c	mr	1581
Ag_2O_3	aq	s	1064
AgOH	aq	p	2555
AgCl		a	D-15
	c	n	1069
		s	2195
	non-aq	s	1007
$Ag(I):Cl^-$	non-aq	r	1066
$AgCl\text{-}CuCl_2$	c	b	1673
AgCl-NaCl	c	b	A-12
	liq	q	A-33
$AgCl\text{-}NaCl\text{-}PbCl_2$	non-aq	s	1694
AgCl-KCl	non-aq	p	1879
$AgCl_2^-$		p	D-22
Ag_2Cl^+		p	D-22
$AgClO_4$	c	q	2592
AgBr	c	p	2524
	non-aq	pq	1005
		s	1007
$Ag(I):Br^-$	c	r	2524
AgBr-RbBr	non-aq	p	1385
AgI	c	am	2034
		m	2585
	non-aq	pqs	1005
AgI-CuI	c	m	2585
		v	2586
AgI_2^-	non-aq	r	1327
$Ag_3I_4^-$	non-aq	r	1327
AgI/H_2	aq	s	1567
Ag_2SO_4	aq	nq	A-46
$AgSO_4^-$	non-aq	p	1203
Ag_2Se	c	p	1706
Ag_2Te	c	p	1706
$Ag_2Te\text{-}Bi_2Te_3$	c	b	1292
$AgNO_3$		bi	D-22
	c	n	1386
	aq	n	1471
$AgNO_3\text{-}(CH_3)_2SO_2$		p	2476
$AgNO_3\text{-}LiNO_3$		i	D-22
$AgNO_3\text{-}NaNO_3$		i	D-22

Substance	State	Prop.	Ref.
$AgNO_3$-KNO_3		b	D-8
		i	D-22
Ag(I):NH_2O^-	c	r	1255
Ag/Sb		s	D-23
	c	s	1010
$AgBiTe_2$	c	a	1292
$AgBiTe_2$-PbTe	c	b	1292
$AgClO_4 \cdot C_6H_8O_2$		l	C-7
		mv	B-14
	c	h	D-26
AgCN	aq	r	2549
$AgC_2N_2H_8^+$-C_2H_5OH (ethylenediamine)	aq	s	1707
$Ag(CH_3NH_2)_2$	aq	r	2356
$Ag(C_2H_5NH_2)_2$	aq	r	2356
Ag(I):$C_3N_2H_4$ (imidazole)	aq	r	1083
Ag(II):C_5NH_5 (pyridine)		nr	A-15
Ag(II):C_6NH_{15} (triethylamine)	aq	nq	A-15
$AgC_7NH_9^+$-C_2H_5OH (o-toluidine)	aq	s	1707
$AgC_7NH_9^+$-C_2H_5OH (m-toluidine)	aq	s	1707
$AgC_7NH_9^+$-C_2H_5OH (p-toluidine)	aq	s	1707
$AgCN(C_6H_7N)$ (aniline)	c	pr	1319
AgC_8NH_{11}-C_2H_5OH (2,4-xylidine)	aq	s	1707
Ag(I):$C_4N_2H_7$ (N-methylimidazole)	aq	r	1083
Ag(I):C_3NH_9O (mono-2-hydroxypropylamine)	aq	r	2555
Ag(I):$C_6NH_{15}O_2$ (di-2-hydroxypropylamine)	aq	r	2555
$AgCNO(C_6H_7N)$ (aniline)	c	pr	1319
Ag(I):$C_9NH_{21}O_3$ (tri-2-hydroxypropylamine)	aq	r	2555
Ag(I):$C_{10}NH_{11}O_4$ (aniline-N,N-diacetic acid)	aq	r	2554
Ag(I):$C_{20}N_2H_{24}O_2$ (quinine)	aq	r	1456
$(AgCNO)_2(C_6H_7N)_3$	c	pr	1319

Substance	State	Prop.	Ref.
Ag(I):CN_2SH_4-aq dioxane (thiourea)		r	2249
Ag(I):$C_3N_2SH_6$-aq dioxane (ethylenethiourea)		r	2249
$AgC_7N_2SH_7$	c	pr	1319
Ag(I):$C_{13}N_2SH_{10}$-aq dioxane (phenylenethiourea)		r	2249
Ag(I):$(C_6H_5)_2PH_{15}O_2$	aq	r	2554
Ag(I):$C_{10}AsH_{11}O_4$ ($C_6H_5As(CH_2COOH)_2$)	aq	r	2554
Ag(I):$C_{15}AsH_{15}O_2$ ($(C_6H_5)_2AsCH_2CH_2COOH$)	aq	r	2554
Ag(I):$C_{12}AsClH_{14}O_4$ (p-$ClC_6H_4As(CH_2CH_2COOH)_2$	aq	r	2554
Ag/Sn		s	D-23
Ag/Al/Pb	non-aq	b	1741
Ag/In	non-aq	s	1025
		s	1201
Ag_3InCl_6	c	b	1458
Ag/Cd	non-aq	p	1304
$AgCl \cdot CuCl_2$	c	a	1673
Ag/Cu/Al	non-aq	b	1249

38 - Gold

Substance	State	Prop.	Ref.
Au		y	B-33
	c	a	1598
		a	2334
		a	2345
		v	1313
		v	1406
		v	2243
Au-Sn	liq	q	A-37
		t	A-42
$AuCl$-$ZnCl_2$	c	r	1122
AuCl-NaCl-KCl	c	r	1122
AuBr-NaBr-KBr	c	r	1122
Au(I):CN_2SH_4 (thiourea)	aq	s	1398
$AuAl_2$	c	v	1150
$AuGa_2$	c	v	1150
$AuIn_2$	c	v	1150
Au/Cd	c	p	2527
	liq	p	2527
Au/Hg-Zn/Hg		q	A-27

Substance	State	Prop.	Ref.
Au/Hg-Hg/Cd		q	A-23
Au/Hg-Mg/Hg		q	A-23
$AuCu_3$	c	m	1548
		w	1830

39 - Nickel

Substance	State	Prop.	Ref.
Ni		k	C-31
		m	B-33
		p	C-13
	g	m	1048
Ni-Sn	liq	q	A-37
Ni-Cu	liq	q	1669
Ni-Fe		q	A-56
Ni(II)	aq	r	1215
Ni^{++}	non-aq	s	2549
NiO	c	s	1175
$NiO-Nb_2O_5$	non-aq	b	1489
$NiOH^+$	aq	r	1215
		r	2181
$Ni(OH)_2$	aq	r	1565
$Ni(OH)_2 \cdot H_2O$	c	n	1889
NiF		l	C-35
NiF_2		n	A-36
	c	km	2109
$Ni(II):Cl^-$	non-aq	r	1824
$NiCl_2$	aq	n	2557
	non-aq	s	2295
$NiCl_2-FeCl_2-H_2O$	c	p	1499
$NiCl_2-NaCl-PbCl_2$	non-aq	s	1371
$NiCl_2 \cdot 6H_2O$		v	B-25
NiS	c	v	2434
NiS_2	c	l	1768
Ni_3S_2	c	v	2434
$NiSO_4$		n	A-39
		v	B-21
	aq	h	1328
$NiSO_4 \cdot nH_2O$	c	l	1015
		l	1987
$NiSO_4 \cdot 6H_2O$	c	v	1047
$NiSO_4 \cdot 7H_2O$-aq H_2SO_4	c	q	1140
$NiSeO_3 \cdot 2H_2O$	c	nq	1140
	amorph	n	1481

Substance	State	Prop.	Ref.
$Ni(II):NO_3^-$	aq	r	2595
$Ni(NO_3)_2$	c	n	1481
$Ni(NO_3)_2 \cdot 6H_2O$	c	n	1140
		n	1889
$Ni(II):NH_2O^-$	c	r	1255
$Ni(NH_3)_6Cl_2$	c	v	1885
$Ni(NH_3)_6Br_2$	c	v	1885
$Ni(NH_3)_6I_2$	c	v	1885
$(NH_4)_2Ni(SO_4)_2 \cdot nH_2O$	c	l	1985
$Ni(II):P_2O_7^{----}$	aq	r	1104
$Ni(II):P_3O_{10}^{-----}$	aq	r	1104
		r	2266
$Ni(II):P_2H_2O_5^{--}$	aq	r	2306
$NiHP_3O_{10}$	aq	r	1379
Ni/Sb	non-aq	n	1480
$Ni(CO)_4$	g	w	1646
$Ni(II):C_2H_4O_2$ (acetic acid)	aq	r	2104
$Ni(II):C_4H_6O_6$ (tartaric acid)	aq	r	2216
$Ni(II):C_6H_8O_6$ (tricarballylic acid)	c	r	1251
$Ni(II):C_6H_8O_7$ (citric acid)	c	r	1251
$Ni(II):C_7H_6O_2$ (salicylaldehyde)	aq	r	2167
$Ni(II):C_7H_6O_3$ (salicylic acid)	aq	r	2167
$Ni(II):C_7H_8O_2$ (salicylalcohol)	aq	r	2167
$Ni(II):C_9H_{10}O_3$ (ethylsalicylate)	aq	r	2167
$NiC_{17}H_{16}O_6$-aq dioxane (2-hydroxy-2',4',4-trimethoxybenzil)		r	1725
$Ni(CN)_4^{--}$	aq	n	2492
$Ni(II):C_2N_2H_8$ (ethylenediamine)	c	r	1630
$Ni(II):C_3N_2H_4$ (imidazole)	aq	nr	A-79
		r	1083
$Ni(II):C_3N_2H_4$ (pyrazole)	aq	r	2506
$Ni(II):C_4N_2H_6$ (N-methylimidazole)	aq	r	2506

Substance	State	Prop.	Ref.
Ni(II):$C_4N_3H_{13}$ (diethylenetriamine)	c	r	1630
Ni(II):$C_5N_3H_9$ (histamine)	aq	r	2506
Ni(II):$C_6N_2H_8$ (2-picolylamine)	c	r	1630
Ni(II):$C_6N_4H_{18}$ (triethylenetetramine)	c	r	1630
Ni(II):$C_7N_2H_{10}$ (2-(2-aminoethyl)pyridine)	c	r	1630
$Ni(CN)_2 \cdot NH_3 \cdot C_6H_6$	liq	kn	2250
Ni(II):$C_8N_5H_{23}$ (tetraethylenepentamine)	aq	r	2557
$Ni(CN)_2 \cdot CH_3NH_2 \cdot C_6H_6$	liq	kn	2250
Ni(II):$C_9N_3H_{15}$ (N-aminoethyl-2-(2-aminoethyl)pyridine)	c	r	1630
$Ni(CN)_2 \cdot C_2H_5NH_2 \cdot C_6H_6$	liq	kn	2250
$NiC_{10}N_6H_{28}^{++}$ (penten)	aq	n	2558
$NiC_{10}N_6H_{29}^{+++}$ (penten H^+)	aq	n	2558
$Ni(CN)_2 \cdot C_3H_7NH_2 \cdot C_6H_6$	liq	kn	2250
$Ni(CN)_2 \cdot C_4H_9NH_2 \cdot C_6H_6$	liq	kn	2250
$Ni(CN)_2 \cdot CH_3(CH_2)_4NH_2 \cdot C_6H_5NH_2$	liq	kn	2250
Ni(II):$C_{14}N_4H_{18}$ (ethylenebis-α,α'-(2-aminoethyl)pyridine)	c	r	1630
$Ni(CN)_2 \cdot CH_3(CH_2)_4NH_2 \cdot (CH_3)_2C_6H_4$	liq	kn	2250
Ni(II):$C_2NH_5O_2$ (glycine)	aq	r	1033
Ni(II):$C_2N_4H_4O_2$ (urazine)	aq	r	1496
Ni(II):$C_3N_3H_5O_2$ (urazole)	aq	r	1496
Ni(II):$C_4NH_9O_3$ (threonine)	aq	r	1418
Ni(II):$(C_4N_2H_8O_2)_n$	aq	r	1014
$Ni(C_2NH_4O_2)_2 \cdot nH_2O$ (glycinate)	c	n	1764
Ni(II):$C_5NH_{11}O_3$ (3-hydroxyvaline)	aq	r	1418
Ni(II):$C_5NH_{11}O_3$ (3-hydroxynorvaline)	aq	r	1418
Ni(II):$C_5N_2H_6O_2$ (imidazole acetic acid)	aq	r	2506
Ni(II):$C_5N_3H_3O_6$ (5-nitroorotic acid)	c	r	1228
Ni(II):$C_5N_3H_5O_4$ (5-aminoorotic acid)	c	r	1228
$NiC_6NH_6O_6^-$ (nitrilotriacetate)	aq	n	2553
Ni(II):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2269
$Ni(C_3NH_6O_2)_2 \cdot nH_2O$ (β-alanine)	c	n	1764
$Ni(C_3NH_6O_2)_2 \cdot nH_2O$ (α-alanine)	c	n	1764
Ni(II):$C_6NH_{13}O_3$ (3-hydroxyleucine)	aq	r	1418
Ni(II):$C_6NH_{13}O_3$ (3-hydroxynorleucine)	aq	r	1418
Ni(II):$(C_6N_2H_{10}O_2)_n$	aq	r	1014
Ni(II):$C_6N_3H_9O_2$ (histidine)	aq	r	2506
Ni(II):$C_7NH_7O_2$ (salicylamide)	aq	r	2167
Ni(II):$C_7NH_{14}O_3$ (2-methyl-3-hydroxyleucine)	aq	r	1418
Ni(II):$(C_7N_2H_{12}O_2)_n$	aq	r	1014
$NiC_8NH_7O_3$-13 organic solvents (resacetophenone oxime)	p		1826
Ni(II):$C_8N_2H_{12}O$ (N-hydroxyethyl-(2-aminoethyl)pyridine)	c	r	1630
$NiC_8N_2H_{16}O_4 \cdot nH_2O$ (α-aminobutyrate)	c	n	1764
$NiC_8N_2H_{16}O_4 \cdot nH_2O$ (β-aminobutyrate)	c	n	1764
Ni(II):$C_9NH_{11}O_3$ (phenylserine)	aq	r	1418
Ni(II):$C_{10}NH_7O_2$ (1-nitroso-2-naphthol)	aq	r	2451
Ni(II):$C_{10}NH_{17}O_4$ (hexylamine-N,N-diacetic acid)	aq	r	2554
Ni(II):$C_{10}N_2H_8O_4$	aq	r	1014
Ni(II):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
$[Ni(C_5N_2H_{12}O)_2-H]^+$ (2-amino-2-methyl-3-butanone oxime)	aq	n	1904
$[Ni(C_6N_2H_{14}O)_2-H]^+$ (2-methylamino-2-methyl-3-butanone oxime)	aq	n	1904

Substance	State	Prop.	Ref.
Ni(II):$C_{13}NH_{11}O_2$ (salicylanilide)	aq	r	2167
Ni(II):$C_{13}N_4H_{12}O$ (diphenylcarbazone)	non-aq	r	2593
Ni(II):$C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
Ni(II):$C_{14}N_3H_{14}O_2$ (3-hydroxy-3-phenyl-1-(p-acetylphenyl)-triazene)	aq	r	1840
$[Ni(C_7N_4H_{16}O)_2-H]^+$ (2-ethylamino-2-methyl-3-butanone oxime)	aq	n	1904
Ni(II):$(C_{10}N_2H_{16}O_8)(C_6NH_9O_3)$ (ethylenediaminetetracetic acid)(nitrilotriacetic acid)	c	r	1802
$[Ni(C_8N_2H_{18}O)_2-H]^+$ (2-n-propylamino-2-methyl-3-butanone oxime)	aq	n	1904
Ni(II):$C_{18}N_4H_{30}O_{12}$ (triethylenetetraminehexaacetic acid)	aq	r	2218
$[N(CH_3)_4]_2NiCl_4-H_2O$	c	nq	1093
Ni(II):$C_{12}N_3ClH_{10}$ (3-hydroxy-3-(p-chlorophenyl)-1-phenyltriazene)	aq	r	1839
$[N(C_2H_5)_4]_2NiCl_4-H_2O$	c	nq	1093
$NiCl_2 \cdot 2Cl_6H_5O_2N-H_2O$	c	p	2361
Ni(II):$C_{12}N_3ClH_{10}O$ (3-hydroxy-3-phenyl-1-o-chlorophenyltriazene)	c	r	1975
$NiCl_2 \cdot 2C_6H_6ON_2-H_2O$	c	p	2361
$NiC_{16}N_2Br_4H_{40}$		q	A-15
Ni(II):$C_5N_2BrH_3O_4$ (5-bromobrotic acid)	c	r	1228
$NiBr_2 \cdot 2C_6H_5O_2N-H_2O$	c	p	2361
$NiBr_2 \cdot 2C_6H_6ON_2-H_2O$	c	p	2361
$NiBr_2 \cdot 4C_6H_6ON_2-H_2O$	c	p	2361
Ni(II):$C_5N_2IH_3O_4$ (5-iodobrotic acid)	c	r	1228
$NiI_2 \cdot 2C_6H_5O_2N-H_2O$	c	p	2361
$NiI_2 \cdot 2C_6H_6ON_2-H_2O$	c	p	2361
Ni(II):SCN^-	aq	r	1748
$Ni(CNS)_2$	aq	r	1389
Ni(II):$C_5N_5SH_5$ aq dioxane (2-amino-6-mercaptopurine)		r	2163
Ni(II):$C_9N_3SH_8$ (o-(2-thiazolylazo)-phenol)	aq	r	2134
Ni(II):$C_{13}N_4SH_{12}$ (dithizone)	non-aq	r	2593
Ni(II):$C_{15}N_4SH_{16}$ (di-o-tolylthiacarbazone)	non-aq	r	2593
Ni(II):$C_{15}N_4SH_{16}$ (di-p-tolylthiacarbazone)	non-aq	r	2593
Ni(II):$C_{17}N_4SH_{20}$ (di-m-xylylthiacarbazone)	non-aq	r	2593
Ni(II):$C_{21}N_4SH_{16}$ (di-1-naphthylthiacarbazone)	non-aq	r	2593
Ni(II):$C_{21}N_4SH_{16}$ (di-2-naphthylthiacarbazone)	non-aq	r	2593
Ni(II):$C_{12}N_3SH_{11}O_4$ (3-hydroxy-3-phenyl-1-(p-sulfophenyl)-triazene)	aq	r	2121
Ni(II):$C_6H_5As(CH_2COOH)_2$	aq	r	2554
$NiC_{38}As_2Cl_4H_{36}$	aq	q	1046
Ni(II):subst. ethylenediamines		nr	A-15
Ni/Si		q	A-56
	non-aq	n	1480
		q	2437
Ni_2SiO_4	c	a	2430
Ni/Al		q	A-56
	non-aq	n	1480
Ni/Zn	non-aq	n	1480
Ni/Cd	non-aq	b	1297
		n	1381
Ni/Hg		b	D-45
Ni/Cu	non-aq	n	1480
Ni/Cu/S	non-aq	b	1269
Ni/Ag/Al		bp	D-10
Ni/Au	non-aq	s	1284

40 - Cobalt

Substance	State	Prop.	Ref.
Co		m	B-33
	c	m	1861
Co-Ni		q	A-56
Co-Fe		q	A-56
Co(III)	aq	ns	2101
CoO	c	b	2511
CoO-MnO	c	p	1271
CoO-FeO	c	p	1271
$CoO-Nb_2O_5$	non-aq	b	1489

Substance	State	Prop.	Ref.
$CoO-MgO$	c	p	1271
$CoO_3-Mn_3O_4$	non-aq	b	1333
$Co(OH)_2$	aq	r	1565
CoF_2		s	D-44
$CoCl_2$	aq	n	2557
		qv	1167
	non-aq	s	2294
$CoCl_2-H_2O$	c	q	1093
$CoCl_2 \cdot 2H_2O$	c	v	2395
		v	2435
$CoCl_2 \cdot 6H_2O$		v	B-25
$CoBr_2$	c	v	2075
		v	2501
CoS_2	c	l	1768
Co_2S_3	c	n	1534
Co_3S_4	c	l	1768
$CoSO_4$		n	A-39
		v	B-21
	aq	h	1328
$CoSO_4-H_2O$		l	C-9
$CoSO_4 \cdot nH_2O$	c	l	1986
$CoSO_4 \cdot 6H_2O$		q	A-40
		v	B-23
$CoSO_4 \cdot 7H_2O$		q	A-40
		v	B-23
Co/Se	non-aq	l	1239
$CoSe \cdot 2H_2O$	c	n	1481
$CoSeO_3 \cdot 2H_2O$	c	n	2131
$CoNO_3$	aq	a	1468
$CoNO_3 \cdot nH_2O$	c	a	1468
$Co(NO_3)_2$	c	n	1481
	aq	n	2131
$Co(II):NH_2O^-$	c	r	1255
$Co(NH_3)_4(OH_2)N_3^{++}$		r	1607
$Co(NH_3)_4Cl \cdot H_2O^{++}$	aq	r	1686
$[Co(NH_3)_5Cl](ClO_4)_2$	aq	p	1023
$[Co(NH_3)_5NO_2]Cl_2$	aq	p	1023
$[Co(NH_3)_5F]Cl_2$	aq	p	1023
$(NH_4)_2Co(SO_4)_2 \cdot nH_2O$	c	l	1985
$Co(II):P_2O_7^{----}$	aq	r	1104
$Co(II):P_3O_{10}^{-----}$	aq	r	1104
		r	2266

Substance	State	Prop.	Ref.
$Co(III):P_2H_2O_5^{--}$	aq	r	2306
$CoHP_3O_{10}$	aq	r	1379
Co/Bi		b	D-45
CoC	c	ak	1458
$Co(II):C_2H_4O_2$ (acetic acid)	aq	r	2104
$Co(II):C_4H_6O_6$ (tartaric acid)	aq	r	2216
$Co(II):C_6H_8O_6$ (tricarballylic acid)	c	r	1251
$Co(II):C_6H_8O_7$ (citric acid)	c	r	1251
$Co(CH_2COCH_2COCH_3)_3$ (acetylacetonate)	c	kmn	2188
	aq	p	1084
$Co(II):C_{17}H_{16}O_6$ aq dioxane (2-hydroxy-2',4',4-trimethoxybenzil)		r	1725
$Co(II):C_2N_2H_8$ (ethylenediamine)	c	r	1630
$Co(II):C_3N_2H_4$ (imidazole)	aq	nr	A-79
$Co(II):C_3N_2H_4$ (pyrazole)	aq	r	2506
$Co(II):C_4N_2H_6$ (N-methylimidazole)	aq	r	2506
$Co(II):C_4N_3H_{13}$ (diethylenetriamine)	c	r	1630
	aq	r	1724
$Co(II):C_5N_3H_9$ (histamine)	aq	r	2506
$Co(II):C_6N_2H_8$ (2-picolylamine)	c	r	1630
$Co(II):C_6N_4H_{18}$ (triethylenetetramine)	c	r	1630
$Co(III):C_6N_4H_{18} \cdot 2H_2O$ (triethylentetramine)	aq	r	1686
$Co(II):C_8N_5H_{23}$ (tetraethylenepentamine)	aq	r	2557
$Co(II):C_9N_3H_{15}$ (N-aminoethyl-2-(2-aminoethyl)-pyridine)	c	r	1630
$CoC_{10}N_6H_{28}^{++}$ (penten)	aq	n	2558
$CoC_{10}N_6H_{29}^{+++}$ (penten H^+)	aq	n	2558
$Co(II):C_{14}N_4H_{18}$ (ethylenebis-α,α'-(2-aminoethyl)-pyridine)	c	r	1630
$Co(II):C_2NH_5O_2$ (glycine)	aq	r	1033

Substance	State	Prop.	Ref.
$Co(II):C_2N_4H_4O_2$ (urazine)	aq	r	1496
$Co(II):C_3NH_7O_3$ (serine)	aq	r	2374
$Co(II):C_3N_3H_5O_2$ (urazole)	aq	r	1496
$Co(II):C_4NH_9O$ (threonine)	aq	r	1418
$Co(C_2NH_4O_2)_2 \cdot nH_2O$ (glycinate)	c	n	1764
$Co(II):C_5NH_{11}O_3$ (3-hydroxyvaline)	aq	r	1418
$Co(II):C_5NH_{11}O_3$ (3-hydroxynorvaline)	aq	r	1418
$Co(II):C_5N_2H_6O_2$ (imidazole acetic acid)	aq	r	2506
$Co(CN)_5OH_2^{---}$	aq	n	1088
$CoC_6NH_6O_6^-$ (nitrilotriacetate)	aq	n	2553
$Co(II):C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2269
$Co(II):C_6NH_{13}O_3$ (3-hydroxyleucine)	aq	r	1418
$Co(II):C_6NH_{13}O_3$ (3-hydroxynorleucine)	aq	r	1418
$Co(C_3NH_6O_2)_2 \cdot nH_2O$ (α-alanine)	c	n	1764
$Co(C_3NH_6O_2)_2 \cdot nH_2O$ (β-alanine)	c	n	1764
$Co(II):C_6N_3H_9O_2$ (histidine)	aq	r	2506
$Co(II):C_7NH_{11}O_5$ (aminoacetone-N,N-diacetic acid)	aq	r	1334
$Co(II):C_7NH_{14}O_3$ (2-methyl-3-hydroxyleucine)	aq	r	1418
$Co(II):C_8N_2H_{12}O$ (N-hydroxyethyl-(2-aminoethyl)-pyridine)	c	r	1630
$Co(C_4NH_8O_2)_2 \cdot nH_2O$ (n-aminobutyrate)	c	n	1764
$Co(C_4NH_8O_2)_2 \cdot nH_2O$ (β-aminobutyrate)	c	n	1764
$Co(II):C_9NH_{11}O_3$ (phenylserine)	aq	r	1418
$Co(II):C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
$Co(C_7NH_6O_6) \cdot 4H_2O-H_2O$ (p-aminosalicylate)	c	p	1813
$Co(II):C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N'-tetraacetic acid)	c	nr	1635
$Co(II):(C_{10}N_2H_{16}O_8)(C_6NH_9O_3)$ (ethylenediaminetetracetic acid)(nitrilotriacetic acid)	c	r	1802
$Co(C_9NH_6O)_2-H_2O$ (8-quinolinolo)	c	p	1417
$Co(II):C_{18}N_4H_{30}O_{12}$ (triethylenetetraminehexaacetic acid)	aq	r	2218
$Co(C_9NH_7)_2(NCO)_2$ (iso-quinoline)	non-aq	r	2562
$Co(C_9NH_6O)_3$ (8-hydroxyquinolinato)	c	n	1432
$Co_2(II):C_8N_6H_2O_2$ (peroxodiethylenetriamine)	aq	r	1724
$Co(II):(C_2NH_8)_2Cl \cdot H_2O$ (ethylenediamine)	aq	r	1686
$Co(II):C_6N_4H_{18}Cl \cdot H_2O$ (triethylenetetramine)	aq	r	1686
$[N(CH_3)_4]_2CoCl_4-H_2O$	c	nq	1093
$CoCl_2 \cdot (C_5NH_5)_2$ (pyridine)	c	mv am	B-14 2123
$[N(C_2H_5)_4]_2CoCl_4-H_2O$	c	nq	1093
$Co(C_9NH_7)_2Cl_2$ (iso-quinoline)	non-aq	r	2562
$Co[NH_2(CH_2)_2NH_2]_3(ClO_4)_3$	c	n	1534
$CoC_{16}N_2Br_4H_{40}$		q	A-15
$Co(C_9NH_7)_2Br_2$ (iso-quinoline)	non-aq	r	2562
$Co(II):C_5N_2BrH_3O_4$ (5-bromoörotic acid)	c	r	1228
$Co(C_9NBr_2H_4O)_3$ (5,7-dibromo-8-hydroxyquinolinato)	c	n	1432
$Co(C_9NH_7)_2I_2$ (iso-quinoline)	non-aq	r	2562
$Co(II):C_5N_2IH_3O_4$ (5-iodoörotic acid)	c	r	1228
$Co(II):CNS^-$	aq	r	2096
$Co(II):C_5N_5SH_5$ aq dioxane (2-amino-6-mercaptopurine)		r	2163
$Co(II):C_9N_3SH_8$ (o-(2-thiozolylazo)-phenol)	aq	r	2134

Substance	State	Prop.	Ref.
$Co(C_9NH_7)_2(NCS)_2$ (iso-quinoline)	non-aq	r	2562
$CoC_{38}As_2Cl_4H_{36}$	aq	q	1046
CoSi	c	tv	2055
Co/Si	non-aq	q	2437
Co/Al/Ag		bp	D-10
Co/Hg		b	D-45

41 - Iron

Substance	State	Prop.	Ref.
Fe		m	B-33
		y	B-27
	c	a	1298
		k	1091
		km	2589
Fe-Si		s	D-76
Fe-FeO	c	p	1552
Fe-Mn		p	C-21
Fe-V	c	p	1091
Fe ores	c	v	1336
Fe/O	c	l	1482
		n	1374
		s	1349
		s	1944
FeO	liq	km	2348
$FeO-Fe_2O_3-Cr_2O_3$	non-aq	b	1510
FeO-MgO	non-aq	s	1556
FeO_2^-	c	v	1825
Fe_2O_3	c	a	1700
		a	2346
$Fe_2O_3-Al_2O_3$	c	v	1659
$Fe_2O_3-FeO-Cr_2O_3$	non-aq	b	1510
$Fe_2O_3-FeTiO_3$	non-aq	b	1490
$Fe_2O_3-Mn_3O_4$	c	b	1709
$Fe_2O_3-Nb_2O_5$	non-aq	b	1489
$Fe_2O_3-MgO-Cr_2O_3$	c	b	2238
$Fe_2O_3 \cdot H_2O$	c	l	2580
		n	2211
Fe_3O_4		mv	B-34
	c	s	1175
Fe_3O_4-FeO	c	p	1552
$FeOH^+$	aq	p	1708
$FeOH^{++}$	aq	p	2513
$Fe(OH)_2$	c	p	1451
$Fe(OH)_3$	c	y	1876
$Fe(OH)_3-H_2O$	c	p	2482
Fe_4Xe	g	n	1682
Fe_6Xe	g	n	1682
FeF		l	C-35
FeF_3		l	C-35
$Fe(III):Cl^-$	aq	r	2491
$FeCl_2$		ps	A-22
		mv	B-34
	c	m	2282
		v	2338
	aq	n	2557
	non-aq	s	1712
$FeCl_2-HCl-H_2O$	c	p	2507
$FeCl_2$-alkyl chloride	liq	ps	A-22
$FeCl_2-NiCl_2-H_2O$	c	p	1499
$FeCl_2-MnCl_2-H_2O$	c	p	1421
$FeCl_3$	c	l	2499
		p	2482
$FeCl_3-HCl-H_2O$	c	p	2507
Fe_2Cl_6	g	r	2499
$FeBr_2$		mv	B-34
$FeBr_3$	c	l	2499
FeI_2	g	r	C-34
FeS	c	l	2550
		v	1301
FeS-HCl	c	nq	2126
FeS_2		v	B-34
	c	l	1599
$FeSO_4$	c	p	2482
	aq	h	1328
$Fe(III):SO_4^{--}$	aq	r	1623
$FeSO_4 \cdot nH_2O$	c	l	1986
$Fe(OH)SO_4$	c	p	2482
FeSe	c	p	1706
Fe/N	non-aq	p	1484
$Fe(NO_3)_3$	aq	v	A-79
$(NH_4)_2Fe(SO_4)_2 \cdot nH_2O$	c	l	1985
$FePO_4 \cdot 2H_2O-HNO_3$	c	p	1746
$Fe(III):H_2PO_2^-$	aq	r	1620

Substance	State	Prop.	Ref.
Fe/P/S	non-aq	b	1234
FeAsS	c	l	2058
Fe_3C	c	mt	2315
$Fe(CO)_5$	g	w	1646
Fe(III):$C_2H_2O_4$ (oxalic acid)	aq	r	1711
$Fe(HCOO)_2 \cdot 2H_2O$		v	B-25
Fe(III):$C_2H_4O_2$-aq CH_3COOH (acetic acid)		r	1415
Fe(III):$C_3H_4O_4$ (malonic acid)	aq	r	1711
Fe(III):$C_3H_6O_3$ (lactic acid)	aq	r	2530
Fe(III):$C_4H_6O_4$ (succinic acid)	aq	r	1698
Fe(II):$C_4H_6O_5$ (malic acid)	aq	r	2556
Fe(III):$C_4H_6O_5$ (malic acid)	aq	r r	2359 2556
Fe(II):$C_4H_6O_6$ (tartaric acid)	c	r	1426
Fe(III):$C_4H_6O_6$ (tartaric acid)	c	r	1426
Fe(III):$C_5H_8O_7$ (trihydroxyglutaric acid)	aq	r	2359
Fe(II):$C_6H_8O_7$ (citric acid)	aq	r	2556
Fe(III):$C_6H_8O_7$ (citric acid)	aq	r r	1697 2556
Fe(III):$C_6H_{12}O_6$ (fructose)	aq	r	2059
Fe(III):$C_6H_{12}O_7$ (gluconic acid)	aq	r	2359
Fe(III):$C_7H_6O_3$ (salicylic acid)	aq	r	1582
Fe(III):$C_7H_6O_4$ (resorcylic acid)	aq	r	2455
Fe(III):$C_8H_8O_3$ (2-hydroxy-3-methylbenzoic acid)	aq	r	1030
$Fe(C_5H_7O_2)_3$ (acetylacetonate)	c	kmn mn	2188 1780
$Fe(C_6H_{10}O_2)_3$ (propionylacetone)	c	mn	1780
$Fe(C_9H_8O_2)_3$ (benzoylacetaldehyde)	c	mn	1780
$Fe(C_{10}H_{10}O_2)_3$ (benzoylacetone)	c	mn	1780
$Fe(C_{11}H_{12}O_2)_3$ (propionylacetophenone)	c	mn	1780
$Fe(C_{12}H_{14}O_2)_3$ (butyrylacetophenone)	c	mn	1780
$Fe(C_{15}H_{12}O_2)_3$ (dibenzoylmethane)	c	mn	1780
Fe_2(III):$C_4H_6O_6$ (tartaric acid)	c	r	1426
Fe_3(III):$C_4H_6O_6$ (tartaric acid)	c	r	1426
Fe_3(III):$(OH)_2C_2H_4O_2$ (acetic acid)	c	r	1426
Fe(III):$C_7ClH_5O_3$ (2-hydroxy-5-chlorobenzoic acid)	aq	r	1030
Fe(III):$C_7BrH_5O_3$ (2-hydroxy-5-bromobenzoic acid)	aq	r	1030
Fe/C/S	non-aq	b	1234
Fe(III):$C_7SH_6O_6$ (sulfosalicylic acid)	aq	r	1582
Fe(III):CN^-	aq	r	2225
$Fe(CN)_6^{---}$	aq	n	1088
$Fe(CN)_6^{----}$	aq	n	1088
$3FeCl_3 \cdot 2C_6NH_5$-C_6H_6 (triethylamine)	non-aq	r	2579
$[Fe(CN)_6]_4^{----}$	aq	v	1825
Fe(III):$C_6N_4H_{18}$ (triethylenetetramine)	aq	r	2225
Fe(II):$C_8N_5H_{23}$ (tetraethylenepentamine)	aq	r	2557
$FeC_{10}N_6H_{28}^{++}$ (penten)	aq	n	2558
Fe(II):$C_{12}N_2H_8$ (o-phenanthrolene)	c	r	1782
Fe(III):$C_{12}N_2H_8$ (o-phenanthrolene)	c	r	1782
Fe(III):$C_{12}N_2H_{12}$ (4,4'-dimethyl-2,2'-bipyridine)	c	r	1627
Fe(III):$C_{14}N_2H_{12}$ (4,7-dimethyl-1,10-phenanthroline)	c	r	1627
Fe(III):$C_{14}N_2H_{12}$ (5,6-dimethyl-1,10-phenanthroline)	c	r	1627
Fe(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1426

Substance	State	Prop.	Ref.
Fe(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2532
Fe(III):$(OH^-)_2(C_6NH_{13}O_4)$ (N,N-bis(hydroxyethyl)glycine)	aq	r	1557
Fe(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1426
Fe(III):$C_7NH_5O_5$ (2-hydroxy-3-nitrobenzoic acid)	aq	r	1030
Fe(III):$C_7NH_5O_5$ (2-hydroxy-5-nitrobenzoic acid)	aq	r	1030
Fe(III):$C_{10}N_2H_{19}O_7$ (N-hydroxyethylethylenediamine-N,N',N'-triacetic acid)	aq	r	2120
Fe(III):$C_{12}N_2H_{20}O_{11}$ (glycoletherdiaminetetraacetic acid)	aq	r	2120
Fe(III):$C_{14}N_2H_{22}O_8$ (1,2-cyclohexanediaminetetraacetic acid)	aq	r	2120
Fe(III):$C_{14}N_3H_{23}O_{10}$ (diethylenetriaminepentaacetic acid)	aq	r	2120
Fe(III):$(C_{10}N_2H_{16}O_8)(C_6NH_9O_3)$ (ethylenediaminetetracetic acid)(nitrilotriacetic acid)	c	r	1802
$(CH_3)_4NFeCl_4$-C_6H_6	non-aq	r	2579
$[N(CH_3)_4]_2FeCl_4$-H_2O	c	nq	1093
$[N(C_2H_5)_4]_2FeCl_4$-H_2O	c	nq	1093
$3FeCl_3 \cdot 2C_3H_9N$-C_6H_6 (n-propylamine)	non-aq	r	2579
$3FeCl_3 \cdot 2C_4NH_{11}$-$C_6H_6$ (diethylamine)	non-aq	r	2579
$3FeCl_3 \cdot 2C_5H_5N$-C_6H_6 (pyridine)	non-aq	r	2579
$3FeCl_3 \cdot 2C_5H_{11}N$-$C_6H_6$ (piperidine)	non-aq	r	2579
Fe(III):$C_9NH_7O \cdot xHCl$ (p-hydroxyquinoline)	c	l	1431
$FeC_{16}N_2Br_4H_{40}$		q	A-15
$Fe(C_9NH_6O)_3 \cdot xHBr$ (8-hydroxyquinoline)	c	l	1431
Fe(III):CNS^-	aq	r	2096
Fe(III):SCN^-	aq	r	2122
Fe(II):$C_9N_3SH_8$ (o-(2-thiazolylazo)-phenol)	aq	r	2134
Fe(III):$C_{10}NS_2H_9O_7$ (1-amino-8-naphthol-3,6-disulfonic acid)	c	r	1640

Substance	State	Prop.	Ref.
$FeC_{38}As_2Cl_4H_{36}$	aq	q	1046
$Bi_4[Fe(CN)_6]_3$-H_2O	c	p	1206
$Bi_4[Fe(CN)_6]_3$-dil HNO_3	c	p	1206
$Bi_4[Fe(CN)_6]_3$-aq C_2H_5OH	c	p	1206
$Bi_4[Fe(CN)_6]_3$-$(CH_3)_2CO$	c	p	1206
Fe(III):dextran	aq	r	2450
Fe(III):38 phenols	aq	r	2144
Fe/Si		q	A-56
FeSi		s	D-76
	c	mtv	1202
		t	2199
		tv	2292
Fe/Si	c	v	2441
	liq	p	D-41
	non-aq	q	2437
$FeSi_2$		s	D-76
	c	tv	2292
	non-aq	v	1344
Fe_3Si		s	D-76
	c	mt	2199
		tv	2292
	liq	t	2199
Fe_5Si_3	c	mtv	1202
		t	2199
		tv	2292
$FeSiO_3$	c	r	1858
Fe_2SiO-20% HF	c	q	1171
Fe_2SiO_4	non-aq	s	1918
$Fe_2Si_2O_5$	c	v	1809
Fe/Si/S	non-aq	b	1234
$(Sb_{0.93},Fe_{0.07})Fe_2[(SiO_4)_2(OH)]$	c	a	1537
Fe/Ge	c	v	2441
Fe/Sn	c	v	2441
Fe/Sn/S	non-aq	b	1515
Fe/Pb/S	non-aq	b	1543
Fe/Pb/Bi		b	D-45
$FePb_2C_6N_6$	non-aq	s	2186
Fe/Al		q	A-56
FeAl	c	n	1279
Fe/Al	c	v	2022
	non-aq	p	1232
$FeAl_2O_4$	c	r	2066

Substance	State	Prop.	Ref.
Fe/Zn/S		t	B-21
$FeZn_2C_6N_6$	non-aq	s	2186
$FeCd_2C_6N_6$	non-aq	s	2186
Fe/Hg		b	D-45
$FeCuO_2$	c	amt	2316
Fe_2CuO_4	c	l	2316
$FeCuS_2$	c	w	1865
$FeCu_5S_4$	c	a	1377
$FeAg_4C_6N_6$	non-aq	s	2186
Fe/Ag/Al		bp	D-10
Fe/Ni	non-aq	v	1299
$FeNi_3$	c	w	1830
Fe/Ni/S	non-aq	b	1268
		b	1544
Fe/Ni/As	non-aq	b	1491
Fe/Ni/C		bs	D-10
Fe/Co/C		bs	D-10
Fe/Co/Al	c	v	2142
Fe garnets		v	B-26

42 - Palladium

Substance	State	Prop.	Ref.
Pd		lm	C-24
	c	km	1945
		v	2339
$Pd-H_2$		y	D-13
$Pd-D_2$		y	D-13
Pd-As	c	b	1103
Pd-Sn	liq	q	A-37
Pd(II)	aq	s	1497
PdO	c	l	C-24
PdO-RhO	non-aq	b	1626
$Pd(II):Cl^-$	c	rs	2067
	aq	r	2150
		r	2504
$PdCl_4^{--}$		s	1497
$Pd(II):Br^-$	c	p	1791
$PdBr_4^{--}$		s	1497
PdI_2	c	l	2387
PdI_4^{--}		s	1497
$[Pd(NH_3)_4]Cl_2$		v	B-43
$[Pd(NH_3)_4]Cl_2 \cdot H_2O$		v	B-43
$PdC_2Cl_3H_4^-$	aq	r	1894
$Pd(II):C_{14}N_3H_{13}O_2$-aq dioxane (3-hydroxy-3-phenyl-1-(p-acetylphenyl)triazene)		r	1840
$Pd(II):C_{12}N_3ClH_{10}O$-aq dioxane (3-hydroxy-3-(p-chlorophenyl)-1-phenyltriazene)		r	1839
$Pd(II):C_{12}N_3ClH_{10}O$ (3-hydroxy-3-phenyl-1-o-chlorophenyltriazene)	c	r	1975
$PdCNS^{--}$	aq	p	2011
$Pd(SCN)_4^{--}$		s	1497
$Pd(II):C_{12}N_2SH_9O_5$ (p-benzylsulfonic acid azoresorcein)	c	r	1638
$Pd(II):C_{12}N_3SH_{11}O_4$ (3-hydroxy-3-phenyl-1-(p-sulfophenyl)-triazene)	aq	r	2121
$PdCNSI_2^-$	aq	p	2011
Pd/Au		t	A-37
PdNi	non-aq	v	1341
Pd/Fe	c	v	2339
	non-aq	b	1287

43 - Rhodium

Substance	State	Prop.	Ref.
Rh	c	km	2472
RhO-PdO	non-aq	b	1626
RhO-PtO	non-aq	b	1626
Rh_2O_3	c	l	C-24
		l	1626
$RhCl_6^{--}$	c	r	1627
Rh/C	non-aq	p	1208

44 - Ruthenium

Substance	State	Prop.	Ref.
Ru	c	k	1989
		km	2472
	non-aq	s	2258
RuO_4	c	n	1017
	liq	n	1017
	aq	p	2386
RuF_5	c	n	A-36
$RuCl_3$	c	mn	2358
$RuCl_4$	g	ln	2358
$Ru(III):(NH_3)_5H_2O$	aq	r	1628
$Ru(III):(NH_3)_5Cl^-$	aq	r	1628
$RuNOCl_3(H_2O)_2$	c	r	1845
$RuNOCl_4(H_2O)^-$	c	r	1845
$Ru(III):C_{12}N_2H_8$ (1,10-phenanthroline)	c	r	1627

Substance	State	Prop.	Ref.
Ru(III):$C_{10}NH_7O_2$ (1-nitroso-2-naphthol)	aq	r	1730
Ru(III):$C_{10}NH_7O_2$ (2-nitroso-1-naphthol)	aq	r	1730
Ru(III):$(C_6H_6O_7)(C_{10}NH_7O_2)$ (citric acid, 2-nitroso-1-naphthol)	aq	r	1730
Ru(III):$(C_6H_6O_7)(C_{10}NH_7O_2)$ (citric acid, 1-nitroso-2-naphthol)	aq	r	1730

45 - Platinum

Substance	State	Prop.	Ref.
Pt	c	a	1787
		k	2413
Pt-Bi		b	D-45
Pt^{++}	non-aq	s	2549
PtO-RhO	non-aq	b	1626
PtF_6		mv	B-34
$PtCl_4^{--}$	aq	v	1825
		r	2093
$PtCl_6^{--}$	aq	v	1825
		s	2357
PtI_3	c	l	2388
PtI_4	c	l	2388
$Pt(NH_3)_2H_2O^{++}$	aq	r	2350
$Pt(NH_3)Cl_3^-$	aq	r	2093
$(NH_2)(PtCl_4)$		nq	A-75
$Pt(NH_3)_2Cl_2$	aq	r	2093
cis-$[Pt(NH_3)_2Cl_3]Cl$		v	B-43
cis,trans-$[Pt(NH_3)_2Cl_4]$		v	B-43
$Pt(NH_3)_3Cl^+$	aq	r	2093
trans-$[Pt(NH_3)_3Cl_3]$		v	B-43
cis, trans-$[Pt(NH_3)_4Cl_2]Cl_2$		v	B-43
cis-$[Pt(NH_3)_5Cl]Cl_3$		v	B-43
$[Pt(NH_3)_6]Cl_4$		v	B-43
$(NH_4)_2PtBr_6$	c	a	1942
$Pt(NH_3)_2BrH_2O^+$	c	r	1992
$[Pt(NH_3)_3Cl]Br$		nq	A-75
$(CH_3)_3PtI$		n	A-77
$Pt(NH_3)_2(CN)_3^+$	aq	p	2375
$Pt(CH_3NH_2)_2(CN)_3^+$	aq	p	2375
$Pt(NH_3)_2(CN)_2NO_2NO_3$	aq	p	2375
$Pt(CH_3NH_2)_2Cl_2$	aq	r	1822
$Pt(C_2H_5NH_2)_2Cl_2$	aq	r	1822
$(p\text{-}ClC_6H_4N_2)_2PtCl_6\text{-}HCl$	c	p	1163
$(p\text{-}HOC_6H_4N_2)_2PtCl_6\text{-}HCl$	c	p	1163
$(p\text{-}O_2NC_6H_4N_2)_2PtCl_6\text{-}HCl$	c	p	1163
$(p\text{-}CH_3OC_6H_4N_2)_2PtCl_6\text{-}HCl$	c	p	1163
$(\beta\text{-}C_{10}H_7N_2)_2PtBr_6\text{-}HBr$	c	p	1163
$(p\text{-}O_2NC_6H_4N_2)_2PtBr_6\cdot HBr$	c	p	1163
$(p\text{-}CH_3OC_6H_4N_2)_2PtBr_6\text{-}HBr$	c	p	1163
$(p\text{-}ClC_6H_4N_2)_2PtBr_6\text{-}HBr$	c	p	1163
PtAl	c	a	1787
Pt/Al	non-aq	b	1787
Pt_2Al_3	c	a	1787
Pt_3Al	c	a	1787
Pt_5Al_3	c	a	1787
Pt/Cu		p	C-13
Pt/Au		v	B-7
Pt/Ni		p	C-13
Pt/Co/O	non-aq	l	2021
Pt/Rh	c	tv	2265

46 - Iridium

Substance	State	Prop.	Ref.
Ir	c	km	2472
Ir/Bi		b	D-45
IrO_2	c	l	C-24
IrF_6		mv	B-34
	c	v	2399
$IrCl_6^{--}$	c	r	1627
$IrCl_6^{---}$	aq	s	1618
IrO_2Cl	g	p	C-24
$IrBr_6^{--}$	c	r	1627
Ir/C	c	km	2472
Ir/Pt		v	B-7

47 - Osmium

Substance	State	Prop.	Ref.
Os	c	k	1989
OsF_6		mv	B-34
	c	v	2399
$OsCl_3$	c	l	1011
		l	1624
$OsCl_4$	c	l	1011
Os/Bi		b	D-45
Os/Ir	non-aq	b	1742

Substance	State	Prop.	Ref.
Manganese - 48			
Mn		m	B-33
Mg-Fe-C-Si		p	D-61
Mn-Ag	liq	p	D-61
Mn-Fe		p	C-21
Mn-Mn/Fe/Ni	non-aq	l	1608
MnO	c	r	1614
MnO_2	c	a	1312
MnO_4^-	aq	r	1825
Mn_2O_3	c	l	1207
Mn_3O_4-Co_2O_3	non-aq	b	1333
Mn_3O_4-Fe_2O_3	c	b	1709
$MnOH^{++}$	aq	r	1970
$Mn(OH)_2$-H_2O	c	p	2482
MnF		l	C-35
	g	l	2110
MnF^{++}	aq	r	1970
MnF_2	c	km	2110
$MnCl_2$		vy	B-23
		vy	D-50
	c	v	1106
	aq	n	2557
$MnCl_2$-H_2O	c	q	1093
$MnCl_2$-$FeCl_2$-H_2O	c	p	1421
$MnCl_3^-$	non-aq	s	1402
$MnBr_2 \cdot 4H_2O$		v	B-25
MnS-HCl	c	nq	2126
$MnSO_4$	aq	h	1328
$MnSO_4$-H_2O		l	C-9
Mn/N	non-aq	p	1484
Mn(II):NH_2O^-	c	r	1255
$MnCl_2 \cdot 2NH_3$	c	l	2347
$MnCl_2 \cdot 6NH_3$	c	l	2347
$(NH_4)_2Mn(SO_4)_2 \cdot nH_2O$	c	l	1985
Mn(II):$P_3O_{10}^{-----}$	aq	r	2266
Mn/Bi		b	D-45
Mn_7C_3		np	D-61
$Mn(CHO_2)_2 \cdot nH_2O$ (formate)	c	q	1957
$Mn(CHO_2)_2 \cdot 2H_2O$ (formate)		v	B-25

Substance	State	Prop.	Ref.
Mn(II):$C_2H_4O_2$ (acetic acid)	aq	r	2104
$Mn(C_2H_3O_2)_2$ (acetate)		v	B-25
$MnC_{15}H_{21}O_6$ (trisacetylacetonate)	c	kmn	2188
Mn(II):$C_{17}H_{16}O_6$-aq dioxane (2-hydroxy-2',4',4-trimethoxybenzil)		r	1725
Mn(II):$C_2ClH_3O_2$ (chloroacetic acid)	aq	r	1157
$Mn(CN)_6^{----}$	aq	n	1088
Mn(II):$C_6N_4H_{18}$ (triethylenetetramine)	c	r	1630
Mn(II):$C_8N_5H_{23}$ (tetraethylenepentamine)	aq	r	2557
$MnC_{10}N_6H_{28}^{++}$ (penten)	aq	n	2558
Mn(II):$C_{14}N_4H_{18}$ (ethylenebis-α,α'-(2-aminoethyl)pyridine)	c	r	1630
Mn(II):$C_2NH_5O_2$ (glycine)	aq	r	1033
Mn(II):$C_5N_3H_3O_6$ (5-nitroorotic acid)	c	r	1228
$MnC_6NH_6O_6^-$ (nitrilotriacetate)	aq	n	2553
Mn(II):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2269
Mn(II):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
Mn(II):$C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
Mn(II):$C_{14}N_3H_{13}O_2$-aq dioxane (3-hydroxy-3-phenyl-1-(p-acetylphenyl)triazene)		r	1840
Mn(II):$(C_{10}N_2H_{16}O_8)(C_6NH_9O_3)$ (ethylenediaminetetracetic acid)(nitrilotriacetic acid)	c	r	1802
$[N(CH_3)_4]_2MnCl_4$-H_2O	c	nq	1093
Mn(II):$C_{12}N_3ClH_9$-aq dioxane (3-hydroxy-3-(p-chlorophenyl)-1-phenyltriazene)		r	1839
$[N(C_2H_5)_4]_2MnCl_4$-H_2O	c	nq	1093
Mn(II):$C_{12}N_3ClH_{10}O$ (3-hydroxy-3-phenyl-1-o-chlorophenyltriazene)	c	r	1975
$[(C_2H_5)_4N]_2MnBr_4$		q	A-15

Substance	State	Prop.	Ref.
Mn(II):$C_5N_2BrH_3O_4$ (5-bromoörotic acid)	c	r	1228
Mn(II):$C_5N_2IH_3O_4$ (5-iodoörotic acid)	c	r	1228
Mn(II):SCN^-	aq	r	1748
Mn(II):$C_5N_5SH_5$-aq dioxane (2-amino-6-mercaptopurine)		r	2163
Mn(II):$C_{12}N_3SH_{11}O_4$ (3-hydroxy-3-phenyl-1-(p-sulfophenyl)triazene)	aq	r	2121
$MnC_{38}As_2Cl_4H_{36}$	aq	q	1046
MnSi-Si	c	b	2138
Mn_2CuO_4	c	l	2179
$MnFe_2O_4$	c	r	1856
$Mn_3O_4 \cdot xFe_3O_4$	c	s	1013
Mn/Fe/N	non-aq	p	1484

49 - Technetium

Substance	State	Prop.	Ref.
Tc/Zn	non-aq	b	2023
$TcZn_6$	c	l	1180

50 - Rhenium

Substance	State	Prop.	Ref.
Re		k	C-29
	c	v	1874
		v	2432
ReO_3	g	w	2427
ReO_4^-	aq	r	1825
Re_2O_7	c	km	2391
		q	2196
		r	2545
	g	r	1564
	aq	v	2515
$ReHO_4$	g	r	2545
ReF_6		mv	B-34
	c	v	2399
$ReCl_3$		v	B-36
Re/Bi		b	D-45
$H_3[Re(CN)_5(H_2O)]$	aq	r	2577
$(p\text{-}ClC_6H_4N_2)_2ReCl_6\text{-}HCl$	c	p	1163
$(\beta\text{-}C_{10}H_7N_2)_2ReCl_6\text{-}H_2O$	c	p	1163
$(p\text{-}HOC_6H_4N_2)_2ReCl_6\text{-}HCl$	c	p	1163
$(p\text{-}O_2NC_6H_4N_2)_2ReCl_6\text{-}HCl$	c	p	1163
$(p\text{-}HOOCC_6H_4N_2)_2ReCl_6\text{-}HCl$	c	p	1163
$(p\text{-}CH_3OC_6H_4N_2)_2ReCl_6\text{-}HCl$	c	p	1163
$(\beta\text{-}C_{10}H_7N_2)_2ReBr_6\text{-}HBr$	c	p	1163
$(p\text{-}HOC_6H_4N_2)_2ReBr_6\text{-}HBr$	c	p	1163
$(p\text{-}O_2NC_6H_4N_2)_2ReBr_6\text{-}HBr$	c	p	1163
$(p\text{-}HOOCC_6H_4N_2)_2ReBr_6\text{-}HBr$	c	p	1163
$(p\text{-}CH_3OC_6H_4N_2)_2ReBr_6\text{-}HBr$	c	p	1163
$(p\text{-}ClC_6H_4N_2)_2ReBr\text{-}HBr$	c	p	1163

51 - Chromium

Substance	State	Prop.	Ref.
Cr	c	a	1296
		a	1303
		k	2403
Cr-C-O		z	D-52
$Cr\text{-}Cr_2S_3$		r	A-56
Cr^{+++}	non-aq	s	2549
CrO_2		w	D-55
	g	w	1322
CrO_3	c	km	2391
		l	2564
	g	w	1322
CrO_4^{--}	aq	r	1835
		v	1825
Cr_2O_2		w	D-55
Cr_2O_3	c	n	2025
$Cr_2O_3\text{-}Fe_2O_3\text{-}FeO$	non-aq	b	1510
$Cr_2O_3\text{-}Nb_2O_5$	non-aq	b	1489
$Cr_2O_3\text{-}CaO$	non-aq	b	1561
$Cr_2O_3\text{-}MgO\text{-}Fe_2O_3$	c	b	2238
$Cr_2O_7^{--}$	aq	r	1835
		v	1825
$CrHO_4^-$	aq	r	2393
$CrO_2(OH)_2$	aq	r	1800
		r	2392
		r	2393
	g	l	2564
$Cr(OH)_3$	c	y	1876
CrF		l	C-35
CrF_2		l	C-35
$CrCl^{++}$	aq	r	1004
Cr(III):Cl^-	aq	r	2578
$CrCl_2\text{-}LiCl$	non-aq	b	2565

Substance	State	Prop.	Ref.
$CrCl_2$-NaCl	non-aq	b	2565
$CrCl_2$-KCl	non-aq	b	2565
$CrCl_2$-RbCl	non-aq	b	2565
$CrCl_2$-CsCl	non-aq	b	2565
$CrCl_3$	c	a	1619
$CrClO_3^-$	aq	r	2393
$CrSO_7^{--}$	aq	r	2393
$Cr_2(SO_4)_3$	aq	h	1328
Cr_2Te_3	c	v	1769
Cr_3Te_4	c	v	1769
Cr_5Te_6	c	v	1769
$Cr(NO_3)_3$	aq	v	A-79
Cr(III):$P_2H_2O_5^{--}$	aq	r	2306
Cr_2C_3	c	ak	1458
$Cr_2(C_2O_4)_3 \cdot 9H_2O$	c	n	1212
Cr(III):$C_2H_2O_4$ (oxalic acid)	aq	r	2415
$Cr(C_5H_7O_2)_3$ (acetylacetonate)	c	kmn	2188
	aq	p	1084
$Cr(CN)_3$	non-aq	r	1584
$Cr(CN)_6^{----}$	aq	n	1088
Cr(III):$C_4N_3H_{13}$ (diethylene triamine)	aq	r	2496
Cr(III):$C_6N_4H_{18}$ (triethylenetetramine)	aq	r	2496
Cr(III):$C_2NH_5O_2$ (glycine)	aq	r	2219
Cr(III):$C_5NH_{11}O_2$ (valine)	aq	r	2219
Cr(III):$C_6NH_{13}O_2$ (2-amino-4-methyl pentanoic acid)	aq	r	2219
Cr(III):$C_6N_2H_{14}O_2$ (lysine)	aq	r	2219
$HCrC_{10}H_{12}N_2O_8 \cdot H_2O$ (ethylenediaminetetraacetate)	c	p	1366
Cr(III):$C_{10}N_2H_{16}O_8$ (ethylenediamine tetraacetic acid)	aq	r	2496
$Cr(C_9NH_6O)_3$ (8-hydroxyquinolinato)	c	n	1432
$Cr(C_9NH_6O)_3 \cdot xHCl$ (8-hydroxyquinolinato)	c	l	1431
$Cr(C_9NH_6O)_3 \cdot xHBr$ (8-hydroxyquinolinato)	c	l	1431
$Cr(C_9NBr_2H_4O)_3$ (5,7-dibromo-8-hydroxyquinolinato)	c	n	1432
$Cr(CNS)_3$	non-aq	r	1584
$Cr(CNS)_6^{---}$	non-aq	r	1584
$Bi[Cr(CNS)_4(NH_3)_2]_3$	c	p	2584
CrSi	c	n	2025
$CrSi_2$	c	n	2025
Cr_3Si	c	n	2025
Cr_5Si_3	c	n	2025
$CrPbO_4$	c	a	2533
$PbCrO_4$-Rb_2CrO_4	non-aq	b	2533
$PbCrO_4$-Cs_2CrO_4	non-aq	b	2533
Cr/Al	c	v	2142
$TlCr(CNS)_4(NH_3)_2$	c	p	2584
$ZnCr_2O_4$		v	B-25
$Cd[Cr(CNS)_4(NH_3)_2]_3$	c	p	2584
Cr/Hg		b	D-45
$AgCr(CNS)_4(NH_3)_2$	c	p	2584
	non-aq	s	2213
Cr/Ni	non-aq	b	1222
		p	1303
$[Co(CN_3)_5H_2O]^{+++} \cdot CrO_4^{++}$	aq	r	1629
$[Co(NH_3)_6][Cr(C_2O_4)_3 \cdot 3H_2O\text{-}H_2O]$	c	q	1211
Cr/Fe	non-aq	a	1298
Cr/Fe/Al	c	v	2142
Cr/Fe/Co	non-aq	b	1295
$RuCr_3$	c	a	2318
$RuCr_4$	c	a	2318

52 - Molybdenum

Substance	State	Prop.	Ref.
Mo		v	B-26
		y	B-27
		z	2274
	c	km	1518,
		km	1610
		v	1874
Mo-Mo sulfide		r	A-56
Mo-C-O		z	D-52
Mo-Ni		s	D-76
Mo(VI)	aq	r	2184

Substance	State	Prop.	Ref.
MoO_2		p	D-74
		t	B-40
	c	s	1175
MoO_3		lm	C-24
	c	a	1573
		k	2036
	liq	k	2036
MoO_3-$Na_4P_2O_7$	c	b	1573
MoO_3-NaB_4O_7	c	b	1573
MoO_4^{--}	aq	v	1825
Mo_2O_6		l	C-24
Mo_3O_9		l	C-24
H^+:MoO_4^{--}	aq	r	2171
MoO_2Cl_2	c	ln	2353
$MoOCl_4$	c	ln	2353
MoS_2	c	n	A-36
MoP	c	l	1569
		l	1917
$Bi_2(MoO_4)_3$-$PbMoO_4$	non-aq	b	2203
MoC	c	ak	1458
		n	1587
		z	1127
Mo_2C	c	n	1587
		z	1127
Mo(VI):$C_9H_6O_4$-C_2H_5OH (esculetin)		r	1696
Mo(VI):$C_{10}H_8O_4$-C_2H_5OH (4-methyl esculetin)		r	1696
Mo(VI):$C_{15}H_{10}O_4$-C_2H_5OH (4-phenyl esculetin)		r	1696
$[(MoO_{11})(C_6Cl_2HO_4)_3]^{7-}$ (chloranilate)	aq	r	1508
$[(Mo_6O_{21})(C_6Cl_2HO_4)_6]^{12-}$ (chloranilate)	aq	r	1508
Mo(VI):$C_6N_2H_6O_2$ (nicotinylhydroxamic acid)	aq	r	2303
$(CO)_4MoC_2N_2H_8$ (ethylenediamine)		n	A-55
$(CO)_3MoC_4N_3H_{13}$ (diethylenetriamine)		n	A-55
$C_5H_5NMo(CO)_5$ (pyridine)		kn	A-55
		mv	B-32
Mo/Si		l	2472
$MoSi_2$		t	B-40
$MoPbO_4$	c	a	2533
		v	1038
$PbMoO_4$-$Bi_2(MoO_4)_3$	non-aq	b	2203
$PbMoO_4$-Rb_2MoO_4	non-aq	b	2533
$PbMoO_4$-Cs_2MoO_4	non-aq	b	2533
Mo/Al	non-aq	b	1450
Mo/Ni		s	D-76
Fe(III):MoO_4^{--}	aq	r	1137
Mo/Fe/C	non-aq	r	2277
Mo/Pd	non-aq	b	1286
Mo/Cr	non-aq	b	1743

53 - Tungsten

Substance	State	Prop.	Ref.
W		k	C-29
W-C-O		z	D-52
W/O-H_2O-H_2		l	D-9
WO_2		n	A-3
		v	B-4
	c	an	1752
		l	1399
		s	1175
$WO_{2.72}$		n	A-3
$WO_{2.90}$		n	A-3
WO_3		lm	C-24
		n	A-3
		v	B-4
	c	an	1752
WO_4^{--}	aq	v	1825
W_2O_6		l	C-24
W_3O		n	A-3
	c	l	1399
W_3O_9		l	C-24
$W_{12}O_{39}^{6-}$	aq	r	1847
$W_{12}O_{41}^{10-}$	aq	r	1847
WO_3H_2O	g	l	1594
$W_6HO_{21}^{-----}$	aq	r	1847
$W_6H_3O_4^{---}$	aq	r	2013
WF_6		mv	B-34
	c	v	2399
HWO_3F	aq	r	1012
WCl_6	c	km	1444
		m	1715

Substance	State	Prop.	Ref.
WO_2Cl_2	c	ln	2353
$WOCl_4$	c	ln	2353
WBr_5	c	n	1799
WBr_6	c	n	1799
WBr_2O_2	c	n	2014
WBr_4O	c	n	2014
WS_2	c	n	A-36
		n	2272
WP	c	l	1569
W/P	c	l	1118
HWO_2PO_4	aq	r	1012
$H_3WO_3AsO_4$	aq	r	1012
W/Bi		b	D-45
WC	c	ak	1458
		n	1587
		r	1832
		z	1127
W/C	c	t	1020
W_2C	c	n	1587
		r	1832
		z	1127
W/Si		l	2472
WSi_2		t	B-40
$WPbO_4$	c	v	1038
$PbWO_4$-Rb_2WO_4	non-aq	b	2533
$PbWO_4$-Cs_2WO_4	non-aq	b	2533
W/B	non-aq	b	1272
$WZnO_4$	c	nr	1387
W/Ru	non-aq	b	1224
W/Mo/Ge	non-aq	b	1230

54 - Vanadium

Substance	State	Prop.	Ref.
V		w	D-34
	c	a	1237
		n	1722
		v	1384
V-Bi		a	D-45
V-Fe	c	p	1091
V-V sulfide		r	A-56
VO_2	c	a	1661
VO_3^-	aq	r	2372
VO_4^{---}	aq	r	1835
V_2O_3	c	l	1123
V_2O_5	c	a	2125
		n	1722
	liq	q	1848
V_2O_5-PbO	liq	q	1848
$V_2O_7^{----}$	aq	r	1835
V/H	c	p	1466
VH	c	v	1384
$V(III):OH^-$	aq	r	1693
		r	1801
VHO_3	c	r	1655
$V_2(III):OH^-$	aq	r	1693
		r	1801
VF		l	C-35
VF_3		l	C-35
VCl^{++}	aq	r	1693
VCl_2	g	k	1042
VCl_2^+	aq	r	1693
VCl_3	g	l	1042
VCl_4	c	n	1099
	aq	n	1032
VCl_5	aq	n	1032
VBr_2	c	k	1617
	g	k	1042
VBr_3	g	l	1042
		l	1043
VBr_4	g	l	1043
$VBrCl_3$	g	l	1044
VBr_2Cl_2	g	l	1044
VI_2	c	k	1617
V_2S_3	c	n	2272
V/Sb	c	v	2142
VC	c	ak	1458
		l	1123
		n	1722
V_2C	c	z	1127
VOC	c	n	1722
$V(V):C_2H_2O_4$ (oxalic acid)	aq	r	2508
$VO(C_7H_4O_3)_2$ (salicylate)	c	r	1777
	aq	r	1691
$V(C_5H_8O_2)_3$ (acetylacetonate)	c	kmn	2188

Substance	State	Prop.	Ref.
$VO(C_7SH_3O_6)_2$ (sulfosalicylate)	c	r	1777
$V(CN)_6^{----}$	aq	n	1088
V/Sn	c	v	2142
$Pb_2V_2O_7$-V_2O_5	c	nq	1848
$Pb(VO_4)_2$-V_2O_5	c	nq	1848
$Pb_3(VO_4)_2$	c	n	1848
$8PbO \cdot V_2O_5$-V_2O_5	c	nq	1848
V/Al	c	v	2142
$TlVO_3$	aq	p	2298
$Tl_4V_2O_7$	aq	p	2298
V/Cr/Al	c	v	2142

55 - Niobium

Substance	State	Prop.	Ref.
Nb		z	2274
	c	a	1237
		m	1153
		m	1817
		t	2085
		t	2086
		v	1666
		v	1757
		v	2429
	g	t	2085
Nb-Nb sulfide		r	A-56
Nb_2-Fe_2O_3	non-aq	b	1489
NbO	c	lm	1153
		n	1785
NbO_2	c	l	1123
		ln	1126
		m	1153
Nb_2O_5	c	ln	1126
		n	2002
Nb_2O_5-Al_2O_3	c	b	1393
	non-aq	b	1489
Nb_2O_5-NiO	non-aq	b	1489
Nb_2O_5-CoO	non-aq	b	1489
Nb_2O_5-Cr_2O_3	non-aq	b	1489
NbH	c	v	1409
NbF_5	c	n	A-36
NbO_2F	c	n	1887
$NbOF_3$	c	n	1887
$NbCl_2$	c	n	2033
$NbCl_3$	c	n	2033
$NbCl_5$	c	i	1502
$NbCl_5$-$TiCl_4$-$POCl_3$	c	b	1155
Nb_3Cl_8	c	n	2033
NbO_2Cl	c	n	1887
$NbOCl_2$	c	n	1785
$NbOCl_3$	c	n	1887
	g	l	1147
$NbCl_3O$-RbCl	non-aq	b	1187
$NbCl_3O$-CsCl	non-aq	b	1187
$NbOBr_3$	c	n	1887
$NbOI_3$	c	n	1887
Nb_4S_7	c	n	2272
NbP	c	l	1569
Nb/Bi		b	D-45
NbC	c	ak	1458
		l	1123
		v	2026
Nb_2C	c	z	1127
Nb(V):CNS^--CH_3OH	c	r	1501
Nb_3Sn		v	B-28
NbB_2	c	n	A-36
$Al_2O_3 \cdot 9Nb_2O_5$	c	a	1393
$Al_2O_3 \cdot 25Nb_2O_5$	c	a	1393
Nb/Hg		b	D-45
NbCo	c	a	2317
$NbCo_3$	c	a	2317
Nb/Fe	non-aq	b	2063

56 - Tantalum

Substance	State	Prop.	Ref.
Ta	c	v	1738
		v	1874
		v	2263
Ta-Ta sulfide		r	A-56
Ta_2O_5	c	l	1123
		n	2003
Ta/H	c	p	1466
TaF_5		n	A-36
$TaOF_3$	c	n	1887
$TaCl_2$	c	lm	2582
$TaCl_{2.5}$	c	n	2033
$TaCl_3$	c	l	1149
		n	2033

Substance	State	Prop.	Ref.
$TaCl_4$	g	l	1149
$TaCl_5$	c	i	1502
		lm	2582
		m	1715
	g	l	1149
$TaCl_5$-$TiCl_4$-$POCl_3$	c	b	1155
TaO_2Cl	c	n	1887
$TaOCl_3$	c	n	1887
$TaOBr_3$	c	n	1887
$TaOI_3$	c	n	1887
TaS_2	c	n	2272
TaP	c	l	1569
Ta/Bi		b	D-45
TaC		n	A-39
		t	B-40
	c	l	1123
Ta/C	non-aq	p	1536
Ta_2C	c	z	1127
$TaSi_2$		t	B-40
TaB_2	c	n	A-36
Ta/Hg		b	D-45
Ta/Fe/O	non-aq	b	1281
Ta/Rh	non-aq	b	1229
TaIr	c	a	1274
Ta/Ir	non-aq	b	1274
$TaCr_2$	c	np	2526
Ta/Nb	non-aq	v	2429
Ta/Nb/W/Mo	non-aq	b	1595

57 - Titanium

Substance	State	Prop.	Ref.
Ti	c	v	2151
Ti-Ir	c	b	1833
TiO_2		n	A-69
	c	n	2027
		y	2288
TiO_2-H_2O	c	p	2365
TiO_3^{--}	aq	v	1825
TiO_4^{----}	aq	v	1825
Ti_2O_3-Al_2O_3	c	b	2050
$TiO(OH)_2$	c	p	2482
TiF_4	c	n	1683
$TiCl_4$-C_6H_6	c	b	1915
$TiCl_4$-C_7H_8	c	b	1915
$TiCl_4$-C_8H_{10}	c	b	1915
$TiCl_4$-C_9H_{12}	c	b	1915
$TiCl_4$-C_7H_8O	c	b	1915
$TiCl_4$-$C_8H_{10}O$	c	b	1915
$TiCl_4$-$C_{12}H_{10}O$	c	b	1915
$TiCl_4$-$SiCl_4$	liq	p	1262
$TiCl_4$-$AlCl_3$-$POCl_3$	c	b	1155
$TiCl_4$-$NbCl_5$-$POCl_3$	c	b	1155
$TiCl_4$-$TaCl_5$-$POCl_3$	c	b	1155
$TiBr_2$	c	n	1993
$TiBr_3$	c	n	1993
$TiBr_4$	c	n	1993
TiP	c	l	1569
$TiCl_4 \cdot n(POCl_3)$	c	a	1518
$TiPCl_7O$	c	r	1797
Ti/Bi		b	D-45
TiC	c	ak	1458
$TiOC_6H_8O_6$ (ascorbic acid)	aq	r	1396
Ti(IV):$C_9H_6O_4$ (7,8-dihydroxycoumarin)	aq	r	2221
Ti(IV):$C_9H_6O_4 \cdot H_2O$ (esculetin)	aq	r	1811
Ti(IV):$C_{10}H_8O_4 \cdot H_2O$ (4-methylesculetin)	aq	r	1811
$(p\text{-}ClC_6H_4N_2)_2TiCl_6$-HCl	c	p	1163
$(\beta\text{-}C_{10}H_7N_2)_2TiCl_6$-HCl	c	p	1163
$(p\text{-}CH_3OC_6H_4N_2)_2TiCl_6$-HCl	c	p	1163
TiB_2		t	A-4
Ti/Hg		b	D-45
$TiNiO_3$	non-aq	s	1918
Ti/Co	non-aq	v	2151
$TiCoO_3$	non-aq	s	1918
$TiCo_2O_4$	non-aq	s	1918
$TiFe_2$-$ZrFe_2$	c	v	1373
$TiFeO_3$	c	l	2446
	non-aq	s	1918
$TiFeO_3$-Fe_2O_3	non-aq	b	1490

Substance	State	Prop.	Ref.
$TiFe_2O_4$	non-aq	s	1918
Ti/Ir	c	b	1833
$TiIr_3$	c	a	1833
Ti_3Ir	c	a	1833
Ti/Mn	non-aq	v	2151
Ti/Cr	non-aq	b	1273
$TiCr_2$	c	b	1273
Ti/Mo/Al	non-aq	b	1547
		b	1551
Ti/V/Al	c	v	2142
Ti/Nb/Cr	non-aq	b	1550

58 - Zirconium

Substance	State	Prop.	Ref.
Zr		y	A-2
Zr-H_2		w	D-51
Zr-Mg		p	D-64
ZrO_2		t	B-35
	c	n	1131
		n	1941
ZrO_2-ThO_2-UO_2	c	p	1805
ZrO_2-CaO-La_2O_3	non-aq	b	1511
Zr/H	c	w	1604
ZrH_2	c	n	1683
		v	1759
ZrD_2	c	v	1759
ZrF_4		l	C-31
	c	km	2531
ZrF_4-NaF	c	r	1853
$ZrCl_3$	c	ln	1566
$ZrCl_4$	c	n	A-78
	g	l	1082
ZrP	c	l	1569
ZrC		mn	C-15
		t	B-40
	c	ak	1458
		ln	2411
		n	2254
Zr carbides		s	D-48
ZrC_4O_8	c	p	2099
Zr(IV):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetraacetic acid)		r	1538
$ZrSiO_4$		t	B-35
ZrB_2		mn	C-15
		t	A-4
	c	n	A-36
		n	1941
		t	1110
Zr/Hg		b	D-45
$ZrFe_2$-$TiFe_2$	c	v	1373
Zr/Nb	non-aq	b	1218
Zr/Nb/H	non-aq	b	1218
Zr/Nb/Sn	non-aq	b	1218
Zr/Ta/W	non-aq	b	1225
Zr/Ti/Ta/O	non-aq	b	1226
Zr inorganic and organic complexes	c	z	1656

59 - Hafnium

Substance	State	Prop.	Ref.
Hf		v	B-34
HfO_2	c	km	2472
HfO_2-La_2O_3	c	b	1143
HfF_4	c	km	2531
		n	1683
$HfCl_4$	c	n	A-78
		n	1099
HfI_4	c	akm	1444
HfP	c	l	1569
Hf/Bi		b	D-45
HfC		mn	C-15
		v	B-34
	c	ak	1458
		n	1521
		n	2254
		v	1302
		z	1127
Hf/C	c	t	1020
HfB		mn	C-15
HfB_2		mn	C-15
		v	B-34
	c	n	A-36
Hf/Nb	non-aq	b	2162
Hf inorganic and organic complexes	c	z	1656

60 - Scandium

Substance	State	Prop.	Ref.
Sc	c	k	2030
		km	2088
		l	2360

Substance	State	Prop.	Ref.
Sc-$ScCl_3$	non-aq	bp	1321
Sc_2	g	lr	1050
Sc_2O_3-Al_2O_3	non-aq	b	1332
Sc(III):Cl^-	aq	r	1394
$ScCl_3$	c	k	1347
$ScCl_3$-Sc	non-aq	bp	1321
Sc(III):Br^-	c	r	1964
ScI_3		l	C-27
$Sc(C_5H_7O_3)_3$ (acetylacetonate)	c	kmn	2188
$ScC_{12}N_9H_6O_{15}\cdot 15H_2O$ (dilituratе)	c	p	2262
Sc(III):CNS^-	aq	r	2096
$ScAlO_3$	c	a	1332

61 - Yttrium

Substance	State	Prop.	Ref.
Y	c	k	1750
		km	2031
		km	2088
		l	2360
		t	1665
Y-YCl_3	non-aq	bp	1321
Y_2	g	lr	1050
YO	g	l	1037
Y_2O_3	c	l	1037
YH_2	c	v	1759
YD2	c	v	1759
YF_3	c	n	A-36
YCl_3	c	a	2382
		k	1347
	aq	p	1747
YCl_3-Y	non-aq	bp	1321
YC_2	g	l	1864
Y(III):$C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
Y(III):$C_2H_2O_4$ (oxalic acid)	aq	p	2251
Y(III):$C_2H_4O_2$ (acetic acid)	c	r	1953
Y(III):$C_2H_4O_3$ (glycolic acid)	c	r	1953
Y(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
Y(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117

Substance	State	Prop.	Ref.
Y(III):$C_3H_6O_3$ (lactic acid)	c	r	1238
$YC_4H_4O_4$ (succinate)	c	p	2299
Y(III):$C_4H_6O_5$ (diglycolic acid)	c	v	1100
Y(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Y(III):$C_4H_8O_3$ (α-hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	2217
Y(III):$C_4H_8O_5$ (α,β,β'-trihydroxyisobutyric acid)	aq	r	1074
Y(III):$C_5H_8O_2$ (acetylacetone)	aq	r	1428
		r	2182
$YC_6H_4O_7$-Group II metal citrates	c	p	2416
$YC_6H_4O_7$-alkali metal soln (citrate)	c	p	2416
$YC_6H_5O_7$-HCl-H_2O (citrate)	c	p	2204
Y(III):$C_6H_{10}O_2$ (propionylacetone)	c	r	1428
Y(III):$C_7H_6O_4$ (kojic acid)	aq	r	2182
Y(III):$C_{10}H_{10}O_2$ (benzoylacetone)	c	r	1428
Y(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
Y(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Y(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Y(III):$C_7NH_5O_4$ (dipicolinic acid)	c	v	1100
Y(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Y(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$YC_{12}N_9H_6O_{15}\cdot 12H_2O$ (dilituratе)	c	p	2262
Y(III):CNS^-	aq	r	2096
Y(III):$HO_2CCH_2S(CH_2)_2N(CH_2CO_2H)_2$	aq	r	1816
Y(III):Xylenol orange	aq	r	2456

Substance	State	Prop.	Ref.
Lutetium - 62			
Lu		q	A-53
	c	km	2088
		m	1817
		v	1194
Lu_2O_3		v	B-34
$Lu(III):Cl^-$	c	r	1963
$LuCl_3$	aq	q	A-53
$Lu(III):SO_4^{--}$	c	r	1963
Lu/Bi		b	D-45
$Lu_2(C_2O_4)_3 \cdot 10H_2O$	c	p	2364
$Lu(III):C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
$Lu(III):C_2H_2O_4$ (oxalic acid)	aq	r	1963
		r	2364
$Lu(III):C_3H_6O_2$ (propionic acid)	c	r	1117
$Lu(III):C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
$Lu(III):C_3H_6O_3$ (lactic acid)	c	r	1238
$Lu(III):C_4H_6O_5$ (diglycolic acid)	c	v	1100
$Lu(III):C_4H_8O_2$ (isobutyric acid)	aq	r	1074
$Lu(III):C_4H_8O_3$ (hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	2217
$Lu(III):C_4H_8O_5$ (α,β,β'-tri-hydroxyisobutyric acid)	aq	r	1074
$Lu(III):C_5H_8O_2$ (acetylacetone)	aq	r	2182
$Lu(III):C_7H_6O_4$ (kojic acid)	aq	r	2182
$Lu(III):C_2SH_4O_2$ (thioglycolic acid)	aq	r	1117
$Lu(III):C_6NH_5O_2$ (picolinic acid)	c	r	1971
$Lu(III):C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
$Lu(III):C_7NH_5O_4$ (dipicolinic acid)	c	v	1100
$Lu(III):C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
$Lu(III):C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$Lu(III):SCN^-$ (thiocyanate)	c	r	1963
$LuVO_4 \cdot 2H_2O$	c	p	2311
63 - Ytterbium			
Yb		v	B-18
	c	a	2233
		km	2088
		t	1665
		v	1674
Yb/Bi		b	D-45
Yb/O		b	D-42
Yb_2O_3	c	v	2061
$YbCl_2$	c	k	1347
	liq	k	1616
		r	1621
$YbCl_3$	c	a	1621
		l	1347
	aq	q	A-53
		v	B-30
$YbAsO_4$-(HCl, HNO_3 or H_2SO_4)	c	p	1495
$Yb(III):C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
$Yb(III):C_2H_2O_4$ (oxalic acid)	aq	p	2251
$Yb(III):C_2H_4O_2$ (acetic acid)	c	r	1953
	aq	r	2104
$Yb(III):C_2H_4O_3$ (glycolic acid)	c	r	1953
$Yb(III):C_3H_6O_3$ (lactic acid)	c	r	1238
$Yb(III):C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
$Yb(III):C_3H_6O_2$ (propionic acid)	c	r	1117
$YbC_4H_4O_4$ (succinate)	c	p	2299
$Yb(III):C_4H_6O_5$ (diglycolic acid)	c	v	1100
$Yb(III):C_4H_8O_2$ (isobutyric acid)	aq	r	1074
$Yb(III):C_4H_8O_3$ (hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	1154
		r	2217

Substance	State	Prop.	Ref.
Yb(III):$C_4H_8O_5$ (α,β,β'-tri-hydroxyisobutyric acid)	aq	r	1074
Yb(III):$C_5H_8O_2$ (acetylacetone)	c	r	1257
Yb(III):$C_5H_{10}O_3$ (methylethylglycolic acid)	aq	r	1154
$YbC_6H_5O_7$-HCl-H_2O (citrate)	c	p	2204
Yb(III):$C_6H_{12}O_3$ (methylpropylglycolic acid)	aq	r	1154
Yb(III):$C_6H_{12}O_7$ (gluconic acid)	aq	r	2206
Yb(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
Yb(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Yb(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2105
Yb(III):$C_7NH_5O_7$ (dipicolinic acid)	c	r	1100
Yb(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Yb(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
Yb(IV):$C_8PH_{19}O_4$ (dibutyl phosphate)	aq	r	2222
$Yb_2C_{44}As_4N_8S_4H_{20}O_{28}$ (protonated arsenazo III)	c	r	2037

64 - Thulium

Substance	State	Prop.	Ref.
Tm		q	A-53
		v	B-18
	c	v	1860
Tm_2O_3		v	B-34
$TmCl_3$	aq	q	A-53
Tm(III):$C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
Tm(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
Tm(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
Tm(III):$C_3H_6O_3$ (lactic acid)	c	r	1238
Tm(III):$C_4H_6O_3$ (diglycolic acid)	c	r	1100
Tm(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Tm(III):$C_4H_8O_3$ (hydroxybutyric acid)	aq	r	1074
		r	1238
		r	2217
Tm(III):$C_4H_8O_5$ (α,β,β'-tri-hydroxyisobutyric acid)	aq	r	1074
Tm(III):$C_5H_8O_2$ (acetylacetone)	aq	r	2182
Tm(III):$C_7H_6O_4$ (kojic acid)	aq	r	2182
Tm(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
Tm(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Tm(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Tm(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1100
Tm(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Tm(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
Tm(III):$HO_2CCH_2S(CH_2)_2N(CH_2CO_2H)_2$	aq	r	1816

65 - Erbium

Substance	State	Prop.	Ref.
Er	c	km	2088
		m	1817
Er_2O_3	c	v	2061
$ErCl_3$	c	k	1347
	aq	p	1747
Er(III):CO_3^{--}	aq	r	1142
Er_2(III):$CO_3^{--}\cdot 2.5H_2O$	aq	r	1142
Er(III):$C_2H_2O_4$ (oxalic acid)	aq	p	2251
Er(III):$C_2H_4O_2$ (acetic acid)	c	r	1953
Er(III):$C_2H_4O_3$ (glycolic acid)	c	r	1953
Er(III):$C_2H_4O_4$ (glyoxylic acid)	aq	r	1364
Er(III):$C_3H_6O_2$	c	r	1117
Er(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117

Substance	State	Prop.	Ref.
Er(III):$C_3H_6O_3$ (lactic acid)	c	r	1238
Er(III):$C_4H_5O_5$ (diglycolic acid)	c	r	1100
Er(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Er(III):$C_4H_8O_3$ (α-hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	2217
Er(III):$C_4H_8O_5$ (α,β,β'-tri-hydroxyisobutyric acid)	aq	r	1074
Er(III):$C_5H_8O_2$ (acetylacetone)	aq	r	2182
Er(III):$C_7H_6O_4$ (kojic acid)	aq	r	2182
Er(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
		r	1953
Er(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Er(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Er(III):$C_7NH_4O_4$ (dipicolinic acid)	c	r	1100
Er(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Er(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$ErC_{12}N_9H_6O_{15}\cdot 12H_2O$ (diliturate)	c	p	2262
Er(III):CNS^-	aq	r	2096

66 - Holmium

Substance	State	Prop.	Ref.
Ho		q	A-53
		v	B-18
	c	m	1817
		v	1408
		v	2053
Ho_2O_3	c	v	2061
HoF_3	c	n	A-36
$HoCl_3$	aq	q	A-53
$HoCl_3\cdot 6H_2O$	aq	q	A-53
Ho(III):$C_2H_2O_4$ (glyoxylic acid)	aq	r	1364
Ho(III):$C_2H_2O_4$ (oxalic acid)	aq	r	2364
Ho(III):$C_2H_4O_2$ (acetic acid)	c	r	1953
Ho(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
Ho(III):$C_3H_6O_3$ (lactic acid)	c	r	1238
Ho(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
Ho(III):$C_4H_6O_5$ (diglycolic acid)	c	r	1100
Ho(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Ho(III):$C_4H_8O_3$ (α-hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	2217
Ho(III):$C_4H_8O_5$ (α,β,β'-tri-hydroxyisobutyric acid)	aq	r	1074
Ho(III):$C_5H_8O_2$ (acetylacetone)	c	r	1257
Ho(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
Ho(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Ho(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Ho(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1100
Ho(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N.N,N'-triacetic acid)	aq	r	2223
Ho(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetracetic acid)	aq	r	2308
$HoVO_4\cdot 2H_2O$	c	p	2311

67 - Dysprosium

Substance	State	Prop.	Ref.
Dy		v	B-18
	c	km	2088
		m	1817
		v	2368
Dy_2O_3	c	v	2061
Dy(III):$C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
Dy(III):$C_2H_2O_4$ (oxalic acid)	aq	p	2251
Dy(III):$C_2H_4O_2$ (acetic acid)	c	r	1953

Substance	State	Prop.	Ref.
Dy(III):$C_2H_4O_3$ (glycolic acid)	c	r	1953
Dy(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
Dy(III):$C_3H_6O_3$ (lactic acid)	c	r	1238
Dy(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
Dy(III):$C_4H_6O_5$ (diglycolic acid)	c	r	1100
Dy(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Dy(III):$C_4H_8O_3$ (α-hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	1154
Dy(III):$C_4H_8O_5$ (α,β,β'-trihydroxyisobutyric acid)	aq	r	1074
Dy(III):$C_5H_8O_2$ (acetylacetone)	aq	r	2182
Dy(III):$C_5H_{10}O_3$ (methylethylglycolic acid)	aq	r	1154
Dy(III):$C_6H_{12}O_3$ (methylpropylglycolic acid)	aq	r	1154
Dy(III):$C_7H_6O_4$ (kojic acid)	aq	r	2182
Dy(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
Dy(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Dy(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Dy(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1100
Dy(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Dy(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$DyC_{12}N_9H_6O_{15}\cdot 12H_2O$ (dilituratе)	c	p	2262
Dy(III):CNS^-	aq	r	2096
$Dy_2C_{44}As_4N_8S_4H_{20}O_{28}$ (protonated arsenazo III)	c	r	2037
$DyVO_4\cdot 2H_2O$	c	p	2311

Substance	State	Prop.	Ref.
68 - Terbium			
Tb		n	A-44
		q	A-53
		v	B-18
	c	km	2088
		m	1817
		v	1408
Tb/O		b	D-42
$TbCl_3$	aq	q	A-53
$TbCl_3\cdot 6H_2O$	aq	q	A-53
Tb(III):$C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
Tb(III):$C_2H_2O_4$ (oxalic acid)	aq	p	2251
Tb(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
Tb(III):$C_3H_6O_3$ (lactic acid)	c	r	1238
Tb(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
Tb(III):$C_4H_6O_5$ (diglycolic acid)	c	r	1100
Tb(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Tb(III):$C_4H_8O_3$ (hydroxyisobutyric)	c	r	1238
	aq	r	1074
		r	2217
Tb(III):$C_4H_8O_5$ (α,β,β'-trihydroxyisobutyric acid)	aq	r	1074
Tb(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
Tb(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Tb(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Tb(III):$C_7NH_5O_4$	c	r	1100
Tb(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Tb(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
69 - Gadolinium			
Gd		v	B-18
	c	a	1662
		m	1817
		km	2088

Substance	State	Prop.	Ref.
Gd_2O_3	c	v	2061
GdF_3	c	n	A-36
$GdCl_3$	c	q	2190
		v	2439
$GdAsO_4$-(HCl, HNO_3 or H_2SO_4)	c	p	1495
Gd(III):$C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
Gd(III):$C_2H_2O_4$ (oxalic acid)	aq	p	2251
Gd(III):$C_2H_4O_2$ (acetic acid)	c	r	1953
Gd(III):$C_2H_4O_3$ (glycolic acid)	c	r	1953
Gd(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
Gd(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
Gd(III):$C_3H_6O_3$ (lactic acid)	c	r	1238
$GdC_4H_4O_4$ (succinate)	c	p	2299
Gd(III):$C_4H_6O_5$ (diglycolic acid)	c	v	1100
Gd(III):$C_4H_6O_5$ (malic acid)	aq	r	2541
Gd(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Gd(III):$C_4H_8O_3$ (hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	2217
Gd(III):$C_4H_8O_5$ (α,β,β'-tri-hydroxyisobutyric acid)	aq	r	1074
Gd(III):$C_5H_8O_2$ (acetylacetone)	aq	r	2182
$GdC_6H_5O_7$-aq HCl (citrate)	c	p	2204
$GdC_6H_4O_7$-Group II metal citrates	c	p	2416
$GdC_6H_4O_7$-alkali metal soln. (citrate)	c	p	2416
Gd(III):$C_7H_6O_4$ (kojic acid)	aq	r	2182
Gd(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117

Substance	State	Prop.	Ref.
Gd(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Gd(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Gd(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1100
Gd(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Gd(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$GdC_{12}N_9H_6O_{15}\cdot 12H_2O$ (dilitarate)	c	p	2262
Gd(III):CNS^-	aq	r	2096
$Gd_2C_{44}As_4N_8S_4H_{20}O_{28}$ (deprotonated arsenazo III)	c	r	2037
$Gd_3Ga_5O_{12}$	c	a	2426
$GdVO_4\cdot 2H_2O$	c	p	2311

70-Europium

Substance	State	Prop.	Ref.
Eu		v	B-18
	c	v	1586
		t	1665
		a	1862
		n	1913
		a	2233
Eu-HCl	aq	q	A-41
Eu-$EuC_{1.89}$-C	g	p	C-26
Eu-Na_2O-B_2O_3-NaCl		p	D-74
Eu^{++}	aq	n	1863
Eu/O		b	D-42
Eu_2O_3	c	q	1913
Eu(III):Cl^-	c	r	1654
		r	1963
	aq	r	2091
$EuCl_2$	c	k	1347
	liq	r	1621
$EuCl_3$	c	a	1621
		l	1347
EuS	c	av	1340
$EuSO_4$	aq	s	2385
Eu(III):SO_4^{--}	c	r	1654
		r	1963
	aq	r	2180
EuSe	c	v	2242
EuTe	c	v	2242

Substance	State	Prop.	Ref.
$Eu(III):NO_3^-$	c	r	1654
$Eu(III):H_2PO_2^-$	aq	r	2180
$EuC_{1.89}$-Eu-C		p	C-26
$Eu(III):CO_3^{--}$	aq	r	1073
$Eu(III):HCO_3^-$	aq	r	1073
$Eu(III):C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
$Eu(III):C_2H_2O_4$ (oxalic acid)	c	r	1963
$Eu(III):C_3H_6O_2$ (propionic acid)	c	r	1117
$Eu(III):C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
$Eu(III):C_3H_6O_3$ (lactic acid)	c	r	1238
$Eu(III):C_4H_6O_5$ (diglycolic acid)	c	r	1100
$Eu(III):C_4H_6O_5$ (malic acid)	aq	r	2541
$Eu(III):C_4H_8O_2$ (isobutyric acid)	aq	r	1074
$Eu(III):C_4H_8O_3$ (hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	2217
$Eu(III):C_4H_8O_5$ (α,β,β'-tri-hydroxyisobutyric acid)	aq	r	1074
$Eu(III):C_5H_8O_2$ (acetylacetone)	aq	r	2182
$Eu(III):C_7H_6O_4$ (kojic acid)	aq	r	2182
$Eu(III):C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
$Eu(III):C_6NH_5O_2$ (picolinic acid)	c	r	1971
$Eu(III):C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
$Eu(III):C_7NH_5O_4$ (dipicolinic acid)	c	r	1100
$Eu(III):C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
$Eu(III):C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$Eu(III):SCN^-$	c	r	1963
	aq	r	2180
$EuVO_4 \cdot 2H_2O$	c	p	2311

Substance	State	Prop.	Ref.
71 - Samarium			
Sm		v	B-18
	c	a	1662
		km	2088
		km	2256
Sm-$SmCl_3$	non-aq	b	1321
Sm/O		b	D-42
Sm_2O_3	c	v	2061
$SmCl_2$	c	k	1347
	liq	r	1621
$SmCl_3$	c	a	1621
		a	1792
		l	1347
$SmCl_3$-Sm	non-aq	b	1321
$Sm_2(SO_3)_3$(dil HCl, HNO_3 and H_2SO_4)	c	p	1576
$Sm_2(SeO_3)_3$(dil HCl, HNO_3 and H_2SO_4)	c	p	1576
$Sm(NO_3)_3$-H_2O	c	p	2407
$SmHP_3O_{10}^-$	c	r	1639
$SmAsO_4$-(HCl, HNO_3 or H_2SO_4)	c	p	1495
$Sm(III):C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
$Sm(III):C_2H_2O_4$ (oxalic acid)	aq	p	2251
$Sm(III):C_2H_4O_2$ (acetic acid)	c	r	1953
	aq	r	2104
$Sm(III):C_2H_4O_3$ (glycolic acid)	c	r	1953
$Sm(III):C_3H_6O_2$ (propionic acid)	c	r	1117
$Sm(III):C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
$Sm(III):C_3H_6O_3$ (lactic acid)	c	r	1238
$SmC_4H_4O_4$ (succinate)	c	p	2299
$Sm(III):C_4H_6O_5$ (diglycolic acid)	c	r	1100
$Sm(III):C_4H_6O_5$ (malic acid)	aq	r	2541
$Sm(III):C_4H_8O_2$ (isobutyric acid)	aq	r	1074

Substance	State	Prop.	Ref.
Sm(III):$C_4H_8O_3$ (hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	1154
		r	2217
Sm(III):$C_4H_8O_5$ (α,β,β'-tri-hydroxyisobutyric acid)	aq	r	1074
Sm(III):$C_5H_8O_2$ (acetylacetone)	aq	r	2182
Sm(III):$C_5H_{10}O_3$ (methylethyl glycolic acid)	aq	r	1154
$SmC_6H_5O_7$-HCl-H_2O (citrate)	c	p	2204
Sm(III):$C_6H_{12}O_3$ (methylpropyl glycolic acid)	aq	r	1154
Sm(III):$C_7H_6O_4$ (kojic acid)	aq	r	2182
Sm(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
		r	1953
Sm(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Sm(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Sm(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1100
Sm(III):$C_{10}N_2H_{18}O_7$ N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Sm(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetracetic acid)	aq	r	2308
$SmC_{12}N_9H_6O_{15}\cdot 12H_2O$ (dilitarate)	c	p	2262
Sm(III):CNS^-	aq	r	2096
Sm(III):$(HO_2CCH_2S(CH_2)_2N(CH_2CO_2H)_2$	aq	r	1816
$Sm_2C_{44}As_4N_8S_4H_{20}O_{28}$ (protonated arsenazo III)	c	r	2037
$SmVO_4\cdot 2H_2O$	c	p	2311

72 - Promethium

Substance	State	Prop.	Ref.
Pm	c	y	2443

73 - Neodymium

Substance	State	Prop.	Ref.
Nd		v	B-18
	c	km	2070
		km	2088
		km	2256
		v	1196
Nd-HCl	aq	q	A-44
Nd-Na_2O-B_2O_3-NaCl		p	D-74
NdO-S-Nd_2O_2S	g	p	C-26
Nd_2O_3	c	v	2061
Nd_2O_3-HCl	aq	q	A-44
$NdCl_3$	c	k	1347
		m	2282
Nd/$NdCl_3$	non-aq	bp	1321
Nd_2SO_2-NdO-S	c	p	C-26
$Nd_2(SO_3)_3$(dil HCl, HNO_3 and H_2SO_4)	c	p	1576
$Nd_2(SeO_3)_3$(dil HCl, HNO_3 and H_2SO_4)	c	p	1576
$Nd(NO_3)_3$-H_2O	c	p	2407
$NdHP_3O_{10}^-$	c	r	1639
$NdAsO_4$-(HCl, HNO_3 or H_2SO_4)	c	p	1495
Nd(III):CO_3^{--}	aq	r	1073
		r	1142
$Nd_2(CO_3)_3\cdot 3H_2O$	c	p	1142
$Nd(C_5H_5)_3$	c	km	1035
Nd(III):HCO_3^-	aq	r	1073
Nd(III):$C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
Nd(III):$C_2H_2O_4$ (oxalic acid)	aq	p	2251
Nd(III):$C_2H_4O_2$ (acetic acid)	c	r	1953
	aq	r	2104
Nd(III):$C_2H_4O_3$ (glycolic acid)	c	r	1953
$NdC_3H_2O_5^+$	aq	p	2012
Nd(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
Nd(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
$NdC_4H_4O_4$ (succinate)	c	p	2299
Nd(III):$C_4H_6O_5$ (diglycolic acid)	c	r	1100
Nd(III):$C_4H_6O_5$ (malic acid)	aq	r	2541
Nd(III):$C_4H_6O_6$ (tartaric acid)	aq	r	2540

Substance	State	Prop.	Ref.
Nd(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Nd(III):$C_4H_8O_3$ (α-hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
Nd(III):$C_4H_8O_5$ (α,β,β'-trihydroxyisobutyric acid)	aq	r	1074
Nd(III):$C_5H_8O_2$ (acetylacetone)	c	r	1428
$NdC_6H_5O_7$-HCl-H_2O (citrate)	c	p	2204
Nd(III):$C_6H_{11}O_2$ (propionylacetone)	c	r	1428
Nd(III):$C_6H_{12}O_3$ (methylpropyl glycolic acid)	aq	r	1154
Nd(III):$C_6H_{12}O_7$ (gluconic acid)	aq	r	2206
Nd(III):$C_{10}H_{11}O_2$ (benzoylacetone)	c	r	1428
Nd(III):$(CO_3^{--})(F^-)$	aq	r	1142
Nd(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
Nd(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Nd(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Nd(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1100
Nd(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Nd(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$NdC_{12}N_9H_6O_{15}\cdot 12\,H_2O$ (dilituratе)	c	p	2262
Nd(III):CNS^-	aq	r	2096
Nd(III):$C_8PH_{19}O_4$ (dibutyl phosphate)	aq	r	2222
$NdVO_4\cdot 2H_2O$	c	p	2311

74 - Praseodymium

Substance	State	Prop.	Ref.
Pr		v	B-18
	c	km	2070
		km	2088
		km	2256
		m	1817
		t	1665
		v	1196
Pr/O		b	D-42
$PrCl_3$	c	k	1347
		m	2282
	aq	q	A-53
Pr/$PrCl_3$	non-aq	b	1321
$Pr_2(SO_3)_3$(dil HCl,HNO_3 and H_2SO_4)	c	p	1576
$Pr_2(SeO_3)_3$(dil HCl,HNO_3 and H_2SO_4)	c	p	1576
$Pr(NO_3)_3$-H_2O	c	p	2407
$PrHP_3O_{10}^-$	aq	r	1639
$PrAsO_4$-(HCl,HNO_3 or H_2SO_4)	c	p	1495
Pr(III):CO_3^{--}	aq	r	1142
Pr_2(III):$CO_3^{--}\cdot 3H_2O$	aq	r	1142
Pr(III):$C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
Pr(III):$C_2H_2O_4$ (oxalic acid)	aq	p	2251
Pr(III):$C_2H_4O_2$ (acetic acid)	c	r	1953
$PrC_3H_2O_5^+$	aq	p	2012
Pr(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
Pr(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
$PrC_4H_4O_4$ (succinate)	c	p	2299
Pr(III):$C_4H_6O_5$ (diglycolic acid)	c	r	1100
Pr(III):$C_4H_6O_5$ (malic acid)	aq	r	2541
Pr(III):$C_4H_6O_6$ (tartaric acid)	aq	r	2540
Pr(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Pr(III):$C_4H_8O_3$ (α-hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
Pr(III):$C_4H_8O_5$ (α,β,β'-trihydroxyisobutyric acid)	aq	r	1074
Pr(III):$C_5H_8O_2$ (acetylacetone)	c	r	1428
	aq	r	2182
$PrC_6H_5O_7$-aq HCl (citrate)	c	p	2204

Substance	State	Prop.	Ref.
Pr(III):$C_6H_{10}O_2$ (propionylacetone)	c	r	1428
Pr(III):$C_7H_6O_4$ (kojic acid)	aq	r	2182
Pr(III):$C_{10}H_{10}O_2$ (benzoylacetone)	c	r	1428
Pr(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
Pr(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Pr(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Pr(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1100
Pr(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Pr(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
Pr(III):$HO_2CCH_2S(CH_2)_2N(CH_2CO_2H)_2$	aq	r	1816
Pr(III):$C_8PH_{19}O_4$ (dibutyl phosphate)	aq	r	2222
Pr/Gd		v	B-3
	non-aq	v	1740
Pr/Nd	non-aq	b	2256

75 - Cerium

Substance	State	Prop.	Ref.
Ce		m	B-31
	c	a	1662
		km	2088
		v	1586
	liq	k	1503
Ce(IV)	aq	s	1612
	non-aq	s	1612
		s	2137
CeO_2		t	B-40
	c	l	2092
Ce_2O_3		v	B-34
CeH_2	c	v	2367
$Ce(OH)_3$-H_2O	c	p	2482
CeF_3		k	C-20
$CeCl_3$	c	k	1347
		m	2282
		p	2482
CeS		t	B-40
$CeSO_4$	c	p	2482
Ce(III):SO_4^{--}	aq	r	1622
Ce_2(III):SO_4^{--}	aq	r	1592
$Ce_2(SO_3)_3$(dil HCl,HNO_3 and H_2SO_4)	c	p	1576
Ce(OH)SO_4	c	p	2482
$Ce_2(SeO_3)_3$(dil HCl,HNO_3 and H_2SO_4)	c	p	1576
Ce$(NO_3)_3$-H_2O	c	p	2407
Ce(III):$C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
Ce(III):$C_2H_2O_4$ (oxalic acid)	aq	p	2251
Ce(III):$C_2H_4O_2$ (acetic acid)	c	r	1953
Ce(III):$C_2H_4O_3$ (glycolic acid)	c	r	1953
Ce(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
Ce(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
$CeC_4H_4O_4$ (succinate)	c	p	2299
Ce(III):$C_4H_6O_5$ (diglycolic acid)	c	r	1100
Ce(III):$C_4H_6O_5$ (malic acid)	aq	r	2541
Ce(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
Ce(III):$C_4H_8O_3$ (α-hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
Ce(III):$C_4H_8O_5$ (α,β,β'-trihydroxyisobutyric acid)	aq	r	1074
Ce(III):$C_6H_{12}O_3$ (methylpropyl glycolic acid)	aq	r	1154
Ce(III):$C_2BrH_3O_2$ (bromoacetic acid)	aq	r	1240
Ce(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
Ce(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
Ce(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
Ce(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1100

Substance	State	Prop.	Ref.
Ce(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
Ce(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$CeC_{12}N_9H_6O_{15}\cdot 12H_2O$ (dilituratе)	c	p	2262
$CeSCN^{++}$	aq	r	1158
Ce/Zn		bp	D-60
CeZn		n	A-54
Ce(III):Xylenol orange	aq	r	2456

76 - Lanthanum

Substance	State	Prop.	Ref.
La		v	B-18
	c	a	1504
		a	1662
		km	2088
		l	2360
		t	1665
La_2	g	lr	1050
LaO	g	y	D-43
La_2O_3	c	s	2029
		v	2061
La_2O_3-UO_2		l	D-30
$La(OH)_3$	c	r	1148
$La(OH)_3$-H_2O	c	p	2482
LaF_3		l	C-35
	c	n	A-36
$LaCl_3$	c	k	1347
		m	2282
		p	2482
	aq	q	A-53
		v	B-30
La/$LaCl_3$	non-aq	b	1321
$LaSO_4$	c	p	2482
La(III):SO_4^{--}	c	r	1963
$La_2(SO_3)_3$(dil HCl,HNO_3 and H_2SO_4)	c	p	1576
$La(OH)SO_4$	c	p	2482
$La_2(SeO_3)_3$(dil HCl,HNO_3 and H_2SO_4)	c	p	1576
LaTe	c	a	2502
La_3Te_4	c	a	2502
$La(NO_3)_3$-H_2O	c	p	2407

Substance	State	Prop.	Ref.
$LaHP_3O_{10}^-$	aq	r	1639
$LaAsO_4$-(HCl,HNO_3 or H_2SO_4)	c	p	1495
LaC_2	g	w	1979
$La_2(C_2O_4)_3$-HNO_3	c	p	1454
La(III):$C_2H_2O_4$ (oxalic acid)	c	r	1963
	aq	p	2251
La(III):$C_2H_4O_2$ (acetic acid)	c	r	1953
	aq	r	2104
La(III):$C_2H_4O_3$ (glycolic acid)	c	r	1953
La(III):$C_3H_6O_2$ (propionic acid)	c	r	1117
La(III):$C_3H_6O_3$ (methoxyacetic acid)	c	r	1117
La(III):$C_4H_6O_5$ (diglycolic acid)	c	r	1100
La(III):$C_4H_6O_5$ (malic acid)	aq	r	2541
La(III):$C_4H_6O_6$ (tartaric acid)	aq	r	2207
La(III):$C_4H_8O_2$ (isobutyric acid)	aq	r	1074
La(III):$C_4H_8O_3$ (α-hydroxyisobutyric acid)	c	r	1238
	aq	r	1074
		r	1154
La(III):$C_4H_8O_5$ (α,β,β'-trihydroxyisobutyric acid)	aq	r	1074
La(III):$C_5H_8O_2$ (acetylacetone)	c	r	1428
	aq	r	2182
La(III):$C_5H_{10}O_3$ (methylethyl glycolic acid)	aq	r	1154
$LaC_6H_4O_7$-aq HCl (citrate)	c	p	2204
$LaC_6H_4O_7$-alkali metal solution (citrate)	c	p	2416
$LaC_6H_4O_7$-Group II metal citrates (citrate)	c	p	2416
La(III):$C_6H_{10}O_2$ (propionylacetone)	c	r	1428
La(III):$C_6H_{12}O_3$ (methylethyl glycolic acid)	aq	r	1154
La(III):$C_6H_{12}O_7$ (gluconic acid)	aq	r	2206

Substance	State	Prop.	Ref.
La(III):$C_7H_6O_4$ (kojic acid)	aq	r	2182
La(III):$C_{10}H_{10}O_2$ (benzoylacetone)	c	r	1428
La(III):$C_2SH_4O_2$ (thioglycolic acid)	c	r	1117
		r	1953
La(III):$C_6NH_5O_2$ (picolinic acid)	c	r	1971
La(III):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
La(III):$C_7NH_5O_4$ (dipicolinic acid)	c	r	1100
La(III):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
La(III):$C_{10}N_2H_{18}O_7$ (N'-(hydroxyethyl)ethylene diamine-N,N,N'-triacetic acid)	aq	r	2223
La(III):$C_{11}N_2H_{18}O_8$ (propylenediaminetetraacetic acid)	aq	r	2308
$LaC_{12}N_9H_6O_{15}\cdot 12H_2O$ (dilitURate)	c	p	2262
La(III):$C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
La(III):$C_{18}N_4H_{30}O_{12}$ (triethylenetetraminehexaacetic acid)	aq	r	2218
La(III):SCN^- (thiocyanate)	c	r	1963
La(III):CNS^-	aq	r	2096
La(III):$C_8NSH_{13}O_6$ ($HO_2CCH_2S(CH_2)_2N(CH_2CO_2H)_2$)	aq	r	1816
La_2(III):$C_{37}N_2SH_{41}O_{13}$ (methylthymol blue)	c	r	2518
La_2(III):$C_{22}As_2N_4S_2H_{18}O_4$ (arsenazo III)	c	r	2037
$LaAlO_3$	c	a	2140
La_2O_3/Al_2O_3	c	b	2140
$La_2O_3\cdot 11Al_2O_3$	c	a	2140
$LaVO_4\cdot 2H_2O$	c	p	2311
$La_2Hf_2O_7$	c	a	1143
La_2O_3/HfO_2	c	b	1143
La/Y	c	l	2360
LaY	g	lr	1050
$La_2O_3/CaO/ZrO_2$	non-aq	b	1511
La(III):Xylenol orange	aq	r	2456

Substance	State	Prop.	Ref.
84 - Curium			
Cm	c	a	1765
Cm(III):SCN^-	aq	r	1158
85 - Americium			
Am		z	D-52
Am-Na_2O-B_2O_3-NaCl		p	D-74
$AmCl^{++}$	c	r	1654
Am(III):Cl^-	c	r	1963
$AmCl_3$-aq HCl	c	nq	1527
Am(III):SO_4^{--}	c	r	1963
Am(III):NO_3^-	c	r	1654
Am(III):$C_2H_2O_4$ (oxalic acid)	c	r	1963
Am(III):SCN^-	c	r	1963
	aq	r	1158
$AmC_{24}P_3H_{36}O_{12}$	non-aq	r	1814
86 - Plutonium			
Pu		y	D-6
		y	D-56
		z	D-52
	liq	km	1920
		l	1177
	g	w	1113
Pu-aq HCl	c	nq	1527
PuO_2	c	v	1342
$PuCl_3$-aq HCl	c	nq	1527
Pu(IV):SO_4^{--}	c	r	1653
PuN	c	l	1177
Pu(III):NO_3^-	aq	r	1357
Pu(IV):NO_3^-	c	r	1653
PuC	c	t	1563
Pu/C	c	z	1820
Pu(III):$C_2H_4O_2$ (acetic acid)	aq	r	2040
Pu(IV):$C_2H_4O_2$ (acetic acid)	c	r	1977
Pu(III):$C_4H_6O_6$ (tartaric acid)	aq	r	2040
Pu(III):$C_6H_8O_7$ (citric acid)	aq	r	2040
$Pu(NO_3)_3\cdot 3(CH_3CH_2CH_2CH_2)_4PO_4$	aq	r	1357

Substance	State	Prop.	Ref.
Pu/Ga	non-aq	b	2019
Pu/Zn	c	s	2529
$PuZn_{12}$	c	s	2529
87 - Neptunium			
Np		z	D-52
	liq	km	1920
NpO_2Cl	aq	r	2519
NpO_2NO_3	aq	r	2519
$Np(IV):(C_2O_4)_2 \cdot 6H_2O$ (oxalate)	c	p	1434
$Np(V):Cr(H_2O)_5^{+++}$	aq	l	1085
88 - Uranium			
U	c	a	1221
		amt	1270
		amt	1571
$U-H_2$		w	D-51
U-Bi	liq	sp	D-62
U-fissium alloy	c	amt	1270
U^{++++}	aq	s	1214
U(VI)	aq	s	1560
U/O	c	pz	1828
UO_2		q	A-44
	c	v	2145
		y	1447
$UO_2-ThO_2-ZrO_2$	c	p	1805
UO_2-U	liq	b	1512
UO_2^+	aq	n	2074
UO_2^{++}	aq	n	A-21
		s	1214
		s	1254
		s	1256
		z	1253
$UO_{2+x}-La_2O_3$		l	D-30
UO_3		q	A-21
		q	A-44
	c	k	1849
		q	2074
$UO_3-U_3O_8$		ln	A-21
$U_2O_5^{++}$	aq	z	2192
U_3O_8		l	2354
		q	A-44
	c	v	2146
$U_3O_8 \cdot xH_2O$	c	p	1965
U_4O_9		l	2354
$U(IV):OH^-$	aq	r	1102
$UO_2(II):OH^-$	aq	r	2494
$UO_2(OH)UO_2^{+++}$	c	r	1981
$U(IV):F^-$	aq	r	1685
UF_3		s	D-44
UF_4		n	A-7
UF_6	c	k	2261
UF_6-BrF_5	g	h	1761
$UClF_3$	c	w	2100
UCl_2F_2	c	w	2100
UCl_3F	c	w	2100
UBr_3	c	v	2355
US		v	B-34
$US_{1.9}$		v	B-34
US_2		v	B-34
US_3		v	B-34
UO_2SO_4	c	t	1250
$UO_2SO_4 \cdot nH_2O$	c	lt	1250
$U(SO_4)_2 \cdot nH_2O$	c	n	1790
USe_2		v	B-34
UN		mv	B-9
	c	n	A-36
		n	1683
$UN_{1.53}$		v	B-9
U_2N_3	c	l	2447
$U(IV):NO_3^-$	aq	r	1102
$UO_2(NO_3)_2$		q	A-21
	c	p	1260
$UO_2(NO_3)_2-H_2O$	c	q	1372
$UO_2(NO_3)_2-(C_4H_9O)_3PO$	c	q	2444
$UO_2NO_3 \cdot 3H_2O$	c	nq	2074
$UO_2(NO_3)_2 \cdot 6H_2O$	c	nq	2074
	non-aq	p	1827
$(NH_4)_2UO_4$		q	A-21
UP		mv	B-9
	c	l	1570
$UO_2^{++}:P_2H_2O_5^{--}$	aq	r	2306
U/Bi	non-aq	p	2445

Substance	State	Prop.	Ref.
UC		p	D-62
		tv	2265
	c	t	2442
		v	1781
		z	1676
U/C	c	b	1675
		z	1820
UC_2		p	D-62
		s	D-44
	c	t	2442
		v	1781
U_2C_3		p	D-62
	c	v	1781
$UC_2(CH)_2UC_2^{++}$	c	r	1981
$UO_2^{++}:C_2H_4O_2$ (acetic acid)	c	r	1974
$UO_2^{++}:C_4H_6O_5$ (malic acid)	aq	r	2309
$UO_2^{++}:C_4H_6O_6$ (tartaric acid)	aq	r	2309
$UO_2^{++}:C_{17}H_{16}O_6$-aq dioxane (2-hydroxy-2',4',4-trimethoxybenzil)		r	1725
$UO_2^{++}:C_7SH_6O_6$ (5-sulfosalicylic acid)	c	r	1433
$UO_2^{++}:C_4NH_7O_4$ (iminodiacetic acid)	c	r	1433
$UO_2^{++}:C_6NH_{11}O_5$ (N-hydroxyethylimenodiacetic acid)	c	r	1433
$UO_2^{++}:C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	r	1252
$U(IV):C_{13}NH_{11}O$ (salicylideneaminobenzene)	non-aq	r	2594
$U(IV):C_{13}NH_{11}O_2$ (o-aalicylideneaminophenol)	non-aq	r	2594
$UO_2(NO_3)_2 \cdot 2(C_4H_9)_3PO_4$	c	q	1459
	liq	n	2444
U/Re	non-aq	b	1308
URe_2	c	a	1308
U/Mo	non-aq	b	1223
U/Nb/Cr	non-aq	b	1309
$UO_3 \cdot 3Y_2O_3$	c	k	1849
$UO_3 \cdot 3Lu_2O_3$	c	k	1849
$UO_3 \cdot 3Ho_2O_3$	c	k	1849
$UO_3 \cdot 3Gd_2O_3$	c	k	1849
$UO_3 \cdot 3Nd_2O_3$	c	k	1849
$UO_3 \cdot 3La_2O_3$	c	k	1849

Substance	State	Prop.	Ref.
89 - Protactinium			
$Pa\text{-}Th(NO_3)_4\text{-}HNO$	c	p	1815
$Pa(V):SO_4^{--}$	aq	r	1425
$Pa(V):NO_3^{-}$	aq	r	1425
$Pa(II):C_4H_8O_3$ (α-hydroxyisobutyric acid)	aq	r	1382
90 - Thorium			
Th	c	a	2064
	g	ln	1610
ThO_2	c	km	2472
		s	2029
$ThO_2\text{-}UO_2\text{-}ZrO_2$	c	p	1805
$Th(IV):OH^{-}$	aq	r	2169
$ThCl_4$		m	B-31
	non-aq	s	1689
$Th(NO_3)_4$		b	D-8
Th/C	c	z	1820
ThC_2	c	a	2089
		kl	2487
		km	1610
		n	1897
		s	1130
$Th(IV):C_7SH_5O_5$ (tropolone-5-sulfonic acid)	aq	r	1713
$Th(IV):(NO_3^{-})(C_6H_9O_3)$ (acetoacetone)	aq	r	1705
$Th(IV):C_{18}N_4H_{30}O_{12}$ (triethylenetetraminehexaacetic acid)	aq	r	2218
$Th(IV):C_{10}NS_2H_9O_8$ (1-nitroso-2-naphthol-3,6-disulfonic acid)	c	r	1637
$Th(IV):C_8PH_{19}O_4$ (dibutylphosphate)	aq	r	2222
$ThSiO_4$	c	a	2234
Th borides		s	D-48
ThPd	c	a	1227
Th/Pd	non-aq	b	1227
$ThPd_3$	c	a	1227
Th_2Pd	c	a	1227
Th/Zr/B/C		b	B-27
Th/U/C		b	B-27
Th/U/B/C		b	B-27
Th/U/Al	c	v	1405
Th(IV):chromotrope 2R	aq	r	2576

Substance	State	Prop.	Ref.
92 - Beryllium			
Be		k	C-31
	c	km	1857
	liq	r	1119
BeO		v	B-35
		y	B-27
	c	l	1952
Be_2O	g	n	2198
Be-H-O	liq	n	1198
$Be(II):OH^-$	aq	r	2170
$Be(OH)_2$	c	r	1324
BeF		kn	A-65
	liq	n	1198
BeF_2		km	C-31
	c	n	1818
	liq	n	1198
	g	z	1528
BeCl	g	nr	1119
$BeCl_2$		l	C-31
	c	k	2531
	liq	k	2531
	g	r	1119
		z	1528
Be_3N_2		tv	B-35
	c	ln	1914
$(NH_4)_2BeF_4$-aq C_3H_7OH	c	p	2052
$(NH_4)_2BeF_4$-aq C_4H_9OH	c	p	2052
Be/Bi		b	D-45
BeC_2	g	w	1979
Be_2C	c	l	1952
$Be(II):C_7H_6O_3$ (salicylic acid)	aq	r	2423
$Be(II):C_{17}H_{16}O_6$-aq dioxane (2-hydroxy-2',4',4-trimethoxybenzil)		r	1725
$BeO \cdot SiO_2$	c	nz	2201
$2BeO \cdot SiO_2$	c	nz	2201
$Be(BO_2)_2$	g	n	1910
$B_2O_3 \cdot 3BeO$	c	n	C-15
$BeO \cdot Al_2O_3$		tv	B-35
$BeO \cdot 3Al_2O_3$		v	B-35
Be/W	non-aq	b	1272
$Be_{13}U$	c	q	1170
Be/U/C		b	B-27
Be/Th/C		b	B-27
Be compounds	g	z	2583
93 - Magnesium			
Mg		l	C-24
		m	B-31
		y	A-2
	c	l	1770
Mg-HCl	c	q	2280
Mg-aq HCl	c	q	1527
Mg^+	aq	s	1400
MgO		lm	C-24
	c	s	2029
		z	1546
MgO-aq HCl	c	q	2340
MgO-aq HCl, aq HF	c	q	2340
$MgO-B_2O_3-SiO_2$	non-aq	b	1488
$MgO-Al_2O_3$	c	b	1602
MgO-CuO	non-aq	b	1485
$MgO-Cr_2O_3-Fe_2O_3$	c	b	2238
$MgO-MgCr_2O_4$	non-aq	b	1216
$MgO-BaO-P_2O_5$	c	b	1264
MgO_2		w	D-55
MgH_2	c	n	1997
$Mg(OH)_2$		z	A-51
$Mg(OH)_2-H_2O$	c	p	2482
MgF_2		l	C-31
	c	am	2370
		k	1181
		km	1129
		km	1956
		km	2331
		m	2550
		n	1943
	liq	k	1181
	g	z	1528
$MgCl_2$	c	k	1181
		m	2550
	liq	km	2531
	g	z	1528
$MgCl_2$-aq HCl	c	p	2164
$MgCl_2-MgBr_2$	aq	q	A-49
$MgCl_2-CaCl_2$	aq	q	A-49

Substance	State	Prop.	Ref.
$MgCl_2$-$CaBr_2$	aq	q	A-49
$MgCl_2$-$SrCl_2$	aq	q	A-49
$MgCl_2$-$BaCl_2$	aq	q	A-49
$MgCl_2$-LiCl		s	D-44
$Mg(ClO_4)_2$	c	q	2592
		qt	1873
$Mg(ClO_4)_2$-alcohols	c	q	2568
$MgBr_2$	c	m	2550
$MgBr_2$-$MgCl_2$	aq	q	A-49
$MgBr_2$-$CaCl_2$	aq	q	A-49
$MgBr_2$-$SrCl_2$	aq	q	A-49
MgI_2	c	m	2550
$MgSO_3$-$Mg(HSO_3)_2$-$MgSO_4$	c	l	1723
$MgSO_4$	aq	h	1328
$MgSO_4$-$Mg(HSO_3)_2$-$MgSO_3$	c	l	1723
$MgSO_4 \cdot nH_2O$	c	l	1987
$Mg(HSO_3)_2$-$MgSO_3$-$MgSO_4$	c	l	1723
$3Mg(OH)_2 \cdot MgSO_4 \cdot 8H_2O$	c	nq	2114
$Mg(NO_3)_2$-KNO_3		b	D-15
$Mg(NO_3)_2 \cdot \frac{1}{2}H_2O$-aq HNO_3	c	q	2436
$(NH_4)_2Mg(SO_4)_2 \cdot nH_2O$	c	l	1985
Mg(II):$P_3O_{10}^{-----}$	aq	r	2266
Mg_3Sb_2	c	s	2015
Mg/Bi		b	D-45
$MgCO_3$		z	A-51
$MgCO_3 \cdot 3H_2O$		z	A-51
$MgCO_3 \cdot 5H_2O$		z	A-51
Mg(II):$C_2H_4O_2$ (acetic acid)	aq	r	2104
Mg(II):$C_6H_8O_6$ (tricarballylic acid)	c	r	1251
Mg(II):$C_6H_8O_7$ (citric acid)	c	r	1251
Mg(II):$C_7H_6O_2$ (salicylaldehyde)	aq	r	2167
Mg(II):$C_7H_6O_3$ (salicylic acid)	aq	r	2167
Mg(II):$C_7H_8O_2$ (salicylalcohol)	aq	r	2167
Mg(II):$C_9H_{10}O_3$ (ethylsalicylate)	aq	r	2167

Substance	State	Prop.	Ref.
Mg(II):$C_{17}H_{16}O_6$-aq dioxane (2-hydroxy-2',4',4-trimethoxybenzil)		r	1725
$MgCO_3 \cdot Mg(OH)_2 \cdot 3H_2O$		z	A-51
$3MgCO_3 \cdot Mg(OH)_2 \cdot 3H_2O$		z	A-51
Mg(II):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2105
		r	2269
Mg(II):$C_7NH_5O_5$ (4-hydroxydipicolinic acid)	c	r	1773
Mg(II):$C_7NH_7O_2$ (salicylamide)	aq	r	2167
Mg(II):$C_7NH_{11}O_5$ (aminoacetone-N,N-diacetic acid)	aq	r	1334
Mg(II):$C_7N_2H_6O_4$ (4-aminodipicolinic acid)	c	r	1773
Mg(II):$C_8N_2H_8O_4$ (4-(N-methylamino)-dipicolinic acid)	c	r	1773
Mg(II):$C_9N_2H_{10}O_4$ (4-(N,N-dimethylamino)-dipicolinic acid)	c	r	1773
Mg(II):$C_{10}N_2H_6O_8$ (ethylenediaminetetraacetic acid)	c	nr	1635
Mg(II):$C_{13}N_2H_{10}O_4$ (4-(N-phenylamino)-dipicolinic acid)	c	r	1773
Mg(II):$C_{14}N_2H_{22}O_8$ (<u>trans</u>-1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
Mg(II):$C_{18}N_4H_{30}O_{12}$ (triethylenetetraminehexaacetic acid)	aq	r	2218
Mg(II):$C_7NClH_4O_4$ (4-chlorodipicolinic acid)	c	r	1773
MgSi	c	qs	1854
Mg_2Si	non-aq	s	2376
Mg_2SiO_4	c	a	1267
Mg/Sn	non-aq	s	1346
		s	2024
MgPb	c	qs	1854
Mg/Pb	liq	bp	D-65
Mg/Al	non-aq	s	2024
$MgAl_2O_4$	c	n	2073
Mg/Al/Bi		b	D-45
$Mg_2Al_4Si_5O_{18}$	c	v	1531
Mg/Ga	liq	s	A-26
Mg/In	liq	s	A-26
Mg/Zn	liq	s	D-60
	non-aq	p	2421
		s	2024

Substance	State	Prop.	Ref.
$MgZn_2$		m	B-31
		n	A-54
Mg/Cd	non-aq	s	1348
		s	2024
Mg/Hg-Au/Hg		q	A-23
$MgCu_3O_4$	c	l	1485
MgAg		y	B-33
MgNi	c	qs	1854
$MgFe_2O_4$	c	r	1856
$MgCr_2O_4$-MgO	non-aq	b	1216
$MgTiO_3$	c	n	2535
Mg/Zr	c	p	D-64
Mg_2Y		pq	D-59
$Mg_{24}Y_5$		pq	D-59
Mg/Lu		p	D-59
Mg/Tm		p	D-59
Mg/Er		p	D-59
Mg/Ho		p	D-59
Mg/Dy		p	D-59
Mg/Tb		p	D-59
Mg/Gd		p	D-59
Mg/Eu		p	D-59
Mg/Nd		p	D-59
Mg/Pr		p	D-59
Mg/Ce		p	D-59
$Mg_2Ce_2N_{12}O_{36}$	c	v	1474
Mg/La		p	D-59
$Mg_2La_2N_{12}O_{36}\cdot 24H_2O$	c	v	1474
$MgUO_4$	c	l	1217
		l	1663
Mg_2Th	c	l	2147

94 - Calcium

Substance	State	Prop.	Ref.
Ca		l	C-24
	c	n	1722
Ca^+	aq	s	1400
Ca^{++}		z	A-51
CaO		lm	C-24
		n	A-3
CaO	c	l	2420
		m	1108
		n	1553
		r	1564
		s	1275
		s	2029
		z	1546
	g	m	1095
CaO-P_2O_5	aq	qv	A-68
CaO-Al_2O_3	c	b	1392
CaO-Cr_2O_3	non-aq	b	1561
CaO-La_2O_3-ZrO_2	non-aq	b	1511
CaO-BaO-Al_2O_3	non-aq	b	1331
CaO-slag	non-aq	p	1233
CaO_2		w	D-55
Ca_2O		l	C-24
Ca_2O_2		l	C-24
$Ca(OH)_2$	c	z	2192
	aq	nq	A-46
$Ca(OH)_2$-CaF_2-$CaCO_3$	c	b	2047
CaF_2	g	z	1528
CaF_2-Al_2O_3	c	b	2409
CaF_2-$Ca(OH)_2$-$CaCO_3$	c	b	2047
$CaCl_2$	c	p	2380
	liq	k	1138
		k	1616
	g	z	1528
$CaCl_2$-$MgCl_2$	aq	q	A-49
$CaCl_2$-$MgBr_2$	aq	q	A-49
$CaCl_2$-$CaBr_2$	aq	q	A-49
$CaCl_2SrCl_2$	aq	q	A-49
$CaCl_2$-$BaCl_2$	aq	q	A-49
$CaCl_2$-Na_2TiF_6	c	b	2220
$CaCl_2$-KCl		s	D-44
$Ca(ClO_4)_2$-alcohols	c	q	2568
$CaBr_2$	c	mt	1031
	liq	mt	1031
$CaBr_2$-$MgCl_2$	aq	q	A-49
$CaBr_2$-$CaCl_2$	aq	q	A-49
$Ca(IO_3)_2$		l	D-9
		n	A-3
		v	B-4
$Ca_5(IO_6)_2$		n	A-3
		v	B-4

Substance	State	Prop.	Ref.
CaS		l	C-20
	c	l	2550
	g	m	1095
CaS-slag	non-aq	p	1233
$CaSO_4$-aq NaCl	c	p	1112
$CaSO_4 \cdot nH_2O$	c	p	1641
$CaSO_4 \cdot \frac{1}{2}H_2O$-HCl	c	q	1184
$CaSO_4 \cdot \frac{1}{2}H_2O$-aq NaCl	c	p	1112
$CaSO_4 \cdot 2H_2O$	c	q	2320
$CaSO_4 \cdot 2H_2O$-HCl	c	q	1197
$CaSO_4 \cdot 2H_2O$-aq NaCl	c	p	1112
$Ca(NO_3)_2$-aq HNO_3	c	q	2436
$Ca(NO_3)_2$-$NaNO_3$		b	D-15
$Ca(NO_3)_2$-KNO_3		b	D-15
$Ca(NO_3)_2$-$CsNO_3$		b	D-15
Ca(II):$P_2O_7^{----}$	aq	r	2516
Ca(II):$P_3O_{10}^{-----}$	aq	r	2266
		r	2516
$Ca_3(PO_4)_2$-$C_6H_8O_7$ (citric acid)	c	p	1744
$4CaO \cdot P_2O_5$	c	l	2420
		s	1275
$CaHPO_4$		v	B-38
	c	v	2083
$CaHPO_4 \cdot 2H_2O$		v	B-38
	c	v	2082
Ca/Bi		b	D-45
CaC	c	n	1722
CaC_2	c	lm	2466
$CaCO_3$		z	A-51
$CaCO_3$-H_2O	c	p	1160
		p	2461
$CaCO_3$-$Ca(OH)_2$-CaF_2	c	b	2047
Ca(II):$C_2H_2O_3$ (glyoxylic acid)	aq	r	1364
Ca(II):$C_2H_2O_4$ (oxalic acid)	aq	p	2251
Ca(II):$C_2H_4O_2$ (acetic acid)	aq	r	2104
Ca(II):$C_4H_6O_6$ (tartaric acid)	aq	r	2216
Ca(II):$C_6H_8O_6$ (tricarballylic acid)	c	r	1251
Ca(II):$C_6H_8O_7$ (citric acid)	c	r	1251

Substance	State	Prop.	Ref.
Ca(II):$C_6NH_9O_6$ (nitrilotriacetic acid)	aq	n	2553
		r	2269
Ca(II):$C_7NH_5O_5$ (4-hydroxydipicolinic acid)	c	r	1773
Ca(II):$C_7NH_{11}O_5$ (aminoacetone-N,N-diacetic acid	aq	r	1334
Ca(II):$C_7N_2H_6O_4$ (4-aminodipicolinic acid)	c	r	1773
Ca(II):$C_8N_2H_8O_4$ (4-(N-methylamino)-dipicolinic acid)	c	r	1773
Ca(II):$C_9N_2H_{10}O_4$ (4-(N,N-dimethylamino)-dipicolinic acid)	c	r	1773
Ca(II):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
		r	1252
Ca(II):$C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
Ca(II):$C_{18}N_4H_{30}O_{12}$ (triethylenetetraminehexaacetic acid)	aq	r	2218
Ca(II):$C_7NClH_4O_4$ (4-chlorodipicolinic acid)	c	r	1773
$2CaO \cdot SiO_2$	c	a	1276
Ca_2SiO_4-Ca_2GeO_4	c	b	1380
Ca_3SiO_3	c	n	1837
Ca_2GeO_4-Ca_2SiO_4	c	b	1380
CaC_4B_2	c	a	2512
$CaO \cdot Al_2O_3$-H_2O	c	p	1311
$CaO \cdot Al_2O_3$-aq NaOH	c	p	1311
$CaO \cdot Al_2O_3$-aq Na_2CO_3	c	p	1311
$CaO \cdot Al_2O_3$-aq NaOH,Na_2CO_3	c	p	1311
$3CaO \cdot Al_2O_3$	c	n	1553
	aq	n	1076
$3CaO \cdot Al_2O_3 \cdot 6H_2O$	c	n	A-61
$3CaO \cdot Al_2O_3 \cdot 6H_2O$-HCl	c	q	1197
$5CaO \cdot 3Al_2O_3$	c	a	1392
$3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot nH_2O$-HCl	c	qn	1197
$CaAlH(PO_3)_2 \cdot 6H_2O$	c	p	2068
$3CaO \cdot Al_2O_3 \cdot 3CaCO_3 \cdot 30H_2O$	c	nq	A-61
$Ca_2Al_2SiO_7$	c	v	1531
Ca/Hg	c	pq	1921
$CaFe_2O_4$	c	r	1236
$CaFe_3O_5$	c	r	1236

Substance	State	Prop.	Ref.
$CaFe_5O_7$	c	r	1236
$4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$	c	n	1463
Ca/Mn	non-aq	b	1294
$CaMoO_3$		s	D-76
$CaMoO_4$		s	D-76
$CaWO_4$		s	D-76
$3CaO{\cdot}WO_3$		s	D-76
$CaTiO_3$		s	D-76
	c	n	2536
	non-aq	s	2590
$CaZrO_3$		t	B-40
$CaMg_2$		m	B-31
		n	A-52
		n	A-54
		t	B-29
$CaMg(CO_3)_2$		z	A-51
$CaMgSi_2O_7$	c	v	1531
$Ca_3MgSi_2O_8$	c	v	1531

95 - Strontium

Substance	State	Prop.	Ref.
Sr		l	C-24
	c	k	1330
		km	1188
	aq	r	1060
	ads	k	C-24
$Sr\text{-}Na_2O\text{-}B_2O_3\text{-}NaCl$		p	D-74
Sr^+	aq	s	1400
SrO		lm	C-24
	c	z	1546
	g	m	1095
SrO_2		w	D-55
Sr_2O		l	C-24
Sr_2O_2		l	C-24
SrF_2		k	C-20
		l	C-35
	c	am	2370
		km	1956
		v	1245
$SrCl_2$		l	C-31
		l	C-35
	c	mt	1031
		v	1245
	liq	k	1138
		k	1616
		mt	1031
$SrCl_2\text{-}MgCl_2$	aq	q	A-49
$SrCl_2\text{-}MgBr_2$	aq	q	A-49
$SrCl_2\text{-}CaCl_2$	aq	q	A-49
$SrCl_2\text{-}BaCl_2$	aq	q	A-49
$SrCl_2\text{-}LiCl$		s	D-44
$SrCl_2\text{-}KCl$	c	b	2474
$SrCl_2\text{-}RbCl$	c	b	2474
$SrCl_2\text{-}CsCl$	c	b	2474
$Sr(ClO_4)_2$	c	qt	1873
$Sr(ClO_4)_2$-alcohols	c	q	2568
SrS	c	l	2550
SrS	g	m	1095
SrSe		l	C-14
$Sr(NO_2,NO_3)\text{-}Na(NO_2,NO_3)$	c	b	1368
$Sr(NO_2,NO_3)\text{-}K(NO_2,NO_3)$	c	b	1368
$Sr(NO_3)_2\text{-}H_2O$	c	q	1145
$Sr(NO_3)_2\text{-}KNO_3$		b	D-15
$Sr(II):P_3O_{10}^{-----}$	aq	r	2266
$Sr_3(PO_4)_2\text{-}C_6H_8O_7$ (citric acid)	c	p	1744
$SrHPO_4\text{-}H_2O$	c	np	1647
$SrCO_3$	c	n	1131
$Sr(II):C_2H_4O_2$ (acetic acid)	aq	r	2104
$SrC_6NH_6O_6^-$ (nitrilotriacetate)	aq	n	2553
$Sr(II):C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2269
$Sr(II):C_7NH_5O_5$ (4-hydroxydipicolinic acid)	c	r	1773
$Sr(II):C_7NH_{11}O_5$ (aminoacetone-N,N-diacetic acid)	aq	r	1334
$Sr(II):C_7N_2H_6O_4$ (4-aminodipicolinic acid)	c	r	1773
$Sr(II):C_8N_2H_8O_4$ (4-(N-methylamino)-dipicolinic acid)	c	r	1773
$Sr(II):C_9N_2H_{10}O_4$ (4-(N,N-dimethylamino)-dipicolinic acid)	c	r	1773
$Sr(II):C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
$Sr(II):C_{13}N_2H_{10}O_4$ (4-(N-phenylamino)-dipicolinic acid)	c	r	1773

Substance	State	Prop.	Ref.
Sr(II):$C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocylcohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
Sr(II):$C_7NClH_4O_4$ (4-chlorodipicolinic acid)	c	r	1773
SrB_2O_4	c	a	1424
SrB_4O_7	c	a	1424
$Sr_2B_2O_5$	c	a	1424
SrC_4B_2	c	a	2512
$3SrO \cdot B_2O_3 \cdot 3C_5H_6O_6 \cdot 12H_2O$	c	a	2232
$3SrO \cdot 2(NH_4)_2O \cdot B_2O_3 \cdot 3C_5H_6O_6 \cdot 16H_2O$	c	a	2232
$2SrO \cdot 3(NH_4)_2O \cdot B_2O_3 \cdot 3C_5H_6O_6 \cdot 12H_2O$	c	a	2232
$SrO \cdot 6Fe_2O_3$	c	nq	1755
7/5 $SrO \cdot Fe_2O_3 \cdot HCl$	c	nq	1755
$2SrO \cdot Fe_2O_3 \cdot HCl$	c	nq	1755
$3SrO \cdot Fe_2O_3 \cdot HCl$	c	nq	1755
$SrMoO_3$	c	n	1524
$SrTiO_3$	c	n	2536
$SrZrO_3$	c	n	1131

96 - Barium

Substance	State	Prop.	Ref.
Ba	ads	k	C-24
Ba-HCl		n	A-78
Ba-Na_2O-B_2O_3-NaCl		p	D-74
Ba^+	aq	s	1400
BaO		lm	C-24
	c	s	2029
		z	1546
	g	m	1095
BaO-CO_2	c	h	1101
BaO-ZnO-P_2O_5	c	b	1264
BaO-MgO-P_2O_5	c	b	1264
BaO-CaO-Al_2O_3	non-aq	b	1331
BaO_2		w	D-55
Ba_2O		l	C-24
Ba_2O_2		l	C-24
BaH_2		n	A-78
BaH_2-H_2O		n	A-78
$Ba(OH)_2$	c	l	1132
	liq	l	1132
	aq	nq	A-46
$Ba(OH)_2 \cdot xH_2O$	c	l	1132
	liq	l	1132
BaF	c	l	2287
BaF_2		k	C-20
		l	C-31
		l	C-35
	c	am	2370
		km	1956
		km	2129
BaCl	c	l	2328
$BaCl_2$		l	C-31
	c	mt	1031
	liq	k	1138
		mt	1031
$BaCl_2$-$MgCl_2$	aq	q	A-49
$BaCl_2$-$CaCl_2$	aq	q	A-49
$BaCl_2$-$SrCl_2$	aq	q	A-49
$BaCl_2$-Ba_3N_2	non-aq	b	1771
$BaCl_2$-KNO_3		b	D-8
$BaCl_2 \cdot nH_2O$	c	l	1015
$BaCl_2 \cdot 2H_2O$	c	n	1575
$Ba(ClO_4)_2$-alcohols	c	q	2568
$BaBr_2$	c	mt	1031
	liq	mt	1031
$BaBr_2$-Ba_3N_2	non-aq	b	1771
BaI_2		lm	C-24
BaI_2-Ba_3N_2	non-aq	b	1771
BaS		l	C-20
	g	m	1095
Ba_3N_2-H_2O	c	q	1771
Ba_3N_2-$BaCl_2$	non-aq	b	1771
Ba_3N_2-$BaBr_2$	non-aq	b	1771
Ba_3N_2-BaI_2	non-aq	b	1771
$Ba(NO_3)_2$-H_2O	c	q	1145
$Ba(NO_3)_2$-$NaNO_3$		b	D-15
$Ba(NO_3)_2$-$RbNO_3$		b	D-15
$Ba(NO_3)_2 \cdot NH_3$	c	l	2330
Ba_2NCl-H_2O	c	q	1771
Ba_2NBr-H_2O	c	q	1771
Ba_6NI_9-H_2O	c	q	1771
$Ba_3(PO_4)_2$-$C_6H_8O_7$ (citric acid)	c	p	1744

Substance	State	Prop.	Ref.
$Ba(II):P_3O_{10}^{-----}$	aq	r	2266
BaC_2	c	lm	2467
$BaCO_3$	c	n	1131
$BaCO_3-H_2O$	c	p	1453
$Ba(II):C_2H_4O_2$ (acetic acid)	aq	r	2104
$Ba(II):C_6H_8O_6$ (tricarballylic acid)	c	r	1251
$Ba(II):C_6H_8O_7$ (citric acid)	c	r	1251
$Ba_2XeO_6 \cdot 1.5\ H_2O \cdot 0.05\ BaCO_3-H_2O$	c	p	1316
$Ba(II):C_6NH_9O_6$ (nitrilotriacetic acid)	aq	r	2269
$Ba(II):C_7NH_5O_5$ (4-hydroxypicolinic acid)	c	r	1773
$Ba(II):C_7N_2H_6O_4$ (4-aminodipicolinic acid)	c	r	1773
$Ba(II):C_8N_2H_8O_4$ (4-(N-methylamino)-dipicolinic acid)	c	r	1773
$Ba(II):C_9N_2H_{10}O_4$ (4-(N,N-dimethylamino)-dipicolinic acid)	c	r	1773
$Ba(II):C_{10}N_2H_{16}O_8$ (ethylenediaminetetracetic acid)	c	nr	1635
$Ba(II):C_{13}N_2H_{10}O_4$ (4-(N-phenylamino)-dipicolinic acid)	c	r	1773
$Ba(II):C_{14}N_2H_{22}O_8$ (trans-1,2-diaminocyclohexane-N,N,N',N'-tetracetic acid)	c	nr	1635
$Ba(II):C_7NClH_4O_4$ (4-chlorodipicolinic acid)	c	r	1773
BaC_4B_2	c	a	2512
$Ba_3B_2C_{15}H_{18}O_{24} \cdot 5H_2O$	c	p	2230
$21BaO \cdot nFe_2O_3$	aq	r	1077
$BaMoO_3$	c	n	1524
$3BaO \cdot WO_3$		s	D-76
$BaTiO_3$	c	n	2536
$BaTiSi_3O_9$	c	y	2017
$BaZrO_3$	c	n	1131

97 - Radium

Substance	State	Prop.	Ref.
Ra^+	aq	s	1400

98 - Lithium

Substance	State	Prop.	Ref.
Li		k	C-31
	c	a	1278
		ik	1107
		km	1407
		q	1008
		v	2329
	liq	s	2569
		z	1285
	g	j	2587
Li-LiH		tv	2278
Li^+	aq	n	1063
Li_2O_2		w	D-55
LiH		v	B-35
	c	av	1320
		mtv	2278
	liq	av	1320
		mtv	2278
LiH-Li		tv	2278
LiOH	aq	r	1951
$LiOH \cdot H_2O$	c	km	1443
Li_4XeO_6	c	p	2189
LiF		q	A-11
		q	B-44
	c	l	1181
	liq	l	1181
$LiF-H_2O$		q	A-11
	c	q	1609
$LiF-AlF_3$		l	C-31
$LiF-LaF_3$	c	b	1391
LiF-NaF		bw	D-29
	liq	q	A-63
$LiHF_2$		q	A-11
LiCl		q	B-44
		t	B-35
	c	a	1901
		l	1181
		q	2592
		v	2379
	liq	l	1181
		s	1961
	non-aq	r	1345
$LiCl-(CH_3)_4NCl$		q	A-49
$LiCl-CrCl_2$	non-aq	b	2565
$LiCl-MgCl_2$		s	D-44
$LiCl-SrCl_2$		s	D-44

Substance	State	Prop.	Ref.
$LiCl-LiNO_3$		q	A-79
$LiCl-NaCl$	aq	q	A-49
		q	1916
$LiCl-Na_2TiF_6$	c	b	2220
$LiCl-KCl$		t	B-35
	aq	q	A-49
$LiCl-K_2TiF_6$	c	b	2220
$LiCl-CsNO_3$		q	A-79
$LiClO_3$	c	a	1901
		amqv	1851
	liq	amqv	1851
$LiClO_3-LiNO_3$	c	qv	1851
	liq	qv	1851
$LiClO_4$	aq	v	A-79
$LiClO_4-(CH_3)_2SO_2$		p	2476
$LiClO_4$-alcohols	c	q	2568
$LiBr$	non-aq	r	1345
Li_2SO_4		vt	B-43
	c	h	1492
		q	1185
	aq	h	1328
$Li_2SO_4-H_2O$	c	p	2479
$Li_2SO_4 \cdot H_2O$	c	km	1443
$LiNO_3$		b	D-8
	g	l	C-15
$LiNO_3-AgNO_3$		i	D-22
$LiNO_3-KNO_3$		b	D-8
$Li_2(NO_2)_2$	g	l	C-15
$Li_2(NO_3)_2$	g	l	C-15
LiH_2PO_3	c	a	2045
$LiH_2PO_3 \cdot H_3PO_3$	c	a	2045
$Li_2HPO_3-H_3PO_3-H_2O$	c	p	2045
$(Li_2HPO_3)_2 \cdot H_3PO_3$	c	a	2045
Li/Bi	c	s	2094
Li_3Bi	c	s	2094
Li_2CO_3	liq	l	1006
$Li_2CO_3-K_2CO_3$		tm	B-38
	c	t	2304
	liq	t	2304
$LiC_2H_3O_2$ (acetate)	aq	p	2417
$Li(I):C_2H_4O_2$ (acetic acid)	aq	r	2104

Substance	State	Prop.	Ref.
$Li_3C_4H_2O_4 \cdot H_3TeO_6$	c	r	1190
$LiC_2H_5:N(C_2H_5)_3$	c	r	1315
$LiNO_3 \cdot 2CO(NH_2)_2$	c	a	1793
$Li(I):C_9NH_7O$ (8-quinolinol)	non-aq	r	2547
$Li(I):C_{10}N_2H_{16}O_8$ (ethylenediaminetetraacetic acid)	aq	r	2041
$LiSCN$	c	m	1079
Li/Si	non-aq	p	1578
$Li_2O \cdot 3SiO_2$	c	v	B-34
Li_2SiF_6	c	l	1938
$Li_2 \cdot 7GeO_2$	c	a	2255
$2Li_2O \cdot GeO_2$	c	a	2255
$3Li_2O \cdot 2GeO_2$	c	a	2255
$3Li_2O \cdot 8GeO_2$	c	a	2255
$LiAlO_2$		l	C-31
$LiAl_5O_8$	c	a	2090
$LiAlH_4$		v	B-35
	c	q	1008
Li_3AlF_6		t	B-35
	c	n	A-7
Li/Ni	non-aq	p	1578
Li/Fe	non-aq	p	1578
$LiCl \cdot FeCl_3-C_5NH_5$	non-aq	r	2579
$LiCl \cdot FeCl_3-(C_2H_5)_2O$	non-aq	r	2579
Li/Cr	non-aq	p	1578
Li/Mo	non-aq	p	1578
Li/W	non-aq	p	1578
Li/V	non-aq	p	1578
Li/Nb	non-aq	p	1578
Li/Ta	non-aq	p	1578
Li/Ti	non-aq	p	1578
Li_2TiO_3	c	n	2535
Li/Zr	non-aq	p	1578
Li_2ZrO_3	c	n	2095
$LiUO_2PO_4 \cdot 4H_2O-H_2O$	c	p	2477
Li/Be	non-aq	p	1578
$LiBeF_3$	g	p	C-15
Li_2BeF_4		n	A-7
		t	B-35
	g	l	C-15

Substance	State	Prop.	Ref.
Sodium - 99			
Na	c	ik	1107
		km	1407
		km	1872
		n	1485
		t	1248
	liq	q	1045
		s	2569
		z	1285
	g	w	2457
		z	1803
$Na-H_2O$	liq	l	2560
Na-Zn	liq	p	1305
Na^+	aq	n	1063
Na/O	c	b	1946
NaO-Na	c	p	1739
Na_2O		v	B-35
$Na_2O-SeO_2-H_2O$	c	p	2205
$Na_2O-B_2O_3-NaCl$		b	D-74
Na_2O_2		w	D-55
NaH		v	B-34
	c	l	2559
NaOH		q	A-46
	aq	n	1083
		n	2280
		n	2492
		q	1120
$NaOH-H_2O$	c	l	2560
		p	2215
		p	2246
NaOH-Na	c	p	1739
$NaOH-KOH-H_2O$	c	p	2215
$NaOH-K_3Fe(CN)_6$-luminal		n	A-31
NaF		q	B-44
	c	a	2525
$NaF-ZrF_4$	c	r	1853
NaF-LiF		bw	D-29
	liq	q	A-63
NaF-KF		bw	D-29
Na_2F_2	c	n	1853
NaCl		q	B-44
	c	a	1619
		a	1901
		l	1147
		v	2379
		v	2489
	liq	s	1961
	amorph	q	1069
	aq	by	D-73
		q	A-46

Substance	State	Prop.	Ref.
NaCl-HCl		ps	D-70
$NaCl-HCl-H_2O$	c	p	2164
NaCl-AgCl		n	A-12
	liq	q	A-33
$NaCl-AgCl-PbCl_2$	non-aq	s	1694
$NaCl-CrCl_2$	non-aq	b	2565
NaCl-LiCl	aq	q	A-49
		q	1916
NaCl-NaBr	liq	q	A-33
	aq	q	A-49
$NaCl-NaNO_3$	liq	q	D-22
	aq	q	A-49
$NaCl-NaH_2PO_4-H_2O$	c	p	1359
NaCl-sodium polyborate	liq	b	D-74
$NaCl-Na_2TiF_6$	c	b	2220
NaCl-KCl		p	D-29
	aq	q	A-49
		q	A-79
		q	1916
$NaCl-KCl-H_2O$	c	p	1359
$NaCl-KCl-CdCl_2$	c	b	1831
	non-aq	bs	1498
NaCl-KBr	aq	q	A-49
$NaCl-KNO_3$	aq	q	A-49
$NaClO_3$	c	a	1901
		n	1338
$NaClO_4$	c	n	1534
		q	2592
	aq	v	A-79
NaBr		a	D-15
		ps	D-39
	c	r	1996
		v	2060
	aq	q	1799
NaBr-TlBr		b	D-15
NaBr-NaCl	liq	q	A-33
	aq	q	A-49
$NaBr-NaI-H_2O$	c	p	1350
NaBr-sodium polyborate	liq	b	D-74
NaBr-KCl	aq	q	A-49
NaBr-KBr	aq	q	A-49
$NaBr-KI-H_2O$	c	p	1350
NaBrO	g	n	1799

Substance	State	Prop.	Ref.
NaI		q	B-44
	c	q	2592
		v	1193
		v	2060
NaI-CH_3OH		v	B-45
NaI-$(CH_3)_2CO$		v	B-45
NaI-aq $C_4H_8O_2$		q	B-45
NaI-C_2NH_5O		q	A-19
NaI-C_3NH_7O		nq	A-19
NaI-sodium polyborate	liq	b	D-74
NaI-NaBr-H_2O	c	p	1350
NaI-$NaIO_3$-H_2O	c	p	1419
NaI-KBr-H_2O	c	p	1350
NaI-KI-H_2O	c	p	1350
$NaIO_3$	c	mv	2440
Na_2S	c	n	1534
Na_2SO_4		v	B-23
	c	h	1492
Na_2SO_4-KCl-K_2SO_4-H_2O	c	p	2051
$Na_2SO_4 \cdot 10H_2O$-Na_2SO_4-KCl-H_2O	c	p	1726
$NaSO_3F$	c	p	1204
$NaSeO_3$	c	n	1481
Na_2SeO_3	c	n	A-79
	aq	n	2131
Na_2SeO_4	c	n	1667
$Na_2SeO_4 \cdot 10H_2O$	c	n	1667
$NaH_3(SeO_3)_2$	c	v	2396
Na_2TeO_3	c	n	1679
$Na_2TeO_3 \cdot 5H_2O$	c	n	1679
$NaNO_2$		mv	B-14
	c	bv	1375
$Na(NO_2,NO_3)$-$Sr(NO_2,NO_3)$	c	b	1368
$NaNO_3$		b	D-8
	c	r	1996
	g	l	C-15
	amorph	q	1069
$NaNO_3$-$AgNO_3$		i	D-22
$NaNO_3$-$Ca(NO_3)_2$		b	D-15
$NaNO_3$-$Ba(NO_3)_2$		b	D-15
$NaNO_3$-NaCl	liq	q	D-22
	aq	q	A-49

Substance	State	Prop.	Ref.
$NaNO_3$-KNO_3	aq	q	A-49
$Na_2(NO_2)_2$	g	l	C-15
$Na_2(NO_3)_2$	g	l	C-15
$NaPO_3$	c	bt	2337
Na_3PO_4		v	B-9
$Na_3P_3O_9$		v	B-9
$Na_4P_2O_7$		v	B-9
	c	a	1573
$Na_4P_2O_7$-MoO_3	c	b	1573
$Na_5P_3O_{10}$		v	B-9
NaH_2PO_4		v	B-9
NaH_2PO_4-NaCl-H_2O	c	p	1359
NaH_2PO_4-KH_2PO_4-H_2O	c	p	1359
Na_2HPO_3-H_3PO_3-H_2O	c	p	2214
$Na_2H_2P_2O_7$		v	B-9
Na/Bi	non-aq	s	1310
Na_2CO_3	liq	l	1006
	aq	nq	A-46
Na_2CO_3-K_2CO_3		t	B-37
	c	amt	2304
	liq	amt	2304
$NaC_2H_3O_2$ (acetate)	c	b	1457
Na(I):$C_2H_4O_2$ (acetic acid)	aq	r	2104
$NaC_7H_5O_3$-H_2O (salicylate)	c	q	1094
$NaC_8H_7O_3$-(HCl-H_2O) (o-vanillan)	c	n	1114
$NaC_8H_7O_3$-(NaOH-H_2O) (o-vanillan)	c	q	1114
$Na_2C_4H_4O_5$ (diglycolate)	c	q	1100
NaCN		mv	B-14
$NaC_6N_3H_2O_7$-CH_3OH		mp	C-37
Na(I):$C_{10}N_2H_{16}O_8$ (ethylenediaminetetraacetic acid)	aq	r	2041
$Na_2C_7NH_3O_4$ (dipicolinate)	c	q	1100
NaSCN-alkali halides		q	D-22
Na/Si	amorph	v	2160
$Na_2O \cdot SiO_2$		v	B-34

Substance	State	Prop.	Ref.
$Na_2O \cdot SiO_3 - H_2O$		p	2313
$Na_2Si_2O_5$	c	a	2065
$Na_2O \cdot 3SiO_2$		v	B-34
Na silicates - alkali halides		q	A-51
NaPb	non-aq	s	1310
Na/Pb/Bi	non-aq	s	1310
$Na_2PbC_{10}H_{12}N_2O_8 \cdot 4H_2O$ (ethylenediaminetetraacetate)	c	p	1366
$NaB_5O_8 \cdot 5H_2O$	c	v	2111
	liq	v	2111
$Na_2B_4O_7$	c	a	1573
$Na_2O \cdot 2B_2O_3 \cdot 10H_2O$	c	b	1509
$NaB(OCH_3)_4$		v	B-19
Na/B/Si	amorph	v	2160
Na polyborate-NaCl		b	D-74
Na polyborate-NaBr		b	D-74
Na polyborate-NaI		b	D-74
Na/Al		p	D-29
$NaAlO_2$		v	B-34
$NaAlF_4$		m	C-15
$NaF:(AlF_3)$	liq	r	1036
$NaAlCl_4$		w	D-55
$NaAlSi_3O_8$-$KAlSi_3O_8$		b	A-51
		q	A-71
$ZnSO_4 \cdot Na_2SO_4 \cdot 2H_2O$	c	l	1015
$Na_2ZnC_{10}H_{12}N_2O_8 \cdot 4H_2O$ (ethylenediaminetetraacetate)	c	p	1366
$Na_2CdC_{10}H_{12}N_2O_8 \cdot 4H_2O$ (ethylenediaminetetraacetate)	c	p	1366
$Na_2CuC_{10}H_{12}N_2O_8 \cdot 4H_2O$ (ethylenediaminetetraacetate)	c	p	1366
$NiSO_4 \cdot Na_2SO_4 \cdot 2H_2O$	c	l	1015
$Na_2NiC_{10}H_{12}N_2O_8 \cdot 3H_2O$ (ethylenediaminetetraacetate)	c	p	1366
$CoSO_4 \cdot Na_2SO_4 \cdot 2H_2O$	c	l	1015
$Na_2CoC_{10}H_{12}N_2O_8 \cdot 4H_2O$ (ethylenediaminetetraacetate)	c	p	1366
$NaFeO_2$		v	B-35
$(Na_2O)_2FeO$	c	n	A-7
$NaFeCl_4$	g	ln	2079

Substance	State	Prop.	Ref.
$Pd(II):Na_2C_{16}AsN_2S_2H_{10}O_{10}$ (sodium 1-(o arsonophenylazo)-2-naphthol-3,6-disulfonate)("Thoron")	aq	r	2542
$Na_2SO_4 \cdot MnSO_4 \cdot 2H_2O$	c	l	1015
$Na_2MnC_{10}H_{12}N_2O_8 \cdot 6H_2O$ (ethylenediaminetetraacetate)	c	p	1366
$NaReO_4$	c	qv	2196
	aq	v	2515
Na_2CrO_3-H_2O	c	q	1211
Na_3CrCl_6	c	a	1619
$Na_3Cr(C_2O_4)_3 \cdot 3H_2O$-$H_2O$	c	q	1211
Na_2MoO_4	c	h	1492
$MoF_6 \cdot 2NaF$	c	l	2185
$Na_2MoO_2:C_2H_4O_3$ (glycolic acid)	aq	r	1411
$Na_2B_4O_7 \cdot MoO_3$	c	b	1573
Na_2WO_4	c	h	1492
	aq	q	1799
$WF_6 \cdot 2NaF$	c	l	2185
$Na_2WO_2:C_2H_4O_3$ (glycolic acid)	aq	r	1411
$3NaCl \cdot VCl_3$	c	n	2202
$NaCl \cdot NbCl_5$	c	ln	2373
		n	2202
$NaCl \cdot NbOCl_3$	c	l	1147
		n	2202
$NaTaCl_6$	c	n	1477
Na_2TiF_6-$CaCl_2$	c	b	2220
Na_2TiF_6-LiCl	c	b	2220
Na_2TiF_6-NaCl	c	b	2220
Na_2TiF_6-K_2TiF_6	c	b	2220
$NaZrF_5$	c	n	1853
Na_3ZrF_7	c	a	2247
Na_2ZrCl_6	c	l	1082
ScF_3NaF	c	b	2281
Na_2ScF_5	c	a	2281
$NaC_2H_3O_2 \cdot LaCl_3$ (acetate)	c	n	2136
$NaC_2H_3O_3 \cdot LaCl_3$ (glycolate)	c	n	2136
$UF_6 \cdot 2NaF$	c	l	2185

Substance	State	Prop.	Ref.
$NaUO_2PO_4 \cdot 3H_2O$	c	p	2477
Na_2BeF_4	c	a	1241
		a	2247
		kmv	1323
Na_2BeF_4-H_2O	c	mq	1404
$Na_2MgC_{10}H_{12}N_2O_8 \cdot 5H_2O$ (ethylenediaminetetraacetate)	c	p	1366
$Na_2TiF_6 \cdot 2CaCl_2$	c	a	2220
$2Na_2TiF_6 \cdot CaCl_2$	c	a	2220
$2Na_2TiF_6 \cdot 12CaCl_2$	c	a	2220
$Na_3Li_3Al_2F_{12}$	c	n	A-7
$Na_2TiF_6 \cdot LiCl$	c	a	2220
$Na_2TiF_6 \cdot 2LiCl$	c	a	2220
$Na_2TiF_6 \cdot 8LiCl$	c	a	2220
Sodium fozhazite		y	C-38

100 - Potassium

Substance	State	Prop.	Ref.
K		j	D-75
		t	B-42
	c	jkv	2438
		ik	1107
		km	1407
		km	1872
		n	1485
		v	1018
		v	1532
	liq	a	D-75
		kmv	1018
		q	1045
		s	2569
		z	1285
	g	j	1018
		z	1803
	aq	r	1060
	non-aq	r	1059
K^+	aq	n	1063
K/O	c	b	1946
KO_2		w	D-55
	c	n	A-49
KO_3		w	D-55
K_2O_2		w	D-55
	c	n	2561
KH	c	l	1413
KOH	aq	q	1087
KOH-H_2O	c	p	2215
KOH-NaOH-H_2O	c	p	2215
KF		q	B-44
	c	am	2525
		n	2027
	aq	p	1749
KF-C_2NH_5O		q	A-19
KF-NaF		bw	D-29
KCl-NaCl-K,Na feldspars		b	A-22
KF-KCl	aq	q	A-49
KF-KBr	aq	q	A-49
KF-$KC_2H_3O_2$	aq	q	A-49
KCl		lm	C-11
		q	B-44
		t	B-35
	c	a	1619
		a	1792
		a	1901
		a	2382
		k	1181
		n	1337
		q	A-76
		q	2074
		q	2084
		q	2106
		v	2016
		v	2379
	liq	k	1616
		s	1961
	aq	q	1087
		v	1523
KCl-H_2O	c	q	1916
		q	1950
		q	2280
KCl-HCl-H_2O	c	p	2164
KCl-HCOOH	c	q	1261
KCl-aq $C_4H_8O_2$ (dioxane)	c	q	1246
KCl-C_2NH_5O		q	A-19
KCl-$(CH_3)_4NCl$	aq	q	A-49
KCl-$PbCl_2$	c	b	2474
	non-aq	p	1385
KCl-$GaCl_3$	non-aq	b	2538
KCl-TlCl		b	D-15
KCl-$CdCl_2$	liq	q	A-59
KCl-AgCl	non-aq	p	1879
KCl-$CrCl_2$	non-aq	b	2565
KCl-$CaCl_2$		s	D-44
KCl-$SrCl_2$	c	b	2474

Substance	State	Prop.	Ref.
KCl-LiCl		t	B-35
	aq	q	A-49
KCl-NaCl		p	D-29
	aq	q	A-49
		q	A-79
		q	1916
KCl-NaCl-H2O	c	p	1359
KCl-NaCl-$CdCl_2$	c	b	1831
	non-aq	b	1498
		s	1498
KCl-NaBr	aq	q	A-49
KCl-KF	aq	q	A-49
KCl-KBr	liq	q	A-33
KCl-K_2SO_4-Na_2SO_4-H_2O	c	p	2051
KCl-KNO_3	aq	v	1523
KCl-KH_2PO_4-H_2O	c	p	1359
KCl-$KC_2H_3O_2$		q	A-49
KCl-RbCl	liq	q	A-33
$KClO_3$	c	a	1901
		n	1338
$KClO_4$		py	A-79
	c	n	1337
		q	A-62
		r	1397
$KClO_4$-$(CH_3)_2SO_2$		p	2476
KBr		lm	C-11
	c	p	2004
		v	1193
		v	2379
	aq	p	1362
KBr-C_2NH_5O		q	A-19
KBr-NaCl	aq	q	A-49
KBr-NaBr		q	A-49
KBr-NaI-H_2O	c	p	1350
KBr-KF	aq	q	A-49
KBr-KCl	liq	q	A-33
KBr-KI-H_2O	c	p	1350
KBr-$KC_2H_3O_2$	aq	q	A-49
$KBr_5O_8 \cdot 4H_2O$	c	v	2111
KI		a	D-15
		q	B-44
	c	v	1193
	non-aq	p	1327
KI-$(CH_3)_2SO_2$		p	2476

Substance	State	Prop.	Ref.
KI-C_2NH_5O		q	A-19
KI-NaBr-H_2O	c	p	1350
KI-NaI-H_2O	c	p	1350
KI-KBr-H_2O	c	p	1350
KI-KIO_3-H_2O	c	p	1419
K_2S		mt	B-36
K_2SO_4		t	B-43
	c	h	1492
K_2SO_4-Na_2SO_4-KCl-H_2O	c	p	2051
KSO_2F	c	l	1133
K_2SeO_4	c	q	1244
		n	2289
$K(NO_2,NO_3)$-$Sr(NO_2,NO_3)$	c	b	1368
KNO_3		ab	D-8
	c	v	2379
	aq	v	1523
KNO_3-$(CH_3)_2SO_2$		p	2476
KNO_3-$AgNO_3$		b	D-8
		i	D-22
KNO_3-$Mg(NO_3)_2$		b	D-15
KNO_3-$Ca(NO_3)_2$		b	D-15
KNO_3-$Sr(NO_3)_2$		b	D-15
KNO_3-$BaCl_2$		b	D-8
KNO_3-$LiNO_3$		b	D-8
KNO_3-NaCl	aq	q	A-49
KNO_3-$NaNO_3$	aq	q	A-49
KNO_3-KCl	aq	v	1523
KH_2PO_4-NaH_2PO_4-H_2O	c	p	1359
KH_2PO_4-KCl-H_2O	c	p	1359
KC_8	c	n	2270
	non-aq	n	2155
K_2CO_3-Li_2CO_3		mt	B-38
	c	t	2304
	liq	t	2304
K_2CO_3-Na_2CO_3		t	B-37
	c	amt	2304
	liq	amt	2304
$K_2C_2O_4 \cdot 2H_2O$	c	n	1212
KC_9H_{11} (Cumyl potassium)		n	A-10
$KC_2H_3O_2$ (acetate)	c	b	1457

Substance	State	Prop.	Ref.
$KC_2H_3O_2$-KF	aq	q	A-49
$KC_2H_3O_2$-KCl (acetate)	aq	q	A-49
$KC_2H_3O_2$-KBr (acetate)	aq	q	A-49
$K_2CS_3 \cdot H_2O$	c	l	2143
KSCN	c	a	1210
		am	1243
$K_2O \cdot 2SiO_2$	c	v	B-34
	amorph	v	B-34
$K_2O \cdot 4SiO_2$	amorph	v	B-34
K silicates-alkali halides		q	A-51
$KB_5O_8 \cdot 4H_2O$	liq	v	2111
KBH_4	c	v	2113
$KAlH_2$	c	l	1413
$KAlH_4$	c	l	1413
$KAlSi_3O_8$-$NaAlSi_3O_8$		b	A-51
		q	A-71
$H_2KAl_3(SiO_4)_3$	c	a	1555
$KAl_3Si_3O_{10}(OH)_2$	c	t	1461
	non-aq	n	1039
$K_2O \cdot Al_2O_3 \cdot 4SiO_2$-$SiO_2$-$Al_2O_3$	non-aq	b	2159
$KGaCl_4$	c	a	2538
$K_2Ga_2Cl_7$	c	a	2538
$K_2Zn(SO_4)_2 \cdot nH_2O$	c	l	1984
$K_2CuCl_4 \cdot 2H_2O$	c	av	1191
		v	2428
$K_2Cu(SO_4)_2 \cdot nH_2O$	c	l	1984
$K_2Ni(SO_4)_2 \cdot nH_2O$	c	l	1984
$KCoF_3$		l	C-35
$K_2Co(SO_4)_2 \cdot nH_2O$	c	l	1984
$K_2Fe(SO_4)_2 \cdot nH_2O$	c	l	1984
$K_3Fe(CN)_6$-NaOH-Luminal or H_2O_2		n	A-31
$KFeZn_{1.5}C_6N_6$	non-aq	s	2186
$K_2FeCdC_6N_6$	non-aq	s	2186
$K_2FeCu_2C_6N_6$	non-aq	s	2186
$KPdCl_4$	c	l	2010
K_2PtCl_4		nq	A-75
K_2PtCl_6		v	B-43
$KPtNH_3Cl_5$		v	B-43

Substance	State	Prop.	Ref.
$KMnF_3$		l	C-35
$KTcO_4$		v	B-36
	aq	q	A-63
K_2ReBr_6		v	B-36
$KCrCl_3$	c	a	2565
K_2CrCl_4	c	a	2565
K_3CrCl_6	c	a	1619
$K_3Cr_2Cl_6$	c	a	1619
$K_3Cr(C_2O_4)_3 \cdot 3H_2O$	c	n	1212
$K_3Cr(C_2O_4)_3 \cdot nH_2O$-$H_2O$	c	q	1211
$3KCl \cdot VCl_3$	c	n	2202
$KCl \cdot NbCl_5$	c	ln	2373
		n	2202
$KCl \cdot NbOCl_3$	c	l	1147
		n	2202
$2KCl \cdot NbOCl_3$	c	l	1147
		n	2202
$KTaCl_6$	c	n	1477
K_2TaCl_5	c	a	2009
K_2TiF_6	c	n	2027
K_2TiF_6-LiCl	c	b	2220
K_2TiF_6-Na_2TiF_6	c	b	2220
K_3YCl_6	c	a	2382
KSm_2Cl_7	c	a	1792
K_3SmCl_6	c	a	1792
$KCl \cdot NdCl_3$	c	l	2010
$3KCl \cdot NdCl_3$	c	lt	2279
$3KCl \cdot 2NdCl_3$	c	lt	2279
$3KCl \cdot PrCl_3$	c	lt	2279
$3KCl \cdot 2PrCl_3$	c	lt	2279
$KCl \cdot CeCl_3$	c	l	2010
$KCl \cdot 3CeCl_3$	c	lt	2279
$3KCl \cdot CeCl_3$	c	lt	2279
$3KCl \cdot 2CeCl_3$	c	lt	2279
$KCl \cdot LaCl_3$	c	l	2010
$KCl \cdot 3LaCl_3$	c	lt	2279
$2KCl \cdot LaCl_3$	c	lt	2279
$KUO_2PO_4 \cdot 3.5H_2O$-H_2O	c	p	2477
K_2BeF_4	c	bqv	1605

Substance	State	Prop.	Ref.
$KMgCl_3$		s	D-44
$K_2Mg(SO_4)_2 \cdot nH_2O$	c	l	1984
$K_2Mg_2(SO_4)_3$	c	a	1763
$K_2Mg_2(SO_4)_3$-$K_2Ca_2(SO_4)_3$	non-aq	b	1763
$K_2MgC_{10}H_{12}N_2O_8 \cdot 5H_2O$ (ethylenediaminetetraacetate)	c	p	1366
$KCaCl_3$		s	D-44
$K_2Ca_2(SO_4)_3$-$K_2Mg_2(SO_4)_3$	non-aq	b	1763
$KSrCl_5$		s	D-44
K_2SrCl_4		s	D-44
$3KNO_2 \cdot 2Sr(NO_2)_2$	c	a	2008
K_2BaCl_4		s	D-44
$K_2TiF_6 \cdot 2LiCl$	c	a	2220
$K_2TiF_6 \cdot 10LiCl$	c	a	2220
K/Na	g	z	1803
	non-aq	p	1872
$3KCH_3COO \cdot 2NaCH_3COO$	c	b	1457
KNa feldspars		b	A-22

101 - Rubidium

Substance	State	Prop.	Ref.
Rb		p	C-17
	c	km	1407
		v	1532
		v	2329
	liq	kz	2405
		q	1045
		s	2569
		z	1285
	aq	r	1060
Rb-B_2O_3-Na_2O-NaCl		p	D-74
RbO_2		w	D-55
	c	n	A-49
Rb_2O		p	D-74
Rb_2O_2		w	D-55
	c	n	2561
RbF	c	a	2525
RbF-NaF		bw	D-29
$RbF \cdot nH_2O$-H_2O	c	b	1390
RbCl		a	D-15
		q	B-44
	c	a	1792
		a	1901
		p	2380
		v	2379
RbCl-H_2O	c	q	1093
RbCl-HCOOH	c	q	1261
RbCl-$PbCl_2$	c	b	2474
RbCl-TlCl		b	D-15
RbCl-$CrCl_2$	non-aq	b	2565
RbCl-$NbOCl_3$	non-aq	b	1187
RbCl-$SrCl_2$	c	b	2474
RbCl-KCl	liq	q	A-33
$RbClO_3$	c	a	1901
RbBr		a	D-15
	c	p	2004
		q	1993
RbBr-TlBr		b	D-15
RbBr-AgBr	non-aq	p	1385
RbI		q	B-44
RbI-C_2NH_5O		q	A-19
RbI-C_3NH_7O		qn	A-19
Rb_2SO_4		t	B-43
Rb_2SO_4-$PbSO_4$	c	b	1672
Rb_2SO_4-Cs_2SO_4	c	b	1672
Rb_2SO_4-Cs_2SO_4-$PbSO_4$	c	b	1672
Rb_2SeO_4	c	n	1471
$RbTeI_6$	c	a	1942
$RbNO_3$-$Ba(NO_3)_2$		b	D-15
RbC_8	non-aq	n	2155
$RbC_2H_3O_2$ (acetate)	c	b	1457
RbCN		mv	B-14
Rb_2GeCl_6	c	l	1583
$Rb_2SO_4 \cdot 2PbSO_4$	c	a	1672
$RbBO_2$		l	A-72
Rb_2ZnCl_4-H_2O	c	nq	1093
Rb_2ZnBr_4		q	A-15
Rb_2CoCl_4-H_2O	c	nq	1093
Rb_2PtCl_4		nq	A-75
$RbPtNH_3Cl_3$		nq	A-75
Rb_2CrO_4	c	a	2533
Rb_2CrO_4-$PbCrO_4$	non-aq	b	2533
$RbCrCl_3$	c	a	2565

Substance	State	Prop.	Ref.
Rb_2CrCl_4	c	a	2565
$Rb_2Cr_2PbO_8$	c	a	2533
Rb_2MoO_4	c	a	2533
Rb_2MoO_4-$PbMoO_4$	non-aq	b	2533
$Rb_2MoO_4 \cdot PbMoO_4$	c	a	2533
Rb_2WO_4	c	a	2533
$Rb2WO_4$-$PbWO_4$	non-aq	b	2533
$Rb_2W_2PbO_8$	c	a	2533
$3RbCl \cdot VCl_3$	c	n	2202
$RbCl \cdot NbCl_5$	c	n	1136
		n	2202
$RbCl \cdot NbOCl_3$	c	a	1187
$2RbCl \cdot NbOCl_3$	c	a	1187
$RbTaCl_6$	c	n	1136
Rb_2TaCl_5	c	a	2009
Rb_2TaCl_6	c	a	1796
$RbTiBr_3$	c	n	1993
Rb_2TiBr	c	n	1993
Rb_3TiBr_6	c	n	1993
$Rb_3Ti_2Br_9$	c	n	1993
$RbSm_2Cl_7$	c	a	1792
Rb_3SmCl_6	c	a	1792
$RbUO_2PO_4 \cdot H_2O$	c	p	2477
$3RbNO_2 \cdot 2Sr(NO_2)_2$	c	a	2008
RbF/NaF		bw	D-29

102 - Cesium

Substance	State	Prop.	Ref.
Cs		j	D-75
	c	km	1407
		mv	1019
		n	1485
		v	1532
		v	2329
		v	2398
	liq	a	D-75
		kz	2405
		q	1045
		s	2569
		v	1019
		z	1285
	g	w	1172
	aq	r	1060
	ads	k	C-24
Cs-Na_2O-B_2O_3-NaCl		p	D-74
Cs^+	aq	n	1063
CsO_2	c	n	A-49
Cs_2O_2	c	n	2561
Cs_2O_3-B_2O_3	c	b	2475
CsF	c	am	2525
		q	2366
CsF-H_2O	c	b	2046
CsCl		l	C-31
		q	B-44
	c	a	1901
		a	2538
		a	2565
		v	2379
CsCl-H_2O	c	q	1093
CsCl-$PbCl_2$	c	b	2474
CsCl-$GaCl_3$	non-aq	b	2538
CsCl-$CrCl_2$	non-aq	b	2565
CsCl-$NbOCl_3$	non-aq	b	1187
CsCl-$SrCl_2$	c	b	2474
CsCl-$LiNO_3$		q	A-79
CsCl-$CsNO_3$		q	A-79
$CsCl_3$	c	a	1792
$CsClO_3$	c	a	1901
		q	1995
$CsClO_4$		py	A-79
CsBr		v	B-14
	c	a	1795
		q	1993
CsI		lm	C-24
		q	B-44
	c	a	1794
		q	2191
		s	2000
CsI-C_2NH_5O		nq	A-19
CsI-C_3NH_7O		nq	A-19
Cs_2SO_4-Rb_2SO_4	c	b	1672
Cs_2SO_4-$RbSO_4$-$PbSO_4$	c	b	1672
Cs_2SeO_4	c	n	1575
	liq	nq	1575
$CsNO_3$-$Ca(NO_3)_2$		b	D-15
CsC_8	non-aq	n	2155
Cs_2CO_3	c	a	2245
CsCN		mv	B-14

Substance	State	Prop.	Ref.
Cs_2GeCl_6	c	l	1583
$CsPbCl_3$	c	s	2514
$Cs_2O \cdot B_2O_3$	c	a	2475
$Cs_2O \cdot 3B_2O_3$	c	a	2475
$Cs_2O \cdot 5B_2O_3$	c	a	2475
$Cs_2O \cdot 9B_2O_3$	c	a	2475
$CsGeCl_4$	c	a	2538
Cs_2ZnCl_4-H_2O	c	nq	1093
Cs_2ZnBr_4		q	A-15
$CsBr \cdot CdBr_2$	c	a	1795
$2CsBr \cdot CdBr_2$	c	a	1795
$2CsI \cdot CdI_2$	c	a	1794
Cs_2CoCl_4-H_2O	c	nq	1093
$Cs[PtCl_4]$		nq	A-75
$CsPtNH_3Cl_3$		nq	A-75
Cs_2CrO_4	c	a	2533
Cs_2CrO_4-$PbCrO_4$	non-aq	b	2533
$CsCrCl_3$	c	a	2565
$Cs_2Cr_2PbO_4$	c	a	2533
Cs_2MoO_4	c	a	2533
Cs_2MoO_4-$PbMoO_4$	non-aq	b	2533
Cs_2WO_4	c	a	2533
Cs_2WO_4-$PbWO_4$	non-aq	b	2533
$CsNbCl_2$	c	n	1136
$CsCl \cdot NbCl_5$	c	n	2202
$2CsCl \cdot NbOCl_3$	c	a	1187
$CsTaCl_6$	c	n	1136
Cs_2TaCl_4	c	a	1796
Cs_2TaCl_5	c	a	2009
Cs_2TiCl_6	c	l	1440
Cs_4TiCl_8	c	l	1440
$CsTiBr_3$	c	n	1993
Cs_2TiBr_6	c	n	1993
Cs_3TiBr_6	c	n	1993
$Cs_3Ti_2Br_9$	c	n	1993
$CsSm_2Cl_7$	c	a	1792
$Cs_3Sm_2Cl_6$	c	a	1792
$CsNO_2 \cdot Sr(NO_2)_2$	c	a	2008

Substance	State	Prop.	Ref.
Miscellaneous			
Acids		z	1259
Air	liq	a	D-14
	g	v	1877
		w	1540
Air plasma	g	z	2546
Alkali halides	c	a	1881
	aq	q	A-79
Alkali halides - NaSCN		q	D-22
Alkali halides - Na,K silicates		q	A-51
Alkali halides(molten)	non-aq	z	1933
Alkali halide binary solid solutions		b	2236
Alkali matals	c	k	1503
M(Cl,Br) mixtures (M = Li,K,Na,Mg,Ca)	liq	p	A-22
Alkali nitrates (Na,K,Rb,Cs)NO_3(liq)-Tl(Cl,Br,I)		b	D-22
Alkalis		z	1259
Alloys	liq	v	1542
Aqueous three-component electrolyte solutions		z	1900
Aqueous solutions		v	2152
Atomic radii		w	2107
Binary metallic solutions		z	1891
Calorimeter, solution			1883
Calorimetry calculations			2571
Calorimetry, radiometric			2573
Carbides of the NbC and TaC type		n	A-78
Cements	c	q	2042
Chlorides		z	1259
Clay	amorph	v	2505
Clay-H_2O	amorph	v	2505
Clays,substituted montmorillonite		y	1871
Complex-formation		z	1473
Concrete	c	y	1737
Diatomic complexes	c	m	1753
Dimerization constants		z	1766
Dissociation constant calculations: acids and bases			2574

Substance	State	Prop.	Ref.
Donor solvents		z	1259
Dowex A-1		r	1907
Electrode potentials-HF		s	2124
Emulsion stabilizers	liq	p	2296
Equation of state for gas mixtures			2575
Group III A metal ions:C_9NH_7O (8-quinolinol)	non-aq	r	2547
Group IV-Group VI molecules	c	l	2043
Halides	g	z	1625
Halide mixtures, binary		q	A-47
Hastelloy alloy X	c	v	2081
Heat resistant alloys		v	2018
Hydrides		z	2404
Hydrogen plasma		w	1729
Hydroxides	c	r	1880
Inorganic ion exchange materials		py	D-20
Inorganic systems, review thermodynamic data			2572
Isothermal jacket titration calorimeter		z	2172
Lanthanide elements:$C_6NH_9O_6$ (nitrilotriacetic acid)		q	A-76
Magnetite	c	t	2291
Metal borates		nz	1908
Metal bromides		nz	1908
Metal chromates		nz	1908
Metal dioximes	aq	r	2210
Metal hydroxides		nz	1908
Metal iodides		nz	1908
Metal metaphosphates		nz	1908
Metal molybdates		nz	1908
Metal orthophosphates		nz	1908
Metal sulfates		nz	1908
Metal sulfides		nz	1908
Metal tungstates		nz	1908
Micro-calorimetry		z	1439
Mineral and allied substances	c	az	1289
Monatomic elements	liq	i	1867
Mono-and polyatomic ions (71 compounds)	c	v	1195
Monovalent chlorides-Multivalent chlorides		bz	2048
Montmorillonite		l	2235
Neutralization potentiometry		z	1852
1962 He^3 scale of temperatures			2118
Oxides		z	1259
Oxidizing and reducing agents		z	1259
Portland cement	c	n	1545
		q	2042
Rare earths	c	km	2498
Rare earth carbonates-H_2O	c	p	1422
Rare earth chalcogenides		z	2259
Rare earth garnets		v	B-26
Rare earth iodates-H_2O	c	p	1422
Silicates		b	D-74
Silicone oil		v	B-35
Solutes in liquid sodium	c	p	2128
Steels/Pb	non-aq	p	1483
Substances involving elements with atomic numbers 1-18	g	w	1401
Thermal bimetallics	non-aq	v	1299
Tin aliphatic hydrocarbon mixtures		h	D-11
Tin,Silicon aliphatic hydrocarbon mixtures		b	D-11
Transition metal refractory carbides	c	z	1283
Trialkyl tin chlorides-picoline		nr	A-18
Uraninite-H_2O	c	p	2300
Uraninite-acid sulfate	c	p	2300
Uraninite-Na_2CO_3	c	p	2300
Vapor pressures		z	1506
Wuestite	c	k	2291
Wurster's blue perchlorate		mv	B-14

1001. G. Verhaegen, F. E. Stafford and J. Drowart, J. Chem. Phys. 40, 1622-1628 (1964).
1002. E. Rudzitis, R. Terry, H. M. Feder and W. N. Hubbard, J. Phys. Chem. 68, 617-619 (1964).
1003. F. J. Keneshea and D. D. Cubicciotti, J. Chem. Phys. 40, 1778-1779 (1964).
1004. R. J. Baltisberger and E. L. King, J. Am. Chem. Soc. 86, 795-801 (1964).
1005. M. Blander and E. B. Luchsinger, J. Am. Chem. Soc. 86, 319-322 (1964).
1006. G. J. Janz and M. R. Lorenz, J. Chem. Eng. Data 9, 94-95 (1964).
1007. K. K. Kundu and M. N. Das, J. Chem. Eng. Data 9, 87-89 (1964).
1008. L. G. Fasolino, J. Chem. Eng. Data 9, 68-71 (1964).
1009. C. Hirayama, J. Chem. Eng. Data 9, 65-68 (1964).
1010. G. M. Lukashenko, V. N. Eremenko and V. R. Sidorko, Zhur. Neorg. Khim. 9, 220-221 (1964).
1011. N. I. Kolbin and I. N. Semenov, Zhur. Neorg. Khim. 9, 203-205 (1964).
1012. K. B. Yatsimirskii and K. E. Prik, Zhur. Neorg. Khim. 9, 178-182 (1964).
1013. I. V. Gordeev, Yu. D. Tret'yakov and K. G. Khomyakov, Zhur. Neorg. Khim. 9, 164-168 (1964).
1014. V. M. Savostina, E. K. Astakhova and V. M. Peshkova, Zhur. Neorg. Khim. 9, 80-84 (1964).
1015. L. G. Berg and V. P. Kovyrzina, Zhur. Neorg. Khim. 9, 29-35 (1964).
1016. R. S. Guzairov, V. A. Leitsin and S. D. Grekov, Zhur. Neorg. Khim. 9, 20-24 (1964).
1017. A. B. Nikol'skii and A. N. Ryabov, Zhur. Neorg. Khim. 9, 7-11 (1964).
1018. A. W. Lemmon, Jr., H. W. Deem, E. A. Eldridge, E. H. Hall, J. Matolich, Jr. and J. F. Walling, Battelle Mem. Inst. Final Rept. 4613-Final, Contract NAS 5-584, 66pp (1963).
1019. A. W. Lemmon, Jr., H. W. Deem, E. A. Eldridge, E. H. Hall, J. Matolich, Jr. and J. F. Walling, Battelle Mem. Inst. Topical Rept. 4673-T7, Contract NAS 5-584, 34pp (1964).
1020. L. S. Levinson, J. Chem. Phys. 40, 1437-1438 (1964).
1021. P. Castle, R. Stoesser and E. F. Westrum, Jr., J. Phys. Chem. 68, 49-51 (1964).
1022. J. C. Trowbridge and E. F. Westrum, Jr., J. Phys. Chem. 68, 42-49 (1964).
1023. W. L. Masterton and J. A. Scola, J. Phys. Chem. 68, 14-16 (1964).
1024. F. S. Pettit, J. Phys. Chem. 68, 9-13 (1964).
1025. E. Przezdziecka-Mycielska, J. Terpilowski and K. Strozecka, Arch. Hutnictwa 8, 85-102 (1963).
1026. E. Kundys, J. Terpilowski and J. Josiak, Arch. Hutnictwa 7, 39-46 (1962).
1027. M. V. Kilday and E. J. Prosen, J. Research Natl. Bur. Standards 68A, 127-137 (1964).
1028. R. D. Goodwin, D. E. Diller, H. M. Roder and L. A. Weber, J. Research Natl. Bur. Standards 68A, 121-126 (1964).
1029. P. Goldfinger and M. Jeunehomme, Trans. Faraday Soc. 59, 2851-2867 (1963).

1030. Z. L. Ernst and J. Menashi, Trans. Faraday Soc. 59, 2838-2844 (1963).
1031. G. J. Janz, F. J. Kelly and J. L. Perano, Trans. Faraday Soc. 59, 2718-2722 (1963).
1032. R. G. Cavell and H. C. Clark, Trans. Faraday Soc. 59, 2706-2712 (1963).
1033. J. R. Brannan, H. S. Dunsmore and G. H. Nancollas, J. Chem. Soc. 1964, 304-310.
1034. G. A. Mountford and P. A. H. Wyatt, J. Chem. Soc. 1964, 518-519.
1035. J. F. Duncan and F. G. Thomas, J. Chem. Soc. 1964, 360-364.
1036. B. F. Yudin and V. P. Mashovets, Izvest. Vysshikh Ucheb. Zavedenii, Tsvetnaya Met. 5, No. 5, 54-61 (1962).
1037. R. J. Ackermann, E. G. Rauh and R. J. Thorn, J. Chem. Phys. 40, 883-889 (1964).
1038. W. W. Weller and K. K. Kelley, U. S. Bur. Mines, Rept. Invest. 6357, 5pp (1964).
1039. R. Barany, U. S. Bur. Mines, Rept. Invest. 6356, 6pp (1964).
1040. A. A. Palko and J. S. Drury, J. Chem. Phys. 40, 278-281 (1964).
1041. J. J. Christensen, R. M. Izatt, L. D. Hansen and J. D. Hale, Inorg. Chem. 3, 130-133 (1964).
1042. R. E. McCarley and J. W. Roddy, Inorg. Chem. 3, 60-63 (1964).
1043. R. E. McCarley and J. W. Roddy, Inorg. Chem. 3, 54-59 (1964).
1044. R. E. McCarley, J. W. Roddy and K. O. Berry, Inorg. Chem. 3, 50-54 (1964).
1045. T. Yokokawa and O. J. Kleppa, J. Chem. Phys. 40, 46-54 (1964).
1046. A. B. Blake and F. A. Cotton, Inorg. Chem. 3, 5-10 (1964).
1047. J. W. Stout and W. B. Hadley, J. Chem. Phys. 40, 55-63 (1964).
1048. J. D. McKinley, J. Chem. Phys. 40, 120-125 (1964).
1049. F. J. Keneshea and D. Cubicciotti, J. Chem. Phys. 40, 191-199 (1964).
1050. G. Verhaegen, S. Smoes and J. Drowart, J. Chem. Phys. 40, 239-241 (1964).
1051. D. M. Waldorf and A. L. Babb, J. Chem. Phys. 40, 1165 (1964).
1052. J. B. Westmore, K. H. Mann and A. W. Tickner, J. Phys. Chem. 68, 606-612 (1964).
1053. S. U. Choi, Daehan Hwahak Hwoejee 7, 65-68 (1963).
1054. C. A. Swenson and J. R. Tedeschi, J. Chem. Phys. 40, 1141-1143 (1964).
1055. D. Cubicciotti and H. Eding, J. Chem. Phys. 40, 978-982 (1964).
1056. C. C. Stephenson, C. A. Wulff and O. R. Lundell, J. Chem. Phys. 40, 967-974 (1964).
1057. E. Douglas, J. Phys. Chem. 68, 169-174 (1964).
1058. M. Goldblatt, J. Phys. Chem. 68, 147-151 (1964).
1059. A. Dadgar and K. Schug, J. Phys. Chem. 68, 112-115 (1964).
1060. K. Schug and A. Dadgar, J. Phys. Chem. 68, 106-111 (1964).
1061. W. D. Good, J. L. Lacina, B. L. De Prater and J. P. McCullough, J. Phys. Chem. 68, 579-586 (1964).
1062. D. M. Waldorf and A. L. Babb, J. Chem. Phys. 39, 432-435 (1963).
1063. G. E. Boyd, F. Vaslow and S. Lindenbaum, J. Phys. Chem. 68, 590-597 (1964).
1064. B. Stehlik, Chem. zvesti 17, 6-13 (1963).
1065. J. Braunstein and A. S. Minano, Inorg. Chem. 3, 218-221 (1964).
1066. H. T. Tien and G. W. Harrington, Inorg. Chem. 3, 215-217 (1964).

1067. A. Sardi, Acta Chim. Acad. Sci. Hung. 38, 177-186 (1963).
1068. R. Colin and J. Drowart, J. Phys. Chem. 68, 428-430 (1964).
1069. T. Hu, H. C. Ko and L. G. Hepler, J. Phys. Chem. 68, 387-390 (1964).
1070. R. R. Hammer and N. W. Gregory, J. Phys. Chem. 68, 314-317 (1964).
1071. K. Arumugam and M. Radhakrishnan, Z. physik. Chem. [NF] 39, 262-264 (1963).
1072. D. F. Gaines and R. Schaeffer, Inorg. Chem. 3, 338-340 (1964).
1073. H. S. Sherry and J. A. Marinsky, Inorg. Chem. 3, 330-335 (1964).
1074. W. R. Stagg and J. E. Powell , Inorg. Chem. 3, 242-245 (1964).
1075. I. Cadariu and L. Oniciu, Acad. Rep. Populare Romine, Filiala Cluj, Studii Cercetari Chim. 12, 77-81 (1961).
1076. H. Tanaka, K. Murakami, I. Monna and T. Karaki, Yogyo Kyokai Shi 70, 302-312 (1962).
1077. F. Massazza, Ann. chim. (Rome) 53, 996-1001 (1963).
1078. S. Gobom, Acta Chem. Scand. 17, 2181-2189 (1963).
1079. D. A. Lee, Inorg. Chem. 3, 289-290 (1964).
1080. K. Moedritzer and J. R. Van Wazer, Inorg. Chem. 3, 268-272 (1964).
1081. R. F. Porter and S. K. Gupta, J. Phys. Chem. 68, 280-289 (1964).
1082. B. G. Korshunov and N. W. Gregory, Inorg. Chem. 3, 451-452 (1964).
1083. J. E. Bauman, Jr. and J. C. Wang, Inorg. Chem. 3, 368-373 (1964).
1084. P. D. Hopkins and B. E. Douglas, Inorg. Chem. 3, 357-360 (1964).
1085. J. C. Sullivan, Inorg. Chem. 3, 315-319 (1964).
1086. W. B. Street, R. E. Sonntag and G. J. Van Wylen, J. Chem. Phys. 40, 1390-1395 (1964).
1087. P. Gerding, I. Leden and S. Sunner, Acta Chem. Scand. 17, 2190-2198 (1963).
1088. F. H. Guzzetta and W. B. Hadley, Inorg. Chem. 3, 259-264 (1964).
1089. L. B. Pankratz and K. K. Kelley, U. S. Bur. Mines, Rept. Invest. 6370, 7pp (1964).
1090. S. R. Gunn, U. S. AEC UCRL 7733, 18pp (1964).
1091. K. M. Myles and A. T. Aldred, J. Phys. Chem. 68, 64-69 (1964).
1092. A. K. Covington, P. K. Talukdar and H. R. Thirsk, Trans. Faraday Soc. 60, 412-416 (1964).
1093. P. Paoletti and . Vacca, Trans. Faraday Soc. 60, 50-55 (1964).
1094. . L. Ernst, R. J. Irving and J. Menashi, Trans. Faraday Soc. 60, 56-61 (1964).
1095. R. Colin, P. Goldfinger and M. Jeunehomme, Trans. Faraday Soc. 60, 306-316 (1964).
1096. J. Blauer and M. Farber, Trans. Faraday Soc. 60, 301-305 (1964).
1097. A. K. Chandra and D. C. Mukherjee, Trans. Faraday Soc. 60, 62-71 (1964).
1098. V. Mathot, Acad. roy. Belg. Classe sci. Mem. Collection in 8° 33, 32pp (1963).
1099. P. Gross and C. Hayman, Trans. Faraday Soc. 60, 45-49 (1964).
1100. I. Grenthe, Acta Chem. Scand. 17, 2487-2498 (1963).
1101. E. H. Baker, J. Chem. Soc. 1964, 699-704.
1102. H. A. C. McKay and J. L. Woodhead, J. Chem. Soc. 1964, 717-723.
1103. G. S. Saini, L. D. Calvert, R. D. Heyding and J. B. Taylor, Can. J. Chem. 42, 620-629 (1964).

1104. G. G. Hammes and M. L. Morrell, J. Am. Chem. Soc. 86, 1497-1502 (1964).
1105. G. A. Hahn and R. Schaeffer, J. Am. Chem. Soc. 86, 1503-1504 (1964).
1106. R. A. Butterworth and W. F. Giauque, J. Chem. Phys. 40, 2379-2389 (1964).
1107. W. T. Hicks, J. Chem. Phys. 38, 1873-1880 (1963).
1108. T. P. J. H. Babeliowsky, J. Chem. Phys. 38, 2035-2036 (1963).
1109. R. M. Gabroff, J. C. Smith and E. H. Lightcap, J. Chem. Eng. Data 9, 178-182 (1964).
1110. R. H. Valentine, T. F. Jambois and J. L. Margrave, J. Chem. Eng. Data 9, 182-184 (1964).
1111. H. A. Walls and W. R. Upthegrove, J. Chem. Eng. Data 9, 184-187 (1964).
1112. W. L. Marshall, R. Slusher and E. V. Jones, J. Chem. Eng. Data 9, 187-191 (1964).
1113. A. Benton, J. Chem. Eng. Data 9, 198-199 (1964).
1114. F. J. Millero, J. C. Ahluwaliu and L. G. Hepler, J. Chem. Eng. Data 9, 319-320 (1964).
1115. K. J. Miler, J. Chem. Eng. Data 9, 173-175 (1964).
1116. A. D. Tevebaugh and E. J. Cairns, J. Chem. Eng. Data 9, 172-173 (1964).
1117. J. E. Powell, R. S. Kolat and G. S. Paul, Inorg. Chem. 3, 518-520 (1964).
1118. K. A. Gingerich, J. Phys. Chem. 68, 768-772 (1964).
1119. M. A. Greenbaum, M. L. Arin, M. Wong and M. Farber, J. Phys. Chem. 68, 791-795 (1964).
1120. J. L. Bills and F. A. Cotton, J. Phys. Chem. 68, 802-806 (1964).
1121. J. L. Bills and F. A. Cotton, J. Phys. Chem. 68, 806-810 (1964).
1122. D. D. Durnan, A. D. Mighell, E. J. Napolski and R. E. Wood, J. Phys. Chem. 68, 847-850 (1964).
1123. W. L. Worrell and J. Chipman, J. Phys. Chem. 68, 860-866 (1964).
1124. S. R. Gunn and L. G. Green, J. Phys. Chem. 68, 946-949 (1964).
1125. S. R. Gunn, J. Phys. Chem. 68, 949-952 (1964).
1126. W. L. Worrell, J. Phys. Chem. 68, 952-953 (1964).
1127. W. L. Worrell, J. Phys. Chem. 68, 954-955 (1964).
1128. P. Balk and D. Dong, J. Phys. Chem. 68, 960-962 (1964).
1129. M. A. Greenbaum, H. C. Ko, M. Wong and M. Farber, J. Phys. Chem. 68, 965-968 (1964).
1130. J. J. Egan, J. Phys. Chem. 68, 978-979 (1964).
1131. A. S. L'vova and N. N. Feodos'ev, Zhur. Neorg. Khim. 38, 28-32 (1964).
1132. B. V. Kondakov, P. V. Kovtuneko and A. A. Bundel', Zhur. Fiz. Khim. 38, 190-196 (1964).
1133. F. Seel and D. Goelitz, Z. anorg. u. allgem. Chem. 327, 28-31 (1964).
1134. A. M. Azzam and I. A. W. Shimi, Z. anorg. u. allgem. Chem. 327, 89-92 (1964).
1135. F. Seel and H. D. Goelitz, Z. anorg. u. allgem. Chem. 327, 32-50 (1964).
1136. E. K. Smirnova, I. V. Vasil'kova and N. F. Kudryashova, Zhur. Neorg. Khim. 9, 489-490 (1964).
1137. N. A. Chukova and L. I. Lebedeva, Zhur. Neorg. Khim. 9, 480-482 (1964).

1138. G. I. Novikov and F. G. Gavryuchenkov, Zhur. Neorg. Khim. 9, 475-476 (1964).
1139. V. N. Fedeev and P. I. Fedorov, hur. Neorg. Khim. 9, 381-388 (1964).
1140. N. M. Selivanova and Z. L. Leshchinskaya, Zhur. Neorg. Khim. 9, 259-263 (1964).
1141. I. V. Tananaev and N. N. Chudirova, Zhur. Neorg. Khim. 9, 244-250 (1964).
1142. [illegible]. D. Fridman and N. V. Dolgashova, Zhur. Neorg. Khim. 9, 623-632 (1964).
1143. L. N. Komissarova, Van Gen'-Shi, V. I. Spitsyn and Yu. P. Simanov, Zhur. Neorg. Khim. 9, 693-697 (1964).
1144. V. P. Vasil'ev and N. K. Grechina, Zhur. Neorg. Khim. 9, 647-653 (1964).
1145. V. P. Vasil'ev, Zhur. Neorg. Khim. 9, 641-646 (1964).
1146. P. K. Migal and V. A. Tseplyokova, Zhur. Neorg. Khim. 9, 601-605 (1964).
1147. S. A. Shchukarev, T. S. Shemyakina and E. K. Smirnova, Zhur. Neorg. Khim. 9, 547-549 (1964).
1148. P. N. Kovalenko and K. N. Bagdasarov, Zhur. Neorg. Khim. 9, 534-537 (1961).
1149. A. R. Kurbanov, A. V. Suvorov, S. A. Shchukarev and G. I. Novikov, Zhur. Neorg. Khim. 9, 520-525 (1964).
1150. J. Rayne, Phys. Letters 7, 114-115 (1963); CA 60-1127.
1151. P. Budininkas, U. S. Dept. Comm., Office Tech. Serv. AD 282,434, 58pp (1961); CA 60-1131.
1152. A. A. Kudryavtsev and G. P. Ustyugov, Tr. Mosk. Khim.-Tekhnol. Inst. 38, 42-46 (1962); CA 60-1134.
1153. S. A. Shchukarev, G. A. Semenov and K. E. Frantseva, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 5, 691-693 (1962); CA 60-1135.
1154. L. Beckhaut, F. Verbeek, H. Deelstra and J. Hoste, Anal. Chim. Acta 30, 369-376 (1964).
1155. B. A. Voitovich and A. S. Barabanova, Dopovidi Akad. Nauk Ukr. R.S.R. 1963, 1068-1072; CA 60-1162.
1156. I. D. Doig, Brit. Chem. Eng. 8, 688-695 (1963); CA 60-1162.
1157. M. S. Kachhawha and A. K. Bhattacharya, Madhya Bharati, Pt. II, Sect. A 9, No. 9, 22-25 (1960); CA 60-1166.
1158. I. A. Lebedev and G. N. Yakovlev, Radiokhimiya 4, 304-308 (1962); CA 60-1167.
1159. T. Erdey-Gruz, L. Majthenye and E. Kugler, Acta Chim. Acad. Sci. Hung. 37, 393-403 (1963); CA 60-1174.
1160. L. Ghiringhelli and G. Bianucci, Ann. Idrol. 1, 36-42 (1963); CA 60-1175.
1161. J. Balej and A. Regner, Collection Czech. Chem. Communs. 28, 3188-3193 (1963); CA 60-1175.
1162. A. K. Gupta and J. E. Powell, U. S. AEC IS-657, 12pp (1963); CA 60-1175.
1163. R. Korewa and W. Rodziewicz, Roczniki Chem. 37, 615-620 (1963); CA 60-1176.

1164. E. L. Shalavina and [illegible]. D. Zhakipova, Tr. Inst. Met. i Obogashch., Akad. Nauk Kaz. S.S.R. 6, 47-50 (1963); CA 60-1176.
1165. B. I. Brounshtein and G. N. Yurkov, Trudy Gosudarst. Inst. Priklad. Khim. No. 49, 5-19 (1962); CA 60-1177.
1166. L. V. Gurvich, B. A. Vorob'ev, V. A. Kvlividize, E. A. Prozorovskii, N. P. Rtishcheva and V. S. Yungman, Trudy Gosudarst. Inst. Priklad. Khim. No. 49, 38-60 (1962); CA 60-1177.
1167. I. S. Galinker and N. A. Belova, Zhur. Obshchei Khim. 33, 3119-3121 (1963); CA 60-1178.
1168. R. A. Polovinskina and T. V. Zabolotskii, Izvest. Sibir. Otdel. Akad. Nauk S.S.S.R., Ser. Khim. Nauk 1963, No. 2, 34-39; CA 60-1178.
1169. V. S. Yungman, L. V. Gurvich and N. P. Rtischeva, Trudy Gosudarst. Inst. Priklad. Khim. No. 49, 20-37 (1962); CA 60-1179.
1170. M. I. Ivanov and V. A. Tumbakov, At. Energ. (USSR) 7, 33-36 (1959); CA 60-1180.
1171. A. F. Kapustinskii and K. K. Samplavskaya, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 7-10 (1962); CA 60-1180.
1172. N. I. Agapova, B. L. Paskar and L. R. Fokin, At. Energ. (USSR) 15, 292-302 (1963); CA 60-1180.
1173. H. E. Robson and P. W. Gilles, J. Phys. Chem. 40, 983-989 (1964).
1174. D. L. Hildenbrand and W. F. Hall, J. Phys. Chem. 68, 989-993 (1964).
1175. G. B. Barbi, J. Phys. Chem. 68, 1025-1029 (1964).
1176. F. P. Galvin and H. O. Pritchard, J. Phys. Chem. 68, 1035-1038 (1964).
1177. W. M. Olson and R. N. R. Mulford, J. Phys. Chem. 68, 1048-1051 (1964).
1178. R. Gary, R. G. Bates and B. A. Robinson, J. Phys. Chem. 68, 1186-1190 (1964).
1179. C. A. Goy and H. O. Pritchard, J. Phys. Chem. 68, 1250-1251 (1964).
1180. E. Veleckis and I. Johnson, J. Phys. Chem. 68, 1257-1258 (1964).
1181. D. L. Hildenbrand, W. F. Hall, F. Ju and N. D. Potter, J. Chem. Phys. 40, 2882-2890 (1964).
1182. G. Grenier and D. White, J. Chem. Phys. 40, 3015-3030 (1964).
1183. R. S. Tobias and M. Jasuda, Can. J. Chem. 42, 781-791 (1964).
1184. H. G. McAdie, Can. J. Chem. 42, 792-801 (1964).
1185. F. G. McCurdy and K. J. Laidler, Can. J. Chem. 42, 818-824 (1964).
1186. D. Brennan and F. H. Hayes, Trans. Faraday Soc. 60, 589-596 (1964).
1187. S. A. Shchukarev, E. K. Smirnova and I. V. Vasil'kova, Vestnik Leningrad. Univ. No. 3, Ser. Fiz. I Khim. 18, 132-133 (1963); CA 60-7504.
1188. A. J. H. Boerboom, H. W. Reyn and J. Kistemaker, Physica 30, 254-257 (1964); CA 60-7484.
1189. I. A. A. Matveenko, Nauchn. Zap. Odessk. Politekhn. Inst. 44, 46-54 (1962); CA 60-7492.
1190. J. G. Danese and B. Jaselskis, Anal. Chem. 35, 1878-1880 (1963); CA 60-3702.
1191. A. R. Miedema, H. Van Kempen and E. J. Huiskamp, Physica 29, 1266-1280 (1963); CA 60-3601.
1192. Yu. K. Delimarskii and Yu. G. Roms, Ukrain. Khim. Zhur. 29, 781-784 (1963); CA 60-3557.
1193. D. L. Martin, Proc. Phys. Soc. (London) 83, 99-108 (1964); CA 60-3556.

1194. O. V. Lounasmaa, Phys. Rev. [2] 133, 219-224 (1964); CA 60-3556.
1195. G. A. Krestov, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 6, 578-587 (1963); CA 60-3556.
1196. O. V. Lounasmaa, Phys. Rev. [2] 133, 211-218 (1964).
1197. H. A. Berman and E. S. Newman, J. Research Natl. Bur. Standards 67A, 1-13 (1963); CA 60-3554.
1198. D. L. Hildenbrand, Western States Sect. Combust. Inst., Paper WSS/CI 6215, 5pp (1962); CA 60-3553.
1199. H. J. Svec and G. D. Flesch, Science 142, 954-955 (1963); CA 60-3553.
1200. S. V. Popova, N. R. Serebryanaya and S. S. Kabalkina, Geokhimiya 1963, 959-961; CA 60-3553.
1201. C. B. Alcock and T. N. Belford, Trans. Faraday Soc. 60, 822-835 (1964).
1202. R. P. Krentsis, P. V. Gel'd and G. I. Kalishevich, Izvest. Vysshikh Ucheb. Zavedenii, Chernaya Met. 6, No. 9, 161-168 (1963); CA 60-3551.
1203. C. Sinistri, Ric. Sci., Rend. Sez. A 2, 638-644 (1962); CA 60-3548.
1204. T. A. Gribanova, Tr. Dnepropetr. Metr. Inst. No. 44, 209-215 (1961); CA 60-3546.
1205. G. D'Amore, G. Calabro and P. Curro, Atti Soc. Peloritana Sci. Fis. Mat. Nat. 8, 265-281 (1962); CA 60-3543.
1206. H. Basinska, Z. Orylski and A. Charaszkiewicz, Chem. Anal. (Warsaw) 8, 473-475 (1963); CA 60-3636.
1207. E. M. Otto, J. Electrochem. Soc. 111, 88-92 (1964); CA 60-3535.
1208. D. H. Klein and G. J. Kersels, J. Inorg. and Nuclear Chem. 26, 1325-1326 (1964).
1209. T. Tomonari, Nippon Kagaku Zasshi 84, 311-313 (1963); CA 60-3497.
1210. Y. Yamada and T. Watanabe Bull. Chem. Soc. Japan 36, 1332-1337 (1963); CA 60-1186.
1211. A. F. Kapustinskii and N. I. Pakhorukov, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 15-17 (1962); CA 60-1180.
1212. N. I. Pakhorukov, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 17-20 (1962); CA 60-1180.
1213. V. I. Minenko and N. S. Ivanova, Izvest. Vysshikh Ucheb. Zavedenii, Tsvetnaya Met. 6, No. 3, 64-69 (1963); CA 60-1179.
1214. H. K. El-Shamy, A. M. El-Aggan and M. G. Habashy, J. Chem. U.A.R. 4, 149-157 (1961); CA 60-1165.
1215. J. A. Bolzan, E. A. Jauregui and A. J. Arvia, Electrochim. Acta 8, 841-845 (1963); CA 60-1166.
1216. A. M. Alper, R. N. McNally, R. C. Doman and F. G. Kuhn, J. Am. Ceram. Soc. 47, 30-33 (1964); CA 60-10359.
1217. R. M. Haag and C. R. Muncy, J. Am. Ceram. Soc. 47, 34-36 (1964); CA 60-10359.
1218. J. C. Tverberg, U. S. AEC GEAP 4089, 4/0-4/58 (1962); CA 60-10331.
1219. S. Wipf and B. R. Coles, J. Inst. Metals 90, 216 (1962); CA 60-10330.
1220. D. D. Todd and W. A. Oates, Trans. AIME 230, 244-246 (1964); CA 60-10327.
1221. B. Penteau and G. Cizeron, Compt. rend. 258, 1794-1797 (1964); CA 60-10323.
1222. V. M. Svechnikov and V. M. Pan, Dopovidi Akad. Nauk Ukr. R.S.R. 1960, 917-920; CA 60-10322.

1223. G. Ostberg, M. Moller and B. Schonning-Christiansson, J. Nucl. Mater. 10, 329-338 (1963); CA 60-10322.
1224. E. J. Rapperport and M. F. Smith, Trans. AIME 230, 6-11 (1964); CA 60-10321.
1225. L. F. Pease and J. H. Brophy, J. Less-Common Metals 6, 118-131 (1964); CA 60-10321.
1226. M. Hoch and D. B. Butrymowicz, Trans. AIME 230, 186-192 (1964); CA 60-10320.
1227. J. R. Thomson, J. Less-Common Metals 6, 94-99 (1964); CA 60-10320.
1228. E. R. Tucci, F. Takahashi, V. A. Tucci and N. C. Li, J. Inorg. and Nuclear Chem. 26, 1263-1276 (1964).
1229. B. C. Giessen, H. Ibach and N. J. Grant, Trans. AIME 230, 113-122 (1964); CA 60-10319.
1230. P. Stecher, F. Benesovsky and H. Nowotny, Monatsh. 94, 1154-1162 (1963); CA 60-10318.
1231. T. Heumann and O. Alpout, J. Less-Common Metals 6, 108-117 (1964); CA 60-10317.
1232. J. Eldridge and K. L. Komarek, Trans. AIME 230, 226-233 (1964); CA 60-10289.
1233. I. S. Kulikov and G. I. Ahmoidin, Tr. Inst. Met. im. A. A. Baikova, Akad. Nauk S.S.S.R. No. 14, 3-12 (1963); CA 60-10279.
1234. E. Schuermann and H. C. Groth, Giesserei, Tech.-Wiss. Beih. Giessereiw. Metallk. 15, 183-189 (1963); CA 60-10279.
1235. T. R. Ingraham and H. H. Kellogg, Trans. AIME 227, 1419-1426 (1963); CA 60-10271.
1236. G. I. Chufarov and L. I. Leont'ev, Doklady Akad. Nauk S.S.S.R. 154, 881-882 (1964); CA 60-10267.
1237. Yu. A. Kocherzhenskii, G. P. Kobzenko, V. M. Pan, V. K. Sviridenko and L. M. Lupko, Sb. Nauchn. Tr. Inst. Metallofiz., Akad. Nauk Ukr. S.S.R. No. 17, 209-210 (1963); CA 60-10227.
1238. H. Deelstra, W. Vanderleen and F. Verbeek, Bull. soc. chim. Belges 72, 632-641 (1963).
1239. N. G. Eror and J. B. Wagner, Jr., Acta Met. 11, 1339-1345 (1963); CA 60-1212.
1240. M. C. Saxena and A. K. Bhattacharya, Proc. Natl. Acad. Sci., India Sect. A 33, Pt. 3, 391-394 (1963); CA 60-1312.
1241. A. V. Novoselova, Yu. V. Orlova, Yu. P. Simanov and L. M. Kovba, Doklady Akad. Nauk S.S.S.R. 126, 93-96 (1959); CA 60-1192.
1242. R. C. Linares, Met. Soc. Conf. 19, 329-335 (1962); CA 60-1187.
1243. M. Sakiyama, H. Suga and S. Seki, Bull. Chem. Soc. Japan 36, 1025-1032 (1963); CA 60-1186.
1244. N. M. Selivanova, G. A. Yubova, I. I. Abramov, A. V. Kalinkina and T. A. Sazykina, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 21-25 (1962); CA 60-1181.
1245. D. F. Smith, T. E. Gardner, B. B. Letson and A. R. Taylor, Jr., U. S. Bur. Mines, Rept. Invest. 6316, 8pp (1963); CA 60-1181.
1246. A. F. Kapustinskii, A. I. Maier and S. I. Drakin, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 10-14 (1962); CA 60-1181.
1247. N. M. Selivanova and [illegible]. L. Leshchinskaya, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 37-42 (1962); CA 60-1181.

1248. V. A. Gruzdev and V. V. Roshchupkin, hidkie Metal., Sb. Stalei 1963, 248-255; CA 60-11702.
1249. C. Panseri and M. Leoni, 1st Sper. Metalli Leggeri, Mem. Rappt. [11] No. 268, 3-12; Alluminio 30, 289-298 (1961); CA 60-11696.
1250. B. B. Owen and S. W. Mayer, J. Inorg. and Nuclear Chem. 26, 501-507 (1964).
1251. E. Campi, G. Ostacoli, M. Meirone and G. Saini, J. Inorg. and Nuclear Chem. 26, 553-564 (1964).
1252. T. R. Bhat and M. Krishnamurthy, J. Inorg. and Nuclear Chem. 26, 587-594 (1964).
1253. H. S. Dunsmore, S. Hietanen and L. G. Sillen, Acta Chem. Scand. 17, 2644-2656 (1963).
1254. H. S. Dunsmore and H. L. Sillen, Acta Chem. Scand. 17, 2657-2663 (1963).
1255. S. Szilard, Acta Chem. Scand. 17, 2674-2680 (1963).
1256. S. Hietanen, B. R. Row and L. G. Sillen, Acta Chem. Scand. 17, 2735-2749 (1963).
1257. J. Prasilova, J. Inorg. and Nuclear Chem. 26, 661-662 (1964).
1258. P. I. Fedorov and V. N. Fadeev, Zhur. Neorg. Khim. 9, 378-380 (1964).
1259. H. A. Skinner, Pure Appl. Chem. 8, 113-130 (1964).
1260. V. A. Mikhailov and V. G. Torgov, Zhur. Fiz. Khim. 30, 280-286 (1964).
1261. G. P. Kotlyarova and E. F. Ivanova, Zhur. Fiz. Khim. 38, 423-426 (1964).
1262. R. B. Crookston and L. N. Canjar, J. Chem. Eng. Data 8, 544-547 (1963); CA 60-52.
1263. J. J. Brown and F. A. Hummel, J. Electrochem. Soc. 110, 1218-1223 (1963); CA 60-51.
1264. M. V. Hoffman, J. Electrochem. Soc. 110, 1223-1227 (1963); CA 60-49.
1265. C. R. Barber and A. Horsford, Brit. Appl. Phys. 14, 916-919 (1963); CA 60-38.
1266. I. A. Belkovskii, Doklady Akad. Nauk S.S.S.R. 154, 111-113 (1964); CA 60-9028.
1267. B. T. C. Davis and J. L. England, J. Geophys. Res. 69, 1113-1116 (1964); CA 60-9022.
1268. G. Kullerud, Carnegie Inst. Wash. Yearbook 1962, 175-189; CA 60-9022.
1269. G. H. Moh and G. Kullerud, Carnegie Inst. Wash. Yearbook 1962, 189-192; CA 60-9022.
1270. H. Savage and R. D. Seibel, U. S. AEC ANL 6702, 27pp (1963); CA 60-7754.
1271. E. Aukrust and A. Muan, Trans. AIME 227, 1378-1380 (1963); CA 60-7751.
1272. H. J. Goldschmidt, E. A. Catherall, W. M. Ham and D. A. Oliver, NASA Doc. N63-22127, 88pp (1963); CA 60-7749.
1273. P. A. Farrar and H. Margolin, Trans. AIME 227, 1342-1345 (1963); CA 60-7749.
1274. W. H. Ferguson, B. C. Giessen and N. J. Grant, Trans. AIME 227, 1401-1406 (1963); CA 60-7749.
1275. K. Schwerdtfeger and H. J. Engell, Arch. Eisenhüttenw. 34, 647-652 (1963); CA 60-7720.
1276. G. Yamaguchi, Y. Ono, S. Kawamura and Y. Soda, Yogyo Kyokai Shi 71, 9-12 (1963); CA 60-7699.

1277. H. Eklund, Science 142, 1457-1458 (1963); CA 60-6615.
1278. S. A. Been, U. S. Dept. Comm., Office Tech. Serv. PB Rept. 162,003, 26pp (1950); CA 60-6571.
1279. R. Ferro, Atti accad. nazl. Lincei Rend., Classe sci. fis., mat. e nat. 34, 653-658 (1963); CA 60-10227.
1280. A. Duryttere, Mem. Sci. Rev. Met. 60, 359-370 (1963); CA 60-6567.
1281. J. Skala, M. Kase and M. Mandl, Hutnicke Listy 18, 770-773 (1963); CA 60-6545.
1282. R. L. Stegman and E. A. Peretti, Can. Met. Quart. 2, 369-372 (1963); CA 60-6566.
1283. J. E. Senkin and M. T. Milliken, NASA Doc. N63-17569, 196pp (1963); CA 60-5183.
1284. C. M. Sellars and F. Maak, U. S. Dept. Comm., Office Tech. Serv. AD 278,068, 9-35 (1962); CA 60-5163.
1285. W. D. Weatherford, Jr., NASA Doc. N63-17862, 12pp (1963); CA 60-5162.
1286. E. Anderson, J. Less-Common Metals 6, 81-84 (1964); CA 60-5155.
1287. E. Raub, H. Buskow and O. Loebich, Jr., Z. Metallk. 54, 549-552 (1963); CA 60-5130.
1288. H. Sakao and K. Sano, Nippon Kinzoku Gakkaishi 23, 671-674 (1959); CA 60-5124.
1289. F. C. Kracek, U. S. Geol. Survey Bull. 1144-D, 81pp (1963); CA 60-3873.
1290. V. Ya. Chekhovoskoi and V. A. Petrov, Izmeritel'n. Tekhn. 1963, 26-28; CA 60-3852.
1291. E. G. Ponyatovskii, Fiz. Metal. i Metalloved. 16, 622-624 (1963); CA 60-3827.
1292. A. Stegherr, P. Eckerlin and F. Wald, Z. Metallk. 54, 598-600 (1963); CA 60-3826.
1293. C. Liu, A. S. Pashinkin and A. V. Novoselova, Doklady Akad. Nauk S.S.S.R. 151, 1335-1338 (1963); CA 60-3825.
1294. I. Obinata, K. Kurihara, Y. Takeuchi and M. Watanabe, Metall 17, 1205-1208 (1963); CA 60-3825.
1295. A. T. Grigor'ev, V. V. Kuprina and V. B. Bernard, Vestnik Moskov. Univ., Ser. II, Khim. 18, 41-43 (1963); CA 60-3823.
1296. Yu. N. Smirnov and V. A. Finkel, Fiz. Metal. i Metalloved. 16, 637 (1963); CA 60-3823.
1297. R. J. Lott and J. K. Critchley, Nature 200, 773 (1963); CA 60-3817.
1298. J. R. Kerr, Dissertation Abstr. 24, 682-683 (1963); CA 60-3801.
1299. A. I. Minaev and V. V. Kerzhentsev, Tsvetnye Metal. 36, 67-75 (1963); CA 60-3796.
1300. A. I. Okunev, A. K. Kir'yanov and B. I. Sergin, Doklady Akad. Nauk S.S.S.R. 125, 147-148 (1959).
1301. D. N. Klushin and Y. P. Titova, Sbornik Nauch. Tr., Gos. Nauchn.-Issledovatel'. Inst. Tsvetn. Metal. No. 19, 642-646 (1962); CA 60-3767.
1302. W. A. Sanders, J. R. Creagh, C. Talabak and J. J. Gangler, Met. Soc. Conf. 18, 469-483 (1961); CA 60-2618.
1303. G. B. Fedorov, E. A. Smirnov and F. I. Zhomov, Met. i Metalloved. Chistykh Metal., Sb. Nauchn. Rabot. No. 4, 110-121 (1963); CA 60-2503.

1304. W. van Gool, Koninkl. Ned. Akad. Wetenschap., Proc, Ser. B. 66, 209-215 (1963); CA 60-2602.
1305. W. Haeusler, . Metallk. 51, 95-100 (1960); CA 60-2601.
1306. J. R. Cook and D. F. Martin, J. Inorg. and Nuclear Chem. 26, 1249-1253 (1964).
1307. A. J. Leadbetter and J. A. Morrison, Phys. Chem. Glasses 4, 188-192 (1963); CA 60-1424.
1308. R. J. Jackson, D. E. Williams and W. L. Larsen, J. Less-Common Metals 5, 443-461 (1963); CA 60-1393.
1309. G. Petzow and A. Junker, J. Less-Common Metals 5, 462-476 (1963); CA 60-1393.
1310. C. Koh, Ta Han Hua Hsueh Hui-Chih 6, 133-142 (1962); CA 60-1393.
1311. R. V. Lundquist and H. Leitch, U. S. Bur. Mines, Rept. Invest. 6294, 9pp (1963); CA 60-1358.
1312. C. Naganna, Proc. Indian Acad. Sci. Sect. A. 58, 16-28 (1963); CA 60-1357.
1313. P. Franzosini, Ric. Sci. Rend. Sez. A 3, 365-374 (1963); CA 60-1343.
1314. M. A. Doran, S. Chaberek and A. E. Martell, J. Am. Chem. Soc. 86, 2129-2135 (1964).
1315. T. L. Brown, R. L. Gerteis, D. A. Bafus and J. A. Ladd, J. Am. Chem. Soc. 86, 2135-2141 (1964).
1316. E. H. Appelman and J. G. Malm, J. Am. Chem. Soc. 86, 2141-2148 (1964).
1317. E. H. Appelman and J. G. Malm, J. Am. Chem. Soc. 86, 2297-2298 (1964).
1318. K. Niwa, T. Yokokawa, A. Doi and T. Tsiyi, Nippon Kinzoku Gakkaishi 26, 510-512 (1962); CA 60-260.
1319. I. S. S. Chauhan and P. C. Sinha, J. Indian Chem. Soc. 40, 769-773 (1963); CA 60-182.
1320. F. H. Welch, U. S. AEC DC 61-3-73, 6pp (1961); CA 60-179.
1321. O. G. Polyachenok and G. I. Novikov, Zhur. Obshchei Khim. 33, 2797 (1963); CA 60-179.
1322. G. Nagarajan, Australian J. Chem. 16, 908-914 (1963); CA 60-117.
1323. M. E. Levina, Vestnik Moskov. Univ., Ser. II, Khim. 18, 34-38 (1963); CA 60-62.
1324. A. Baur and A. Lecocq, Compt. rend. 257, 1445-1447 (1963); CA 60-61.
1325. G. S. Lin, Chem. Eng. Progr. 59, 70-71 (1963); CA 60-61.
1326. D. Peschanski and J. M. Truchart, Compt. rend. 257, 1853-1856 (1963); CA 60-55.
1327. H. Chateau and M. C. Moncet, J. chim. phys. 60, 1060-1080 (1963); CA 60-55.
1328. M. Murty and Bh. Krishnamurthy, Indian J. Phys. 37, 359-367 (1963); CA 60-4826.
1329. L. P. Ryadneva and A. S. Lenskii, Zhur. Priklad. Khim. 36, 2413-2419 (1963); CA 60-4827.
1330. A. J. H. Boerboom, Vakuum-Tech. 7, 205-207 (1963); CA 60-4827.
1331. F. Massazza, Ann. chim. (Rome) 53, 1002-1017 (1963); CA 60-4853.
1332. N. A. Toropov and V. A. Vasil'eva, Doklady Akad. Nauk S.S.S.R. 152, 1379-1382 (1963); CA 60-4855.
1333. E. Aukrust and A. Muan, J. Am. Ceram. Soc. 46, 511 (1963); CA 60-4856.
1334. T. Ando, Bull. Chem. Soc. Japan 36, 1593-1599 (1963); CA 60-6740.

1335. T. Katan and A. B. Gupta, J. Chem. Eng. Data 8, 574-575 (1963); CA 60-52.
1336. S. G. Bratchikov, Izvest. Vysshikh Ucheb. Zavedenii, Chernaya Met. 6, No. 12, 35-37 (1963); CA 60-4882.
1337. A. F. Vorob'ev and N. M. Privalova, Vestnik Moskov. Univ., Ser. II, Khim. 18, 22-26 (1963); CA 60-4881.
1338. A. F. Vorob'ev, N. M. Privalova and L. Huang, Vestnik Moskov. Univ., Ser. II, Khim. 18, 27-31 (1963); CA 60-4881.
1339. Kh. I. Amirkhanov and A. M. Kerimov, Doklady Akad. Nauk S.S.S.R. 151, 1064-1067 (1963); CA 60-4880.
1340. V. L. Moruzzi and D. T. Teaney, Solid State Commun. 1, 127-131 (1963); CA 60-4880.
1341. C. A. Mackliet and A. I. Schindler, J. Phys. Chem. Solids 24, 1639-1643 (1963); CA 60-4880.
1342. Th. A. Sandenaw, J. Nucl. Mater. 10, 165-172 (1963); CA 60-4880.
1343. H. D. Baehr, Brennstoff-Warme-Kraft 15, 514-522 (1963); CA 60-4880.
1344. R. P. Krentsis, P. V. Gel'd and G. I. Kalishevich, Izvest. Vysshikh Ucheb. Zavedenii, Chernaya Met. 6, 146-152 (1963); CA 60-4879.
1345. A. Krupkowski and A. Block-Bolten, Freiberger Forschungsh. B83, 23-29 (1963); CA 60-4877.
1346. V. N. Eremenko and G. M. Lukashenko, Ukrain. Khim. Zhur. 29, 896-900 (1963); CA 60-4877.
1347. O. G. Polyachenok and G. I. Novikov, Vestnik Leningrad. Univ. 18, Ser. Fiz. i Khim. No.3, 133-134 (1963); CA 60-4875.
1348. V. N. Eremenko and G. M. Lukashenko, Ukrain. Khim. Zhur. 29, 1048-1052 (1963); CA 60-4875.
1349. M. S. Yakovleva and S. M. Ariya, Vestnik Leningrad. Univ. 18, Ser. Fiz. i Khim. No.3, 130-132 (1963); CA 60-4874.
1350. A. I. Dzhabarov and A. I. Agaev, Uch. Zap. Azerb. Gos. Univ., Ser. Fiz.-Mat. i Khim. Nauk 1962, 75-84; CA 60-4870.
1351. M. E. Pozin, V. V. Gubov, L. Ya. Tereshchenko, E. Ya. Tarat and Yu. L. Ponomarev, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 6, 608-616 (1963); CA 60-4870.
1352. G. Schwarzenbach and M. Widmer, Helv. Chim. Acta 46, 2613-2628 (1963); CA 60-4870.
1353. G. M. Anderson, Econ. Geol. 57, 809-828 (1962); CA 60-4869.
1354. L. S. Lilich and O. V. Sapozhnikova, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 6, 572-577 (1963); CA 60-4869.
1355. B. N. Melent'ev, V. V. Ivanenko and L. A. Pamfelova, Doklady Akad. Nauk S.S.S.R. 153, 184-186 (1963); CA 60-4869.
1356. S. Mahapatra and R. S. Subrahmanya, Proc. Indian Acad. Sci. Sect. A. 58, 161-176 (1963); CA 60-4863.
1357. V. B. Shevchenko, V. G. Timoshev and A. A. Volkova, At. Energ. (USSR) 6, 426-430 (1959); CA 60-4864.
1358. R. F. Brebrick, J. Chem. Phys. 41, 1140-1146 (1964).
1359. G. Brunisholz and M. Bodmer, Helv. Chim. Acta 46, 2566-2574 (1963); CA 60-4857.
1360. H. Mackle and P. A. G. O'Hare, Trans. Faraday Soc. 60, 666-668 (1964).
1361. R. Colin and J. Drowart, Trans. Faraday Soc. 60, 673-683 (1964).
1362. I. G. Murgulescu and R. Vilcu, Z. physik. Chem. 225, 37-44 (1964).

1363. I. V. Nelson and R. T. Iwamoto, Inorg. Chem. 3, 661-663 (1964).
1364. J. E. Powell and Y. Suzuki, Inorg. Chem. 3, 690-692 (1964).
1365. C. H. Van Dyke and A. G. Mac Diarmid, Inorg. Chem. 3, 747-752 (1964).
1366. V. D. Nikitin, E. M. Yakimets, N. A. Timakova, V. A. Rad'ko, N. V. Shabashova and V. V. Tribunskii, Tr. Ural'sk. Politekhn. Inst. No. 130, 94-103 (1963); CA 60-11590.
1367. G. K. Czamanske, Econ. Geol. 57, 1268-1269 (1962); CA 60-11426.
1368. G. K. Shurdermov, Materialy 3-ei [Tret'ei] Nauchn. Konf. Aspirantov Sb. 1961, 200-203; CA 60-11428.
1369. A. A. Antonov, D. S. Koval'chuck and P. G. Maslov, Ukrain. Khim. Zhur. 30, 20-24 (1964); CA 60-11431.
1370. W. Kischio, Z. anrog. u. allgem. Chem. 328, 187-193 (1964).
1371. S. Siolkiewicz, M. Bruneaux and G. Morand, Compt. rend. 258, 1786-1789 (1964); CA 60-11432.
1372. V. M. Vdovenko, I. G. Suglobova, D. N. Suglobov and Yu. V. Datyuk, Radiokhimiya 5, 739-741 (1963); CA 60-11433.
1373. C. W. Massena, Dissertation Abstr. 24, 1851 (1963); CA 60-11433.
1374. P. Gerdanian and M. Dode, Compt. rend. 258, 1492-1495 (1964); CA 60-11433.
1375. S. Hoshino, J. Phys. Soc. Japan 19, 140-141 (1964); CA 60-11434.
1376. F. E. McKelvey, Hydrocarbon Process. Petrol. Refiner 43, 129-132 (1964); CA 60-11434.
1377. N. Morimoto, Mineral. Soc. Am., Spec. Paper 1, 153-156 (1963); CA 60-11440.
1378. R. P. Martin and R. A. Paris, Bull. soc. chim. France 1964, 80-85; CA 60-11588.
1379. P. S. Shetty, P. R. Subbaraman and J. Gupta, Indian J. Chem. 2, 8-11 (1964); CA 60-11591.
1380. N. A. Toropov and A. K. Shirvenskaya, Doklady Akad. Nauk S.S.S.R. 153, 1081-1084 (1963); CA 60-11599.
1381. M. I. Gillibrand and B. E. Wilde, Electrochim. Acta 9, 401-411 (1964).
1382. A. V. Lapitskii and I. Geleceanu, Radiokhimiya 5, 330-334 91963); CA 60-2533.
1383. M. Stammler, D. Orcutt and P. C. Colodny, Advan. X-Ray Anal. 6, 202-209 (1962); CA 60-2394.
1384. Z. Bieganski and B. Stalinski, Bull. acad. polon. sci., Ser. sci. chim. 9, 367-372 (1961); CA 60-2390.
1385. S. Sternberg and D. I. Merchidan, Rev. chim., Acad. rep. populaire Roumaine 8, 115-121 (1963); CA 60-2390.
1386. N. M. Selivanova, K. K. Samplavskaya and . I. Maier, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 30-36 (1962); CA 60-2389.
1387. L. A. Sharkova, Ya. I. Gerasimov, T. N. Rezukhina and Yu. P. Simanov, Doklady Akad. Nauk S.S.S.R. 128, 992-994 (1949); CA 60-2389.
1388. N. G. Bereznyak, I. V. Bogoyavlenskii and B. N. Esel'son, Zhur. Eksptl. i Teoret. Fiz. 45, 486-495 (1963); CA 60-2385.
1389. M. Kodama and K. Hanawa, Ibaraki Daigaku Bunrigakubu 13, 9-16 (1962); CA 60-2382.
1390. R. Cohen-Adad and J. C. Vouillon, Compt. rend. 257, 2287-2289 (1963); CA 60-2379.

1391. L. A. Khiripin, Izvest. Sibir. Otdel. Akad. Nauk S.S.S.R., Ser. Khim. Nauk 1963, 107-110.
1392. B. S. Brcic, L. Golic, P. Peternel, J. Siftar and M. Zumer, Vestn. Sloven. Kem. Drustva 9, 27-32 (1962); CA 60-2378.
1393. G. K. Layden, J. Am. Ceram. Soc. 46, 506 (1963); CA 60-2378.
1394. G. L. Reed, K. J. Sutton and D. F. C. Morris, J. Inorg. and Nuclear Chem. 26, 1227-1231 (1964).
1395. S. Pawlenko, Z. anorg. u. allgem. Chem. 328, 133-143 (1964).
1396. M. V. Susic, Bull. Boris Kidric Inst. Nucl. Sci. 14, 125-133 (1963); CA 60-10185.
1397. G. P. Arkhipova, I. E. Flis and K. P. Mishchenko, Tr. Leningr. Tekhnol. Inst. Tsellyulozn, Bumazhn. Prom. No. 11, 124-127 (1962); CA 60-10200.
1398. V. P. Kazakov, A. I. Lapshin and B. I. Peshchevitskii, Zhur. Neorg. Khim. 9, 1299-1300 (1964).
1399. J. Bousquet and G. Perachon, Compt. rend. 258, 934-936 (1964); CA 60-10201.
1400. S. N. Pobedinskii, G. A. Krestov and L. L. Kuz'min, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 6, 768-773 (1963); CA 60-10 10213.
1401. B. J. McBride, S. Heimel, J. G. Ehlers and S. Gordon, NASA Doc. N63-23715, 332pp (1963); CA 60-8707.
1402. M. Bruneaux, S. Ziolkiewicz and G. Morand, Compt. rend. 257, 3591-3594 (1963); CA 60-8709.
1403. I. E. Flis, K. P. Mishchenko and T. A. Tumanova, Tr. Leningr. Tekhnol. Inst. Tsellyulozn.-Bumazhn. Prom. No. 11, 94-98 (1962); CA 60-8710.
1404. M. E. Levina and Z. D. Semenova, Vestnik Moskov. Univ., Ser. II, Khim. 18, 55-58 (1963); CA 60-8710.
1405. W. R. Scott, V. Jaccarino, J. H. Wernick and J. P. Maita, J. Appl. Phys. 35, 1092-1093 (1964); CA 60-8711.
1406. P. Franzosini and K. Clusius, Z. Naturforsch. 18a, 1243-1246 (1963); CA 60-8712.
1407. I. W. Mialki and H. J. Frund, Metall 18, 1-7 (1964); CA 60-8854.
1408. H. van Kempen, A. R. Miedema and W. J. Huiskamp, Physica 30, 229-236 (1964); CA 60-8711.
1409. Z. Bieganski and B. Stalinski, Bull. acad. polon. sci., Ser. sci. chim. 11, 579-582 (1963); CA 60-8711.
1410. L. S. Kothari and V. K. Tewary, Phys. Letters 6, 248 (1963); CA 60-8711.
1411. S. P. Banerjee and A. K. Bhattacharya, J. Proc. Inst. Chem. (India) 35, 247-250 (1963); CA 60-8886.
1412. G. Ahlers and W. H. Orttung, Phys. Rev. [2] 133, 1642-1650 (1964); CA 60-8711.
1413. T. N. Dymova, M. S. Selivokhina and N. G. Eliseeva, Doklady Akad. Nauk S.S.S.R. 153, 1330-1332 (1963); CA 60-8887.
1414. E. Balazs, Femip. Kut. Int. Kozlemeny 6, 121-129 (1962); CA 60-8895.
1415. E. G. Gatilova, S. V. Makhortykh and M. S. Zakhar'evskii, Vestnik Leningrad. Univ. No. 4, Ser. Fiz. i Khim. 18, 114-119 (1963).

1416. W. Kemula and A. Hulanicke, Bull. acad. polon. sci., Ser. sci. chim. 9, 477-482 (1961); CA 60-8699.
1417. J. Fresco and H. Freiser, Anal. Chem. 36, 372-375 (1964); CA 60-11425.
1418. H. W. Krause, F. W. Wilcke, H. Mix and W. Langenbeck, Z. physik. Chem. 225, 342-348 (1964).
1419. S. I. Yavorskii, Raboty po Khim.-Chlenov Krymsk. Otd. Vses. Khim. Obshchestva im. D. I. Mendeleeva Sb. 1960, 29-38; CA 60-11421.
1420. F. Jona, R. F. Lever and H. R. Wendt, J. Electrochem. Soc. 111, 413-417 (1964); CA 60-11421.
1421. A. P. Shchedrina, M. I. Ozerova and K. G. Khomyakov, Vestnik Moskov. Univ., Ser. II, Khim. 19, 51-52 (1964); CA 60-11423.
1422. G. I. Vasil'ev and V. V. Serebrennikov, Tr. Tomskogo Gos. Univ., Ser. Khim. 154, 103-104 (1962); CA 60-11423.
1423. I. A. Lodzinska, Z. Jablonski and J. Gornicki, Roczniki Chem. 37, 1379-1385 (1963); CA 60-11423.
1424. H. Witzmann and W. Beulich, Z. physik. Chem. 225, 336-341 (1964).
1425. Yu. P. Novikov and G. Pfrepper, Z. Naturforsch. 18b, 993-1001 (1963); CA 60-11424.
1426. C. F. Timberlake, J. Chem. Soc. 1964, 1229-1240.
1427. P. L. Timms, C. C. Simpson and C. S. G. Phillips, J. Chem. Soc. 1964, 1467-1475.
1428. N. K. Dutt and P. Bandyopadhyay, J. Inorg. and Nuclear Chem. 26, 729-736 (1964).
1429. J. R. Van Wazer and K. Moedritzer, J. Inorg. and Nuclear Chem. 26, 737-744 (1964).
1430. C. D. Schmulbach, J. Inorg. and Nuclear Chem. 26, 745-749 (1964).
1431. M. M. Jones, K. V. Dandh and G. T. Fisher, J. Inorg. and Nuclear Chem. 26, 773-779 (1964).
1432. J. E. Mix, Jr. and M. M. Jones, J. Inorg. and Nuclear Chem. 26, 781-787 (1964).
1433. K. S. Rajan and A. E. Martell, J. Inorg. and Nuclear Chem. 26, 789-798 (1964).
1434. B. M. L. Bansal and H. D. Sharma, J. Inorg. and Nuclear Chem. 26, 799-805 (1964).
1435. J. M. C. Hess, J. Braunstein and H. Braunstein, J. Inorg. and Nuclear Chem. 26, 811-820 (1964).
1436. E. V. Kiseleva, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 85-87 (1962); CA 60-9976.
1437. E. V. Kiseleva, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 71-85 (1962); CA 60-9976.
1438. R. S. Mkhitaryan and L. O. Zatikyan, Izvest. Akad. Nauk Arm. S.S.R., Khim. Nauki 16, 343-346 (1963); CA 60-1438.
1439. C. T. Mortimer and H. D. Springall, Endeavour 23, 22-26 (1964); CA 60-9979.
1440. R. L. Lister and S. N. Flengas, J. Electrochem. Soc. 111, 343-348 (1964); CA 60-9981.
1441. S. G. Zaitsev and R. I. Soloukhin, Tr. Odessk. Gos. Univ., Ser. Fiz. Nauk 152, 30-35 (1962); CA 60-12668.
1442. S. L. Rivkin and T. S. Akhundov, Izvest. Vysshikh Ucheb. Zavedenii, Neft i Gaz 6, 70 (1963); CA 60-12671.

1443. R. O. Bach, W. W. Boardman, Jr. and M. W. Forsyth, Chimia Switz. 18, 110-111 (1964); CA 60-12682.
1444. F. D. Stevenson, C. E. Wicks and F. E. Block, U. S. Bur. Mines, Rept. Invest. 6367, 32pp (1964); CA 60-12682.
1445. R. A. Isakova, V. N. Nesterov and V. S. Esyutin, Tr. Inst. Met. i Obogashch., Akad. Nauk Kaz. S.S.R. 8, 6-7 (1963); CA 60-12683.
1446. N. E. Phillips, Phys. Rev. [2] 134, 383-391 (1961); CA 60-12723.
1447. D. Kolar, Croat. Chem. Acta 35, 289-293 (1963); CA 60-12724.
1448. T. Morimoto, K. Shiomi and H. Tanaka, Bull. Chem. Soc. Japan 37, 392-395 (1964); CA 60-12724.
1449. D. R. Simpson, Econ. Geol. 59, 150-153 (1964).
1450. L. K. Walford, Phil. Mag. 9, 513-516 (1964); CA 60-12710.
1451. J. Dauphin, S. Dauphin, D. Chatonier and G. Andraud, Bull. soc. chim. France 1963, 2751-2754.
1452. A. M. M. Gadalla and J. White, Trans. Brit. Ceram. Soc. 63, 39-62 (1964); CA 60-12712.
1453. J. Fournier and A. Vedrine, Compt. rend. 258, 2069-2070 (1964); CA 60-12714.
1454. L. I. Dubovenko and T. F. hulinskaya, Ukrain. Khim. hur. 30, 228-232 (1964); CA 60-12714.
1455. H. K. Hofmeister and J. P. Van Wazer, J. Inorg. and Nuclear Chem. 26, 1209-1213 (1964).
1456. J. J. R. F. da Silva, Rev. Port. Quim. 4, 119-132 (1962); CA 60-12715.
1457. G. G. Diogenov and I. F. Sarapulova, hur. Neorg. Khim. 9, 1292-1294 (1964).
1458. P. I. Fedorov and N. I. Il'ina, Zhur. Neorg. Khim. 9, 1207-1210 (1964).
1459. A. V. Nikolaev and Yu. A. Afans'ev, Doklady Akad. Nauk S.S.S.R. 155, 374-375 (1964); CA 60-12721.
1460. J. C. Trowbridge, Dissertation Abstr. 24, 2291-2292 (1963).
1461. L. B. Pankratz, U. S. Bur. Mines, Rept. Invest. 6371, 6pp (1964); CA 60-12724.
1462. N. P. Luzhnaya, G. K. Slavnova, . S. Medvedeva and A. A. Eliseev, Zhur. Neorg. Khim. 9, 1174-1181 (1964).
1463. G. D. Uryvaeva and T. E. Pendyurina, Izvest. Sibir. Otdel. Akad. Nauk S.S.S.R. 1963, 26-29; CA 60-12722.
1464. M. Thackray, Nature 201, 674-675 (1964); CA 60-12730.
1465. R. E. Hanneman, M. D. Banus and H. C. Gatos, J. Phys. Chem. Solids 25, 293-302 (1964); CA 60-12760.
1466. E. Veleckis, U. S. Dept. Comm., Office Tech. Serv. AD 282,433, 174pp (1960); CA 60-9981.
1467. P. Schwerdtfeger, J. Glaciol 4, 789-807 (1963); CA 60-9981.
1468. P. Pouillen and J. Saurel, Compt. rend. 258, 188-191 (1964); CA 60-9982.
1469. O. Knacke and K. E. Prescher, Z. Erzbergbau Metallhüttenw. 17, 28-34 (1964); CA 60-9982.
1470. A. S. Lenskii, A. D. Shaposhnikova and E. S. Sokolova, Zhur. Neorg. Khim. 9, 1147-1154 (1964).
1471. N. M. Selivanova and T. A. Sazykina, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 6, 531-533 (1963); CA 60-9983.

1472. C. E. Holley, Jr., Pure Appl. Chem. 8, 131-142 (1964); CA 60-9983.
1473. I. Leden, Pure Appl. Chem. 8, 171-178 (1964); CA 60-9983.
1474. C. A. Bailey, Proc. Phys. Soc. (London) 83, 369-374 (1964); CA 60-9984.
1475. I. G. Ryss and N. F. Kulish, Zhur. Neorg. Khim. 9, 1103-1108 (1964).
1476. J. Skalyo and S. A. Friedberg, U. S. Dept. Comm., Office Tech. Serv. AD 285,553, 4pp (1962); CA 60-9984.
1477. S. A. Shchukarev, E. K. Smirnova, I. V. Vasil'kova and M. S. Kotova, Vestnik Leningrad. Univ. No. 4, Ser. Fiz. i Khim. 18, 174-176 (1963); CA 60-9985.
1478. A. M. Sirota, Inzhener.-Fiz. Zhur., Akad. Nauk Belorus. S.S.R. 6, 52-55 (1963); CA 60-9985.
1479. H. D. Baehr, Forsch. Gebiete Ingenieurw. 29, 143-146 (1963); CA 60-7484.
1480. K. P. Gupta, C. H. Cheng and P. A. Beck, Phys. Rev. [2] 133, 203-206 (1964); CA 60-3555.
1481. Z. L. Leshchinskaya, N. M. Selivanova, A. I. Maier, I. S. Strel'tsov and E. Yu. Muzalev, Zh. Vses. Khim. Obshchestva im. D. I. Mendeleeva 8, 577-578 (1963); CA 60-3554.
1482. C. A. Washburn, U. S. AEC UCRL 10991, 20pp (1963); CA 60-9971.
1483. I. C. Asada, T. Sugiyama and S. Inagaki, Denki Seiko 34, 128-132 (1963); CA 60-12946.
1484. H. S. Martin, G. Frohberg and W. Kranz, Arch. Eisenhüttenw. 34, 825-830 (1963); CA 60-12948.
1485. N. G. Schmahl and E. Minzl, Z. physik. Chem. [NF] 41, 66-77 (1964).
1486. H. Hatwell, G. Offergold, C. Herinckx and J. van Cakenberghe, Compt. rend. 258, 553-555 (1964); CA 60-11414.
1487. J. P. Bros, E. Calvet and C. Prunier, Compt. rend. 258, 170-173 (1964); CA 60-9986.
1488. H. J. Kuzel, Neues Jahrb. Mineral. Abhandl. 100, 322-338 (1963); CA 60-8690.
1489. A. Burdese and M. L. Borlera, Ricerca sci. 3, 1025-1027 (1963); CA 60-8689.
1490. D. H. Lindsley, Carnegie Inst. Wash. Yearbook 1962, 60-66; CA 60-8689.
1491. P. R. Buseck, Carnegie Inst. Wash. Yearbook 1962, 200-210; CA 60-8689.
1492. M. Blanc, L. Denielou and G. Petit, Compt. rend. 258, 491-494 (1964); CA 60-8663.
1493. N. Bernardes and C. A. Swenson, U. S. AEC IS 359, 64pp (1961); CA 60-8661.
1494. Yu. I. Petrov, Fiz. Tverd. Tela 5, 3533-3540 (1963); CA 60-8653.
1495. G. I. Vasil'ev, S. P. Kazantseva and V. V. Serebrennikov, Tr. Tomskogo Gos. Univ., Ser. Khim. 154, 110-114 (1962); CA 60-8696.
1496. E. Campi, G. Ostacoli and A. Vanni, Ric. Sci., Rend. Sez. A. 3, 1073-1084 (1963).
1497. A. A. Grinberg, N. V. Kiseleva and M. I. Gel'fman, Doklady Akad. Nauk S.S.S.R. 153, 1327-1329 (1963); CA 60-8697.
1498. M. M. Shul'ts and I. M. Bushneva, Vestnik Leningrad. Univ. No. 4, Ser. Fiz. i Khim. 18, 120-130 (1963); CA 60-8706.
1499. A. P. Shchedrina, M. I. Ozerova and K. G. Khomyakov, Vestnik Moskov. Univ., Ser. II, Khim. 18, 62-64 (1963); CA 60-8705.

1500. A. Capkova and V. Fried, Collection Czech. Chem. Communs. 29, 336-340 (1964); CA 60-8703.
1501. A. M. Golub and A. M. Sych, Zhur. Neorg. Khim. 9, 1085-1093 (1964).
1502. L. A. Nisel'son, A. I. Pustil'nik and T. D. Sokolova, hur. Neorg. Khim. 9, 1049-1052 (1964).
1503. S. Ya. Lebedev and Yu. Ya. Stavisskii, Pribory i Tekhn. Eksperim. 1962, 142-144; CA 60-9939.
1504. A. A. Eliseev, E. I. Yarembash, E. S. Vigileva, L. I. Antonova and A. V. Zachatskaya, hur. Neorg. Khim. 9, 1032-1037 (1964).
1505. C. C. Herrick, U. S. AEC LA 2995, 32pp (1964); CA 60-9939.
1506. D. G. Miller, Ind. Eng. Chem. 56, 46-57 (1964); CA 60-9939.
1507. A. R. Miller, U. S. AEC UCRL 10857, 39pp (1963); CA 60-9939.
1508. W. F. Lee, N. K. Shastri and E. S. Amis, Talanta 11, 685-690 (1964).
1509. B. Nador, Nature 201, 921-922 (1964); CA 60-9967.
1510. T. Katsura and A. Muan, Trans. AIME 230, 77-84 (1964); CA 60-9967.
1511. N. Schromek, Ann. chim. (Rome) 53, 1560-1563 (1963); CA 60-9967.
1512. P. L. Blum, P. Guinet and H. Vaugoyeau, Compt. rend 257, 3401-3403 (1963); CA 60-9967.
1513. R. Vieweg, Chem. Tech. (Berlin) 15, 734-740 (1963); CA 60-9967.
1514. G. H. Moh, Carnegie Inst. Wash. Yearbook 1962, 197-198; CA 60-9968.
1515. G. H. Moh, Carnegie Inst. Wash. Yearbook 1962, 198-199; CA 60-9968.
1516. G. H. Moh, Carnegie Inst. Wash. Yearbook 1962, 199-200; CA 60-9968.
1517. M. Fiorani, G. G. Bombi and M. T. Marchetto, Chim. e ind. (Milan) 45, 707-709 (1963); CA 60-9968.
1518. P. A. Vozzella, A. D. Miller and M. A. De Crescente, J. Chem. Phys. 41, 589-590 (1964).
1519. M. L. McGlashan, Pure Appl. Chem. 8, 157-169 (1964); CA 60-9984.
1520. L. I. Marina, A. Ya. Nashel'skii, V. N. Vigdorovich and D. D. Bakanova, hur. Fiz. Khim. 38, 551-555 (1964).
1521. V. I. Zhelankin and V. S. Kutsev, hur. Fiz. Khim. 38, 562-564 (1964).
1522. G. D. Efremova and R. O. Pryanikova, hur. Fiz. Khim. 38, 686-691 (1964).
1523. Ya. A. Epikhin, M. S. Stakhanova and M. Kh. Karapet'yants, Zhur. Fiz. Khim. 38, 692-696 (1964).
1524. L. A. Zharkova and N. G. Barancheeva, hur. Fiz. Khim. 38, 752-754 (1964).
1525. L. A. Reznitskii, Zhur. Fiz. Khim. 38, 760-762 (1964).
1526. G. Gattow and D. Schuetze, Z. anorg. u. allgem. Chem. 328, 44-68 (1964).
1527. J. Fuger and B. B. Cunningham, J. Inorg. and Nuclear Chem. 25, 1423-1429 (1963).
1528. D. L. Hildenbrand, J. Chem. Phys. 40, 3438-3439 (1964).
1529. G. Grenier and D. White, J. Chem. Phys. 40, 3451-3452 (1964).
1530. V. M. Kh. Karapet'yants, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 52-58 (1962).
1531. W. W. Weller and K. K. Kelley, U. S. Bur. Mines, Rept. Invest. 6343, 7pp (1963); CA 60-7517.
1532. W. H. Lien and N. E. Phillips, Phys. Rev. [2] 133, 1370-1377 (1964); CA 60-7517.

1533. C. Nicollin, J. Lenoir, L. Sicard and C. Eyraud, J. chim. phys. 60, 1372-1373 (1963); CA 60-7517.
1534. C. Lenchitz, R. Velicky and B. Haywood, U. S. Dept. Comm., Office Tech. Serv. AD 401,481, 13pp (1962); CA 60-7517.
1535. M. L. Pearce, Trans. AIME 227, 1393-1400 (1963); CA 60-7751.
1536. H. R. Ogden, F. F. Schmidt and E. S. Bartlett, Trans. AIME 227, 1458-1460 (1963); CA 60-7754.
1537. F. Cech and P. Pavondra, Acta Univ. Carolinae, Geol. 1963, 97-114; CA 60-7799.
1538. M. Kyrs and R. Caletka, Talanta 10, 1115-1116 (1963); CA 60-1166.
1539. K. G. Sewell, NASA Doc. N63-15069, 62pp (1962); CA 60-6273.
1540. A. A. Vasserman, Teploenergetika 10, 81-85 (1963); CA 60-6273.
1541. A. Ya. Stomakhin and A. Yu. Polyakov, Byul. Tekhn.-Ekon. Inform., Gos. Nauchn.-Issled. Inst. Nauchn. i Tekhn. Inform. 1963, 10-11; CA 60-6567.
1542. R. L. Orr and R. Hultgren, U. S. Dept. Comm., Office Tech. Serv., AD 294,426, 6pp (1962); CA 60-6568.
1543. P. R. Brett and G. Kullerud, Carnegie Inst. Wash. Yearbook 1962, 196-197; CA 60-9021.
1544. L. A. Clark and G. Kullerud, Econ. Geol. 58, 853-885 (1963); CA 60-9021.
1545. K. Jong and J. H. Kung, J. Am. Concrete Inst. 32, 459-470 (1961); CA 60-8999.
1546. M. S. Chandrasekharaiah, J. Phys. Chem. 68, 2020-2021 (1964).
1547. C. M. Ko and E. N. Pylaeva, Titan i Ego Splavy, Akad. Nauk S.S.S.R., Inst. Met. No. 10, 22-26 (1963); CA 60-8974.
1548. L. J. Schkolnick and S. L. Quimby, U. S. Army Res. Office (Durham), Final Tech. Rept., Part V, AROD-1931-5, Contract DA-30-069-ORD-2195, 36pp (Oct. 1962).
1549. O. K. Belousov, I. I. Kornilov and V. S. Mikheev, Titan i Ego Splavy, Akad. Nauk S.S.S.R., Inst. Met. No. 10, 27-36 (1963); CA 60-1549.
1550. K. I. Shakhova and P. B. Budberg, Titan i Ego Splavy, Akad. Nauk S.S.S.R., Inst. Met. No. 10, 37-41 (1963); CA 60-8973.
1551. C. M. Ko and E. N. Pylaeva, Titan i Ego Splavy, Akad. Nauk S.S.S.R., Inst. Met. No. 10, 14-21 (1963); CA 60-8973.
1552. C. Offroy and J. Aubry, Mem. Sci. Rev. Met. 60, 797-800 (1963); CA 60-8951.
1553. H. H. Cox and L. M. Pidgeon, Minerals Process. 5, 31-33 (1964); CA 60-8925.
1554. P. Gray, J. C. Lee and M. Spencer, Combust. Flame 7, 315-321 (1963); CA 60-7861.
1555. J. P. Eberhart, Bull. soc. franc. mineral. et crist. 86, 213-251 (1963); CA 60-7803.
1556. I. V. Gordeev, Yu. D. Tret'yakov and K. G. Khomyakov, Vestnik Moskov. Univ., Ser. II, Khim. 18, 59-61 (1963); CA 60-7515.
1557. E. R. Nightingale, Jr. and R. F. Benck, Talanta 11, 241-245 (1964); CA 60-5065.
1558. H. L. Clever, W. K. Wong, C. A. Wulff and E. F. Westrum, Jr., J. Phys. Chem. 68, 1967-1969 (1964).

1559. A. M. Gadalla, W. F. Ford and J. White, Trans. Brit. Ceram. Soc. 62, 45-66 (1963); CA 60-7506.
1560. H. K. El-Shamy, A. M. El-Aggan and M. G. Habashy, J. Chem. U.A.R. 4, 159-168 (1961).
1561. T. Nashino and K. Moteki, Kogyo Kagaku Zasshi 66, 407-412 (1963); CA 60-1318.
1562. R. F. Brebrick and A. J. Strauss, J. Chem. Phys. 40, 3230-3241 (1964).
1563. O. L. Kruger and H. Savage, J. Chem. Phys. 40, 3324-3328 (1964).
1564. Yu. A. Nikiforov and V. D. Ponomarev, Tr. Inst. Met. i Obogashch., Akad. Nauk Kaz. S.S.R. 6, 51-54 (1963); CA 60-1324.
1565. J. Shankar and B. C. de Souza, Australian J. Chem. 16, 1119-1122 (1963); CA 60-5065.
1566. A. G. Turnbull and J. A. Watts, Australian J. Chem. 16, 947-953 (1963); CA 60-5064.
1567. H. B. Hetzer, R. A. Robinson and R. G. Bates, J. Phys. Chem. 68, 1929-1933 (1964).
1568. P. Lumme and H. Lumme, Suomen Kemistilehti 36B, 176-182 (1963); CA 60-5052.
1569. K. A. Gingerich, Nature 200, 877 (1963); CA 60-5049.
1570. K. A. Gingerich and P. K. Lee, J. Chem. Phys. 40, 3520-3526 (1964).
1571. L. S. Levinson, J. Chem. Phys. 40, 3584-3585 (1964).
1572. J. E. Griffiths, R. P. Carter, Jr. and R. R. Holmes, J. Chem. Phys. 41, 863-876 (1964).
1573. A. L. Grigoryan, Nauchn. Tr. Nauchn.-Issled. Gornomet. Inst. Arm. S.S.R. 1961, 113-118; CA 60-9970.
1574. J. Myl and D. Koubova, Chem. průmysl 14, 38-40 (1964); CA 60-9970.
1575. N. M. Selivanova and T. A. Sazykina, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 26-29 (1962); CA 60-3555.
1576. A. M. Aleksandrovich and V. V. Serebrennikov, Tr. Tomskogo Gos. Univ., Ser. Khim. 154, 103-109 (1962); CA 60-8696.
1577. V. E. Ostrouskii, I. R. Karpovich, N. V. Kul'kova and M. I. Temkin, Zhur. Fiz. Khim. 37, 2596-2600 (1963); CA 60-5083.
1578. O. S. Jessemen, G. D. Roben, A. L. Grunewald, W. S. Fleshman, K. Anderson and V. P. Calkins, U. S. Dept. Comm., Office. Tech. Serv., PB Rept. 160,750, 15pp (1961); CA 60-5164.
1579. F. C. Haas, U. S. Dept. Comm., Office Tech. Serv. AD 404,619, 80pp (1963); CA 60-6494.
1580. T. K. Dzhabagin, D. K. Rai and P. A. Semenov, Khim. Prom. 1963, 870-875; CA 60-7484.
1581. Yu. Ts. Val and N. A. Shishakov, Izvest. Akad. Nauk S.S.S.R., Ser. Khim. 1963, 1920-1923; CA 60-6465.
1582. W. P. Han, Y. C. Wang and T. H. Wang, K'o Hsueh T'ung Pao 1963, 51-53; CA 60-6456.
1583. F. Klanberg, Z. Naturforsch. 18b, 845-846 (1963); CA 60-6453.
1584. A. M. Golub and R. A. Kostrova, Ukrain. Khim. Zhur. 29, 784-789 (1963); CA 60-6455.
1585. C. D. Thurmond and C. J. Frosch, J. Electrochem. Soc. 111, 184-191 (1964); CA 60-6277.
1586. O. V. Lounasmaa, Phys. Rev. [2] 133, 502-509 (1964); CA 60-6274.

1587. A. D. Mah, U. S. Bur. Mines, Rept. Invest. 6337, 9pp (1963); CA 60-6274.
1588. I. I. Kurnits'kii, Farmatsevt. Zh. 18, 39-41 (1963); CA 60-6266.
1589. P. Lumme and H. Lumme, Suomen Kemistilehti 36B, 192-198 (1963); CA 60-6265.
1590. K. Wuethrich and S. Fallao, Chimia (Aarau) 17, 356-358 (1963); CA 60-6265.
1591. G. S. Klebanov and A. V. Morozova, Zhur. Priklad. Khim. 37, 207-209 (1964).
1592. L. A. Blatz, U. S. AEC LA 2513, 28pp (1963); CA 60-6265.
1593. R. Nasanen and P. Merilainen, Suomen Kemistilehti 36B, 205-208 (1963); CA 60-6265.
1594. G. R. Belton and R. L. McCarron, J. Phys. Chem. 68, 1852-1856 (1964).
1595. J. J. English, NASA Doc. N63-16586, 139pp (1963); CA 60-6260.
1596. W. S. Miller, F. Dachille, E. C. Shafer and R. Roy, Am. Mineralogist 48, 1024-1032 (1963); CA 60-6259.
1597. V. I. Minenko and N. S. Ivanova, Ukrain. Khim. Zhur. 29, 1160-1164 (1963); CA 60-6259.
1598. H. Moser, J. Otto and W. Thomas, Z. Physik 175, 327-336 (1963); CA 60-6238.
1599. F. W. Dickson, L. D. Shields and G. C. Kennedy, Econ. Geol. 57, 1021-1030 (1962); CA 60-6234.
1600. E. Amberger, Angew. Chem. 72, 494 (1960); CA 60-4171.
1601. M. T. Beck and F. Gaizer, Magyar Chem. Folyoirat 69, 560-561 (1963); CA 60-7764.
1602. C. Radford, Ceramics 10, 15-17 (1959); CA 60-5182.
1603. W. C. Child, Jr., J. Phys. Chem. 68, 1834-1838 (1964).
1604. T. B. Douglas, J. Research Natl. Bur. Standards 67A, 403-426 (1963); CA 60-7515.
1605. M. E. Levina and N. V. Khromova, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 6, 717-723 (1963); CA 60-7517.
1606. V. A. Kireev, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 6, 751-753 (1963); CA 60-7518.
1607. A. Haim, J. Am. Chem. Soc. 86, 2352-2356 (1964).
1608. J. H. Smith, H. W. Paxton and C. L. McCabe, J. Phys. Chem. 68, 1345-1354 (1964).
1609. C. C. Stephenson, H. P. Hopkins and C. A. Wulff, J. Phys. Chem. 68, 1427-1429 (1964).
1610. D. D. Jackson, G. W. Barton, Jr., O. H. Krikorian and R. S. Newburg, J. Phys. Chem. 68, 1516-1523 (1964).
1611. D. Cubicciotti, J. Phys. Chem. 68, 1528-1532 (1964).
1612. G. P. Rao and A. R. V. Murthy, J. Phys. Chem. 68, 1573-1576 (1964).
1613. H. S. Dunsmore and G. H. Nancollas, J. Phys. Chem. 68, 1579-1581 (1964).
1614. A. N. Morozov and I. A. Novokhatskii, Izvest. Akad. Nauk S.S.S.R., Met. i Gorn. Delo 1963, 18-22.
1615. T. I. Lezhava and . T. Vagramyan, Izvest. Akad. Nauk S.S.S.R., Ser. Khim. 1964, 435-439.
1616. S. A. Frid, O. G. Polyachenok and G. I. Novikov, hur. Neorg. Khim. 9, 1017-1019 (1964).

1617. V. M. Tsintsius and E. E. Yudovich, Zhur. Neorg. Khim. 9, 1015-1016 (1964).
1618. V. I. Kravtsov and G. M. Petrova, hur. Neorg. Khim. 9, 1010-1013 (1964).
1619. I. V. Vasil'kova, A. I. Efimov and B. . Pitirimov, Zhur. Neorg. Khim. 9, 900-904 (1964).
1620. R. I. Novoselov, Z. A. Muzykantova and B. V. Ptitsyn, Zhur. Neorg. Khim. 9, 799-802 (1964).
1621. O. G. Polyachenok and G. I. Novikov, hur. Neorg. Khim. 9, 773-777 (1964).
1622. K. Baechmann and K. H. Lieser, Ber. Bunsen Ges. physik. Chem. 67, 810-816 (1963).
1623. K. Baechmann and K. H. Lieser, Ber. Bunsen Ges. physik. Chem. 67, 802-809 (1963).
1624. N. I. Kolbin, I. N. Semenov and Yu. M. Shutov, hur. Neorg. Khim. 9, 1029-1031 (1964).
1625. V. P. Vasil'ev and V. N. Vasil'eva, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 6, 693-695 (1963).
1626. N. G. Schmahl and E. Minzl, . physik. Chem. [NF] 41, 78-96 (1964).
1627. P. Hurwitz and K. Kustin, Inorg. Chem. 3, 823-826 (1964).
1628. J. A. Broomhead, F. Basolo and R. G. Pearson, Inorg. Chem. 3, 826-832 (1964).
1629. J. C. Sullivan and J. E. French, Inorg. Chem. 3, 832-836 (1964).
1630. R. G. Lacoste and . E. Martell, Inorg. Chem. 3, 881-884 (1964).
1631. Degeorges, J. Normand and J. M. Vergnaud, Bull. soc. chim. France 1963, 2295-2298.
1632. R. F. Brebrick and A. J. Strauss, J. Chem. Phys. 41, 197-205 (1964).
1633. G. Ahlers, J. Chem. Phys. 41, 86-94 (1964).
1634. J. H. Norman, P. Winchell and H. G. Staley, J. Chem. Phys. 41, 66-67 (1964).
1635. G. Anderegg, Helv. Chim. Acta 46, 1833-1842 (1963).
1636. O. J. Kleppa and T. Yokokawa, J. Am. Chem. Soc. 86, 2749 (1964).
1637. S. P. Sangal, J. prakt. Chem. [4] 23, 108-112 (1964).
1638. R. L. Seth and A. K. Dey, J. Indian Chem. Soc. 40, 794-796 (1963).
1639. S. K. Kundra, Indian J. Chem. 1, 362 (1963).
1640. M. L. N. Reddy and U. V. Seshaiah, Indian J. Chem. 1, 536-537 (1964).
1641. W. H. Power, B. M. Fabuss and C. N. Satterfield, J. Chem. Eng. Data 9, 437-442 (1964).
1642. R. Gary and R. A. Robinson, J. Chem. Eng. Data 9, 376-378 (1964).
1643. M. Paabo, R. A. Robinson and R. G. Bates, J. Chem. Eng. Data 9, 374-376 (1964).
1644. D. A. Scarpiello and W. J. Cooper, J. Chem. Eng. Data 9, 364-365 (1964).
1645. W. D. Van Vorst and R. C. Ahlert, J. Chem. Eng. Data 9, 345-348 (1964).
1646. L. W. Ross, F. H. Haynie and R. F. Hochman, J. Chem. Eng. Data 9, 339-340 (1964).
1647. M. A. Aia, J. E. Mathers and R. W. Mooney, J. Chem. Eng. Data 9, 335-338 (1964).
1648. G. Waita and T. Mussini, J. Chem. Eng. Data 9, 332-335 (1964).

1649. G. Nagarajan, . physik. Chem. 223, 27-32 (1964).
1650. A. Kaczmarczyk, M. Millard, J. W. Nuss and G. Urry, J. Inorg. and Nuclear Chem. 26, 421-425 (1964).
1651. A. Kaczmarczyk and G. Urry, J. Inorg. and Nuclear Chem. 26, 415-420 (1964).
1652. W. Davis, Jr. and H. J. de Bruin, J. Inorg. and Nuclear Chem. 26, 1069-1083 (1964).
1653. T. S. Laxminarayanan, S. K. Patil and H. D. Sharma, J. Inorg. and Nuclear Chem. 26, 1001-1009 (1964).
1654. B. M. L. Bansal, S. K. Patil and H. D. Sharma, J. Inorg. and Nuclear Chem. 26, 993-1000 (1964).
1655. D. Dyrssen and T. Sekine, J. Inorg. and Nuclear Chem. 26, 981-991 (1964).
1656. D. I. Ryabchikov, I. N. Marov, A. N. Ermakov and V. K. Belyaeva, J. Inorg. and Nuclear Chem. 26, 965-980 (1964).
1657. A. N. Fletcher, J. Inorg. and Nuclear Chem. 26, 955-960 (1964).
1658. K. H. Gayer and O. T. ajicek, J. Inorg. and Nuclear Chem. 26, 951-954 (1964).
1659. Yu. G. Popov, Vestnik Leningrad. Univ. 19, No. 4, Ser. Fiz. i Khim. No. 1, 162-164 (1964); CA 60-13938.
1660. S. S. Kabalkina, L. F. Vereshchagin and B. M. Shulenin, Zhur. Eksptl. i Teoret. Fiz. 45, 2073-2076 (1963); CA 60-13944.
1661. T. Kawakubo and T. Nakagawa, J. Phys. Soc. Japan 19, 517-519 (1964); CA 60-13944.
1662. A. Jayaraman and R. C. Sherwood, Phys. Rev. [2] 134, 691-692 (1964); CA 60-13944.
1663. R. L. Altman, U. S. AEC UCRL 7044, 18pp (1962); CA 60-15421.
1664. F. F. Grigorenko and L. I. Sklyarenko, Visn. Kiivs'k. Univ. No. 4, Ser. Astron., Fiz. ta Khim. No. 1, 73-77 (1961); CA 60-15410.
1665. J. R. Berg, F. H. Spedding and . H. Daane, U. S. AEC IS 327, 35pp (1961); CA 60-15217.
1666. B. J. C. Van der Hoeven, Jr. and P. H. Keesom, Phys. Rev. [2] 134, 1320-1321 (1964).
1667. N. M. Selivanova and T. A. Sazykina, hur. Priklad. Khim. 37, 514-517 (1964).
1668. A. D. Mah, U. S. Bur. Mines, Rept. Invest. 6415, 4pp (1964); CA 60-15215.
1669. M. G. Benz and J. F. Elliott, U. S. AEC NYO-4691, 36pp (1963); CA 60-15216.
1670. J. A. Blauer, M. A. Greenbaum, M. Arshadi and M. Farber, U. S. Dept. Comm., Office Tech. Serv. AD 284,066, 19pp (1962).
1671. F. E. Wittig and G. Keil, . Metallk. 54, 576-590 (1963); CA 60-3815.
1672. I. N. Belyaev and N. I. Chikova, Fiz.-Khim. Analiz. Solevykh Sistem Sb. 1962, 69-76; CA 60-8694.
1673. M. S. Golubeva and R. D. Sidakova, Fiz.-Khim. Analiz Solevykh Sistem Sb. 1962, 189-200; CA 60-8694.
1674. B. C. Gerstein, J. Mullaly, E. Phillips, R. E. Miller and F. H. Spedding, J. Chem. Phys. 41, 883-889 (1964).
1675. W. G. Witteman and M. G. Bowman, U. S. AEC TID-7676, 121-127 (1963); CA 60-15197.

1676. M. G. Bowman and M. C. Krupka, U. S. AEC TID 7676, 128-134 (1963); CA 60-15197.
1677. J. Braunstein and J. M. C. Hess, U. S. AEC TID 15741, 14pp (1962); CA 60-15203.
1678. R. P. Martin and R. A. Paris, Compt. rend. 258, 3038-3040 (1964); CA 60-15202.
1679. E. Sh. Ganelina, B. P. Troitskii and V. S. Yakovleva, Zhur. Priklad. Khim. 37, 677-679 (1964); CA 60-15212.
1680. E. Baum and L. Cann, U. S. Dept. Comm., Office Tech. Serv., AD 419,080, 66pp (1963); CA 60-15211.
1681. C. S. Shoup, Jr., U. S. AEC ORNL-TM-440, 26pp (1962); CA 60-15211.
1682. L. Stein and P. Plurien, U. S. AEC CONF-126-7, 11pp (1963); CA 60-15211.
1683. W. N. Hubbard, U. S. AEC TID 15554, 5pp (1962); CA 60-15211.
1684. M. Beck and F. Gaizer, Magyar Kem. Folyoirat 69, 555-559 (1963).
1685. V. M. Vdovenko, G. A. Romanov and V. A. Shcherbakov, Radiokhimiya 5, 581-585 (1963); CA 60-15206.
1686. C. J. Hawkins, A. M. Sargeson and G. H. Searle, Australian J. Chem. 17, 598-600 (1964); CA 60-15205.
1687. D. G. Tskhvirashvilli, Tr. Inst. Energ., Akad. Nauk Gruz. S.S.R. 16, 63-66 (1962); CA 60-15204.
1688. J. E. Bertie, L. D. Calvert and E. Whalley, Can. J. Chem. 42, 1373-1378 (1964).
1689. R. Srinivasan and S. N. Flengas, Can. J. Chem. 42, 1315-1322 (1964).
1690. R. P. Martin and R. A. Paris, Bull. soc. chim. France 1963, 1600-1606; CA 60-55.
1691. A. K. Babko, A. I. Volkova, T. E. Get'man and M. Kh. Pavlova, Ukrain. Khim. Zhur. 29, 1235-1240 (1963); CA 60-10187.
1692. V. S. Sazhin, O. I. Shor, I. A. Kolesnikova and A. I. Volkovskaya, Ukrain. Khim. Zhur. 30, 3-8 (1964); CA 60-11423.
1693. L. Pajdowski, Roczniki Chem. 37, 1351-1361 (1963); CA 60-11604.
1694. A. A. Nazarov, M. M. Shul'ts and A. V. Storonkin, Vestnik Leningrad. Univ. 18, No. 16, Ser. Fiz. i Khim. No. 3, 94-102 (1963); CA 60-11609.
1695. B. Kirson and Y. Israeli, Bull. soc. chim. France 1963, 2527-2531; CA 60-6456.
1696. B. D. Jain and H. B. Singh, Indian J. Chem. 1, 369-371 (1963); CA 60-3701.
1697. A. Yamada, Nippon Kagaku Zasshi 84, 34-41 (1963); CA 60-3731.
1698. A. Yamada, Nippon Kagaku Zasshi 84, 231-235 (1963); CA 60-3731.
1699. J. Podlaha, Chem. Zvesti 18, 9-12 (1964); CA 60-15202.
1700. I. Kushiro, J. Geomagnetism Geoelec. 11, 148-151 (1960); CA 60-14257.
1701. T. P. Floridis and W. R. Chilcott, Jr., Am. Soc. Metals, Trans. Quart. 57, 360-361 (1964); CA 60-14181.
1702. S. Maekawa and Y. Nakagawa, Nippon Kinzoku Gakkaishi 25, 573-577 (1961); CA 60-14181.
1703. J. Nassler, Collection Czech. Chem. Communs. 29, 356-362 (1964); CA 60-10174.
1704. H. Bokos and A. Jakabos, Brit. Chem. Eng. 8, 840 (1963); CA 60-6502.

1705. M. G. Romova, Materialy 4-oi [Chetvertoi] Nauchn. Konf. Aspirantov Sb. 1962, 150-152; CA 60-10185.
1706. R. G. Azerbaeva and A. L. Tseft, Tr. Inst. Met. i Obogashch., Akad. Nauk Kaz. S.S.R. 8, 50-56 (1963); CA 60-13935.
1707. P. Spacu and C. Luca, Analele Univ. "C. I. Parhon" Bucuresti, Ser. Stiint Nat., Chim. 11, No. 35, 105-110 (1962); CA 60-13927.
1708. J. Dauphin, S. Dauphin, D. Chatonier and M. T. Vialatte, Bull. soc. chim. France 1963, 2754-2755; CA 60-13926.
1709. A. Muan and S. Somiya, Am. J. Sci. 260, 230-240 (1962); CA 60-13924.
1710. R. R. Fergusson and T. Gabor, J. Electrochem. Soc. 111, 585-592 (1964); CA 60-13908.
1711. A. Yamada, Nippon Kagaku Zasshi 84, 224-230 (1963); CA 60-3730.
1712. Yu. K. Delimarskii and A. A. Kolotii, Zhur. Priklad. Khim. 36, 1929-1932 (1963); CA 60-3727.
1713. Y. Oka and M. Umehara, Nippon Kagaku Zasshi 84, 928-932 (1963); CA 60-7457.
1714. M. Kh. Karapet'yants and K. Y. Ch'eng, Tr. Mosk. Khim.-Tekhnol. Inst. No. 38, 59-67 (1962); CA 60-1132.
1715. R. B. Dobrotin, A. V. Suvorov and Yu. V. Kondrat'ev, Vestnik Leningrad. Univ. 19, No. 4, Ser. Fiz. i Khim. No. 1, 95-98 (1964); CA 60-13896.
1716. G. W. Morey, R. O. Fournier and J. J. Rowe, J. Geophys. Res. 69, 1995-2002 (1964); CA 60-15596.
1717. C. A. Shiffman, J. F. Cochran, M. Garber and G. W. Pearsall, Rev. Mod. Phys. 36, 127-130 (1964); CA 60-15550.
1718. B. I. Boltaks and N. A. Fedorovich, Fiz. Tverd. Tela 4, 550-552 (1962); CA 60-15550.
1719. A. N. Krestovnikov and A. L. Lomov, Izvest. Vysshikh Ucheb. Zavedenii, Tsvetnaya Met. 6, No. 6, 75-82 (1963); CA 60-15548.
1720. M. J. Pool and C. E. Lundin, Trans. AIME 230, 589-591 (1964); CA 60-15547.
1721. J. L. Durand and H. E. Brandmaier, Western States Sect. Combust. Inst., Paper WSS/CI 62-13, 53pp (1962); CA 60-3553.
1722. N. M. Volkova and P. V. Gel'd, Izvest. Vysshikh Ucheb. Zavedenii, Tsvetnaya Met. 6, No. 5, 89-94 (1963); CA 60-3554.
1723. V. A. Pinaev, Zhur. Priklad. Khim. 36, 2116-2121 (1963); CA 60-3547.
1724. O. Bekaroglu and S. Fallab, Helv. Chim. Acta 46, 2120-2125 (1963); CA 60-3539.
1725. Y. Dutt and R. P. Singh, Indian J. Chem. 1, 402-403 (1963); CA 60-3540.
1726. M. K. Faiziev and K. N. Norov, Doklady Akad. Nauk Uz. S.S.R. 20, No. 5, 32-34 (1963); CA 60-3636.
1727. R. K. Das, R. K. Nanda and S. Aditya, J. Indian Chem. Soc. 40, 739-742 (1963); CA 60-3541.
1728. R. K. Nanda and S. Aditya, J. Indian Chem. Soc. 40, 755-758 (1963); CA 60-3541.
1729. G. M. Harris, Phys. Rev. [2] 133, 427-435 (1964); CA 60-3508.
1730. C. Konecny, Anal. Chim. Acta 29, 423-433 (1963); CA 60-3484.
1731. O. Chanukvadze, G. Talakvadze, S. Namoradze and P. Tsiskaridze, Tr. Gruzinsk. Inst. Subtrop. Khoz. 1961, 439-442; CA 60-9970.

1732. A. V. Baranov and V. G. Karev, Zhur. Priklad. Khim. 30, 2302-2305 (1963); CA 60-9971.
1733. F. Wolf, L. Eckert and H. Schier, Chem. Tech. (Berlin) 15, 728-733 (1963); CA 60-9970.
1734. J. Nassler, Collection Czech. Chem. Communs. 29, 174-181 (1964).
1735. B. N. Ryzhenko, Geokhimiya 1964, 23-30; CA 60-9973.
1736. G. D'Amore, G. Calabro and P. Curro, Atti Soc. Peloritana Sci. Fis. Mat. Nat. 8, 491-502 (1962); CA 60-9974.
1737. A. Basalla, ement-Kalk-Gips 51, No. 3, 136-140 (1962); CA 61-426.
1738. M. Hoch and H. V. L. Narasimhamurty, NASA Doc. N63-20118, 38pp (1963); CA 61-399.
1739. A. D. Bogard and D. D. Williams, U. S. Dept. Comm., Office Tech. Serv., PB 160,007, 27pp (1960); CA 61-399.
1740. B. Dreyfus, A. Lacaze and J. C. Michel, Compt. rend. 257, 3355-3357 (1963); CA 61-399.
1741. E. Bonnier, P. Desre, I. Ansara and F. Vachet, Compt. rend. 258, 3018-3021 (1964); CA 61-397.
1742. R. D. Reiswig and J. M. Dickinson, Trans. AIME 230, 469-472 (1964); CA 61-394.
1743. V. N. Svechnikov and G. F. Kobzenko, Doklady Akad. Nauk S.S.S.R. 155, 611-614 (1964); CA 61-391.
1744. A. N. Akhavan-Niaki, A. Khorassami and B. Houchmand-Araghi, Bull. soc. chim. France 1964, 616-617; CA 61-84.
1745. S. U. Kreingol'd, E. A. Bozhevol'nov and G. S. Serebryakov, Tr. Vses. Nauchn.-Issled. Inst. Khim. Reaktivov No. 25, 422-426 (1963); CA 61-82.
1746. M. A. Kasymova and M. N. Nabiev, Uzbeksk. Khim. hur. 8, 37-39 (1964); CA 61-83.
1747. H. H. Petheram and F. H. Spedding, U. S. AEC IS 770, 69pp (1963); CA 61-82.
1748. S. Tribalat and J. M. Caldero, Compt. rend. 258, 2828-2831 (1964); CA 61-75.
1749. J. Tamas and G. Kosza, Magy. Kem. Folyoirat 70, No. 4, 148-150 (1964); CA 61-62.
1750. A. A. Kruglykh, V. S. Pavlov and G. P. Tikhins'kii, Ukrain. Fiz. Zhur. 9, 214-215 (1964); CA 61-60.
1751. Ya. Ya. Mikhin and A. D. Pogorelyi, Tr. Severo-Kavkazsk. Gornomet. Inst. 1961, No. 17, 34-37; CA 61-48.
1752. J. Bousquet and G. Perachon, Compt. rend. 258, 3869-3871 (1964); CA 61-276.
1753. G. M. Martynkevich, Tr. Odessk. Gos. Univ. Ser. Fiz. Nauk 152, No. 8, 71-81 (1962); CA 61-92.
1754. B. N. Oleinik, Teplofiz. Vysokikh Temperatur., Akad. Nauk S.S.S.R. 2, 109-117 (1964); CA 61-91.
1755. F. Massazza and R. Fadda, Ann. chim. (Rome) 54, 95-102 (1964); CA 61-90.
1756. S. R. Gunn, U. S. AEC UCRL 7343-T, 7pp (1963); CA 61-90.
1757. T. McConville and B. Serin, Rev. Mod. Phys. 36, 112-116, 105-109, 110-112 (1964); CA 61-90.
1758. T. E. Morsy, Ber. Bunsen Ges. physik. Chem. 68, 277-280 (1964); CA 61-89.

1759. H. E. Flotow and D. W. Osborne, U. S. AEC TID 15795, 29pp (1962); CA 61-89.
1760. I. E. Flis, Zhur. Priklad. Khim. 37, 683-685 (1964); CA 61-89.
1761. R. C. Liimatainen and B. S. Swanson, U. S. AEC TID 15770, 21pp (1962); CA 61-87.
1762. L. G. Stevens, B. Park and J. P. Oliver, J. Inorg. and Nuclear Chem. 26, 97-102 (1964).
1763. G. W. Morey, J. J. Rowe and R. O. Fournier, J. Inorg. and Nuclear Chem. 26, 53-58 (1964).
1764. V. S. Sharma, H. B. Mathur and A. B. Biswas, J. Inorg. and Nuclear Chem. 26, 382-384 (1964).
1765. B. B. Cunningham and J. C. Wallmann, J. Inorg. and Nuclear Chem. 26, 271-275 (1964).
1766. S. D. Christian, H. E. Affsprung and C. Lin, J. Chem. Soc. 1964, 1848-1850.
1767. J. E. Lloyd and K. Wade, J. Chem. Soc. 1964, 1649-1654.
1768. T. Leegaard and T. Rosenqvist, Z. anorg. u. allgem. Chem. 328, 294-298 (1964).
1769. F. Grønvold and E. F. Westrum, Jr., Z. anorg. u. allgem. Chem. 328, 272-282 (1964).
1770. K. Grjotheim, O. Herstad and K. S. Johannessen, Z. anorg. u. allgem. Chem. 328, 267-271 (1964).
1771. P. Ehrlich, W. Deissmann, E. Koch and V. Ullrich, Z. anorg. u. allgem. Chem. 328, 243-251 (1964).
1772. K. Quitzsch, R. Huettig, H.-G. Vogel, H.-J. Gesemann and G. Geiseler, Z. physik. Chem. 223, 225-233 (1963).
1773. E. Blasius and E. Brozio, Ber. Bunsenges. physik. Chem. 68, 52-55 (1964).
1774. K. Schwabe, R. Urlass and A. Ferse, Ber. Bunsenges. physik. Chem. 68, 46-52 (1964).
1775. H. Wendt, Ber. Bunsenges. physik. Chem. 68, 29-33 (1964).
1776. D. S. Koval'chuk and A. A. Antonov, Ukrain. Khim. Zhur. 30, 169-173 (1964).
1777. A. I. Volkova and T. E. Get'man, Ukrain. Khim. Zhur. 29, 1240-1246 (1963).
1778. J. N. Butler, J. Phys. Chem. 68, 1828-1833 (1964).
1779. A. J. Panson, J. Phys. Chem. 68, 1721-1724 (1964).
1780. D. T. Farrar and M. M. Jones, J. Phys. Chem. 68, 1717-1721 (1964).
1781. R. J. L. Andon, J. F. Counsell, J. F. Martin and H. J. Hedger, Trans. Faraday Soc. 60, 1030-1037 (1964).
1782. S. C. Lahiri and S. Aditya, Z. physik. Chem. [NF] 41, 173-182 (1964).
1783. E. Wiberg and H. Behringer, Z. anorg. u. allgem. Chem. 329, 290-300 (1964).
1784. E. Thilo and P. Flögel, Z. anorg. u. allgem. Chem. 329, 244-260 (1964).
1785. H. Schäfer and F. Liedmeier, Z. anorg. u. allgem. Chem. 329, 225-228 (1964).
1786. H. Remy and H. Mathies, Z. anorg. u. allgem. Chem. 329, 203-210 (1964).

1787. R. Huch and W. Klemm, Z. anorg. u. allgem. Chem. 329, 123-135 (1964).
1788. O. Glemser, R. v. Haeseler and A. Müller, Z. anorg. u. allgem. Chem. 329, 51-55 (1964).
1789. E. M. Levin and R. S. Roth, J. Research Natl. Bur. Standards 68A, 189-195 (1964).
1790. L. M. Vidavskii, V. Yu. Koval'chuk, N. I. Byakhova and E. A. Ippolitova, Zhur. Neorg. Khim. 9, 1489-1491 (1964).
1791. N. K. Popovicheva, A. A. Biryukov and V. I. Shlenskaya, Zhur. Neorg. Khim. 9, 1482-1483 (1964).
1792. B. G. Koroshunov, D. V. Drobot, V. V. Bukhtiyarov and Z. N. Shevtsova, Zhur. Neorg. Khim. 9, 1427-1430 (1964).
1793. A. G. Bergman and K. Nogoev, Zhur. Neorg. Khim. 9, 1423-1426 (1964).
1794. I. I. Il'yasov and A. G. Bergman, Zhur. Neorg. Khim. 9, 1416-1422 (1964).
1795. I. I. Il'yasov, Zhur. Neorg. Khim. 9, 1411-1415 (1964).
1796. V. V. Safonov, B. G. Korshunov, Z. N. Shevtsova and L. G. Shadrova, Zhur. Neorg. Khim. 9, 1406-1410 (1964).
1797. D. I. Tsekhovol'skaya, Zhur. Neorg. Khim. 9, 1387-1392 (1964).
1798. I. G. Ryss and N. F. Kulish, Zhur. Neorg. Khim. 9, 1382-1386 (1964).
1799. S. A. Shchukarev and G. A. Kokovin, Zhur. Neorg. Khim. 9, 1309-1315 (1964).
1800. D. G. Lee and R. Stewart, J. Am. Chem. Soc. 86, 3051-3056 (1964).
1801. L. Pajdowski, Roczniki Chem. 37, 1363-1377 (1963).
1802. Y. J. Israeli, Nature 201, 389-390 (1964).
1803. K.-H. Spiller, NASA Doc. EUR 357.d, 66pp (1963).
1804. T. Pyle, Phil. Mag. [8] 8, 2005-2012 (1963).
1805. C. Brisi, Atti Accad. Sci. Torino, Classe Sci. Fis., Mat. e Nat. 94, 67-76 (1959); CA 60-6260.
1806. J. van Muylder, N. de Zoubov and M. Pourbaix, CEBELCOR, Rappt. tech. 101, 23pp (1962); CA 60-10336.
1807. R. Delhez, C. Depommier and J. van Muylder, CEBELCOR, Rappt. tech. 100, 9pp (1962); CA 60-10335.
1808. J. Nassler, Collection Czech. Chem. Communs. 29, 863-875 (1964); CA 60-14113.
1809. A. Weisbrod, Bull. Soc. Franc. Mineral Crist. 86, 278-285 (1963); CA 60-6647.
1810. A. Despic and D. Kosanovic, Glasnik Hem. Drustva, Beograd 28, 9-18 (1963); CA 60-15167.
1811. B. D. Jain and H. B. Singh, J. Indian Chem. Soc. 41, 29-32 (1964); CA 60-15136.
1812. M. Simon, Phys. Letters 9, 122-123 (1964); CA 60-15215.
1813. Kh. Kh. Khakimov and M. A. Azizov, Doklady Akad. Nauk Uz. S.S.R. 1961, No. 3, 49-52; CA 60-14112.
1814. V. I. Semlyanukhin, G. P. Savoskina and M. F. Pushlenkov, Radiokhimiya 5, 674-679 (1963); CA 60-14102.
1815. C. J. Barton, D. R. Cuneo, M. J. Kelly and J. E. Strain, U. S. AEC TID 7675, 35-45 (1963); CA 60-14088.
1816. N. M. Dyatlova, O. Yu. Lavrova and B. I. Bikhman, Tr. Vses. Nauchn.-Issled. Inst. Khim. Reaktivov, No. 25, 391-399 (1963); CA 60-15408.

1817. D. White, P. N. Walsh, H. W. Goldstein and D. F. Dever, U. S. Dept. Comm., Office Tech. Serv., P. B. Rept. 157,243, 34pp (1960); CA 58-7438.
1818. P. Gross, C. Hayman, D. L. Levi and M. C. Stuart, U. S. Dept. Comm., Office Tech. Serv., P. B. Rept. 153,445, 32pp (1960); CA 58-7435.
1819. C. Lenchitz and G. Silvestro, U. S. Dept. Comm., Office Tech. Serv., AD 426,958, 9pp (1963); CA 60-15408.
1820. H. A. Eick, E. G. Rauh and R. J. Thorn U. S. AEC TID 17413, 16pp (1962); CA 60-15214.
1821. E. Wicke and G. H. Nernst, Ber. Bunsenges. physik. Chem. 68, 224-235 (1964); CA 60-15213.
1822. A. A. Grinberg and E. S. Postnikova, Doklady Akad. Nauk S.S.S.R. 153, 340-341 (1963); CA 60-10182.
1823. O. Yu. Timofeeva, Sb. Aspirantsk. Rabot Kazansk. Univ., Estestv. Nauki 1962, 13-20; CA 60-10180.
1824. H. Hubacek, B. Stancic and V. Gutmann, Monatsh. 94, 1118-1125 (1963); CA 60-10179.
1825. G. A. Krestov, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 6, No. 3, 408-415 (1963); CA 60-9985.
1826. K. S. Khatki, A. T. Rane and M. B. Kabadi, Proc. Indian Acad. Sci. 58A, 202-208 (1963); CA 60-11424.
1827. T. Nishi and M. Asano, Kogyo Kagaku Zasshi 66, 1428-1433 (1963); CA 60-13935.
1828. D. Jakes and L. Jakesova, Collection Czech. Chem. Communs. 29, 1122-1127 (1964); CA 60-15212.
1829. B. Ya. Sukharevskii and A. M. Gavrish, Doklady Akad. Nauk S.S.S.R. 155, 438-441 (1964); CA 60-13944.
1830. V. Hovi and K. Mansikka, Acta Met. 8, 53-54 (1960); CA 60-13938.
1831. M. M. Shul'ts and I. M. Bushueva, Vestnik Leningrad. Univ. 19, No. 4, Ser. Fiz. i Khim. No. 1, 111-121 (1964); CA 60-13935.
1832. G. W. Orton, Trans. AIME 230, 600-602 (1964); CA 60-15546.
1833. J. G. Croeni, C. E. Armantrout and H. Kato, NASA Doc. N62-16537, 19pp (1962); CA 60-15542.
1834. F. H. Mueller and H. Martin, Kolloid-Z. 172, No. 2, 97-116 (1960); CA 60-15447.
1835. A. M. Shams El Din and A. A. A. Gerges, Electrochim. Acta 9, 613-627 (1964); CA 60-15435.
1836. I. G. Murgulescu and E. Constantinescu, Rev. Chim., Acad. Rep. Populaire Roumaine 8, 5-12 (1963); CA 60-15423.
1837. R. Gauglitz, H. E. Schwiete and A. T. T. Ien, Zement-Kalk-Gips 51, No. 3, 104-120 (1962); CA 61-423.
1838. A. Narten, J. Chem. Phys. 41, 1318-1321 (1964).
1839. D. N. Purohit and N. C. Sogani, Bull. acad. polon. sci., Ser. sci. chim. 12, No. 2, 85-89 (1964); CA 60-15205.
1840. D. N. Purohit and N. C. Sogani, J. Indian Chem. Soc. 41, 20-24 (1964); CA 60-13928.
1841. D. Cubicciotti, Inorg. Chem. 3, 1061-1062 (1964).
1842. S. A. Carrano, K. A. Chen and R. F. O'Malley, Inorg. Chem. 3, 1047-1049 (1964).
1843. A. S. Kana'an and J. L. Margrave, Inorg. Chem. 3, 1037-1038 (1964).

1844. B. Z. Egan, S. G. Shore and J. E. Bonnell, Inorg. Chem. 3, 1024-1027 (1964).
1845. E. E. Mercer, W. M. Campbell, Jr. and R. M. Wallace, Inorg. Chem. 3, 1018-1024 (1964).
1846. J. K. Ruff and G. Paulett, Inorg. Chem. 3, 998-1001 (1964).
1847. J. Aveston, Inorg. Chem. 3, 981-986 (1964).
1848. T. Yokokawa and O. J. Kleppa, Inorg. Chem. 3, 954-957 (1964).
1849. E. A. Aitken, S. F. Bartram and E. F. Juenke, Inorg. Chem. 3, 949-954 (1964).
1850. S. D. Gokhale and W. L. Jolly, Inorg. Chem. 3, 946-949 (1964).
1851. A. N. Campbell and M. K. Nagarajan, Can. J. Chem. 42, 1616-1626 (1964).
1852. A. Tockstein, . Chem. 3, 249-262 (1963).
1853. L. N. Sidorov, P. A. Akishin, V. I. Belousov and V. B. Shol'ts, Zhur. Fiz. Khim. 38, 1173-1181 (1964).
1854. I. T. Sryvalin, O. A. Esin and B. M. Lepinskikh, Zhur. Fiz. Khim. 38, 1166-1172 (1964).
1855. L. M. Kovaleva and A. I. Zebreva, Zhur. Fiz. Khim. 38, 1162-1165 (1964).
1856. A. A. Shchepetkin, N. M. Stafeeva, V. I. Bogoslovskii, M. G. Zhuravleva and G. I. Chufarov, Zhur. Fiz. Khim. 38, 1135-1141 (1964).
1857. G. P. Kovtun, A. A. Kruglykh and V. S. Pavlov, Izv. Akad. Nauk S.S.S.R., Met. i Gorn. Delo 1964, 177-179; CA 61-1574.
1858. A. Muan, R. H. Nafziger and P. L. Roeder, Nature 202, 688-689 (1964); CA 61-2697.
1859. M. F. Mole and J. C. McCoubrey, Nature 202, 450-451 (1964); CA 61-2542.
1860. O. V. Lounasmaa, Phys. Rev. [2] 134, 1620A-1624A (1964); CA 61-2542.
1861. M. Braun and R. Kohlhaas, Z. Naturforsch. 19a, 633-634 (1964); CA 61-2541.
1862. G. De Maria, L. Malaspina and V. Piacente, SIPS, Sci. Tec. 7, 11-15 (1963); CA 61-2541.
1863. C. T. Stubblefield and M. D. Taylor, Proc. Conf. Rare Earth Res., 2nd, Glenwood Springs, Colo. 1961, 29-33 (Pub. 1962); CA 61-2537.
1864. G. De Maria and M. Guido, SIPS, Sci. Tec. 7, 45-53 (1963);CA 61-2538.
1865. A. I. Golomzik, Izvest. Vysshikh Ucheb. Zavedenii, Tsvetnaya Met. 7, No. 2, 47-48 (1964); CA 61-2537.
1866. L. Wilson, Australia Commonwealth Dept. Supply Aeron. Res. Lab. Met. Note ARL/MET 17, 7pp (1963); CA 61-2531.
1867. J. M. Zhivojinov, J. Phys. (Paris) Suppl. 25, 38A-40A (1964); CA 61-2507.
1868. O. C. Bridgeman and E. W. Aldrich, J. Heat Transfer 86, 279-286 (1964); CA 61-2507.
1869. G. Ahlers, Phys. Rev. [2] 135, 10A-16A (1964); CA 61-2504.
1870. G. Nagarajan, Acta Phys. Austriaca 17, 240-245 (1964); CA 61-2503.
1871. D. L. Longwell, Ph. D. thesis, Stanford Univ., taken from Dissertation Abstr. 24, 3116-3117 (1964).
1872. V. M. Khanna, Ph. D. thesis, New York Univ., taken from Dissertation Abstr. 24, 3115 (1964).

1873. H. S. Jongenburger, Ph. D. thesis, Univ. of Delaware, taken from Dissertation Abstr. 24, 3114 (1964).
1874. R. E. Taylor and R. A. Finch, J. Less-Common Metals 6, 283-294 (1964); CA 61-3775.
1875. B. A. Younglove and D. E. Diller, Cryogenics 2, 283-287 (1962); CA 61-3755.
1876. V. P. Chalyi, [illegible] Makarova and V. T. [illegible]ory[illegible], Kolloidn. Zh. 26, 263-267 (1964); CA 61-3755.
1877. H. Senftleben, [illegible] Angew. Phys. 17, No. 2, 86-87 (1964); CA 61-3756.
1878. D. H. Newhall, L. H. Abbot and R. A. Dunn, High-Pressure Meas., Papers Symp., New York City 1962, 339-350 (Pub. 1963); CA 61-3714.
1879. I. G. Murgulescu and L. Marta, Rev. Chim., Acad. Rep. Populaire Roumaine 7, 1103-1107 (1962); CA 61-3714.
1880. O. Glemser, Oesterr. Chemiker- tg. 64, No. 10, 301-312 (1963); CA 61-3710.
1881. H. W. Schamp, Jr., J. N. Mundy and E. Rapoport, High-Pressure Meas., Papers Symp., New York City 1962, 35[illegible]-364 (Pub. 1963); CA 61-3705
1882. R. D. Goodwin, Cryogenics 2, 353-355 (1962); CA 61-3705.
1883. G. C. Fitzgibbon, D. Pavone, E. J. Huber, Jr. and C. E. Holley, Jr., U. S. AEC LA 3031, 24pp (1963); CA 61-2738.
1884. W. L. Smith, Ph. D. thesis, Penn. State Univ., taken from Dissertation Abstr. 24, 3105 (1964).
1885. H. Van Kempen, W. T. Duffy, Jr., A. R. Miedema and W. J. Huiskamp, Physica 30, 1131-1140 (1964); CA 61-2542.
1886. V. Ya. Leonidov, Yu. P. Barskii and N. I. Khitarov, Geokhimiya 1964, 414-419; CA 61-2541.
1887. V. M. Amosov, Izvest. Vysshikh Ucheb. Zavedenii, Tsvetnaya Met. 7, No. 2, 114-122 (1964); CA 61-2537.
1888. M. Beck and L. Dozsa, Magy. Kem. Folyoirat 70, 163-164 (1964); CA 61-2533.
1889. M. Le Van My, Bull. soc. chim. France 1964, 545-549; CA 61-2510.
1890. T. C. Ehlert and J. L. Margrave, J. Chem. Phys. 41, 1066-1072 (1964).
1891. C. Blomberg and G. Borelius, Arkiv Fysik 25, 343-347 (1964).
1892. R. G. Cavell, J. Chem. Soc. 1964, 1992-1995.
1893. R. N. Haszeldine, P. J. Robinson and R. F. Simmons, J. Chem. Soc. 1964, 1890-1894.
1894. P. M. Henry, J. Am. Chem. Soc. 86, 3246-3250 (1964).
1895. I. A. Shevchuk, Tr. Vses. Nauchn. Issled. Inst. Khim. Reaktivov No. 25, 415-419 (1963); CA 61-2535.
1896. J. A. Blauer and M. Farber, J. Phys. Chem. 68, 2357-2359 (1964).
1897. J. R. Hollahan and N. W. Gregory, J. Phys. Chem. 68, 2346-2351 (1964).
1898. D. F. Anthrop and [illegible]. W. Searcy, J. Phys. Chem. 68, 2335-2342 (1964).
1899. J. Blauer, M. A. Greenbaum and M. Farber, J. Phys. Chem. 68, 2332-2334 (1964).
1900. R. M. Rush and J. S. Johnson, J. Phys. Chem. 68, 2321-2331 (1964).
1901. M. M. Markowitz, D. A. Boryta and H. Stewart, Jr., J. Phys. Chem. 68, 2282-2289 (1964).
1902. J. W. Johnson and D. Cubicciotti, J. Phys. Chem. 68, 2235-2239 (1964).
1903. Y. Marcus and M. Givon, J. Phys. Chem. 68, 2230-2234 (1964).

1904. J. C. Wang, J. E. Bauman, Jr. and R. K. Murmann, J. Phys. Chem. 68, 2296-2300 (1964).
1905. K. Heinzinger and R. E. Weston, Jr., J. Phys. Chem. 68, 2179-2183 (1964).
1906. A. C. Makrides, J. Phys. Chem. 68, 2160-2169 (1964).
1907. D. E. Leyden and A. L. Underwood, J. Phys. Chem. 68, 2093-2097 (1964).
1908. W. J. Cooper and D. A. Scarpiello, U. S. AEC TID 4500, 58pp (1964); CA 60-15212.
1909. H. H. Michels and S. B. Schneiderman, Western States Sect. Combust. Inst., Paper WSS/CI 62-3, 39pp (1962); CA 60-3939.
1910. A. Buechler, Western States Sect. Combust. Inst., Paper WSS/CI 62-14, 7pp (1962).
1911. R. F. Porter and S. K. Gupta, J. Phys. Chem. 68, 2732-2733 (1964).
1912. I. Eliezer, J. Phys. Chem. 68, 2722-2725 (1964).
1913. E. J. Huber, Jr., G. C. Fitzgibbon and C. E. Holley, Jr., J. Phys. Chem. 68, 2720-2722 (1964).
1914. R. E. Yates, M. A. Greenbaum and M. Farber, J. Phys. Chem. 68, 2682-2686 (1964).
1915. J. R. Goates, J. B. Ott, N. F. Mangelson and R. J. Jensen, J. Phys. Chem. 68, 2617-2621 (1964).
1916. J. H. Stern and C. W. Anderson, J. Phys. Chem. 68, 2528-2533 (1964).
1917. K. A. Gingerich, J. Phys. Chem. 68, 2514-2522 (1964).
1918. R. W. Taylor and H. Schmalzried, J. Phys. Chem. 68, 2444-2449 (1964).
1919. J. H. Norman and H. G. Staley, J. Chem. Phys. 41, 1503-1504 (1964).
1920. H. A. Eick and R. N. R. Mulford, J. Chem. Phys. 41, 1475-1478 (1964).
1921. D. Tucker and J. S. Drury, J. Chem. Phys. 41, 1678-1681 (1964).
1922. R. W. Crecely and D. J. Wilson, J. Chem. Phys. 41, 1564-1567 (1964).
1923. E. D. Whitney, R. O. Mac Laren, J. J. Hurley and C. E. Fogle, J. Am. Chem. Soc. 86, 4340-4342 (1964).
1924. T. H. Wirth and N. Davidson, J. Am. Chem. Soc. 86, 4325-4329 (1964).
1925. T. H. Wirth and N. Davidson, J. Am. Chem. Soc. 86, 4322-4325 (1964).
1926. T. H. Wirth and N. Davidson, J. Am. Chem. Soc. 86, 4318-4322 (1964).
1927. T. H. Wirth and N. Davidson, J. Am. Chem. Soc. 86, 4314-4318 (1964).
1928. E. Eyal and A. Treinin, J. Am. Chem. Soc. 86, 4287-4290 (1964).
1929. F. Tebbe, P. M. Garrett and M. F. Hawthorne, J. Am. Chem. Soc. 86, 4222-4223 (1964).
1930. F. T. Greene and P. W. Gilles, J. Am. Chem. Soc. 86, 3964-3969 (1964).
1931. S. W. Benson, J. Am. Chem. Soc. 86, 3922-3924 (1964).
1932. J. W. Pyper and F. A. Long, J. Chem. Phys. 41, 2213-2214 (1964).
1933. S. J. Yosim and B. B. Owens, J. Chem. Phys. 41, 2032-2036 (1964).
1934. J. W. Pyper and F. A. Long, J. Chem. Phys. 41, 1890-1896 (1964).
1935. T. C. Ehlert and J. L. Margrave, J. Am. Chem. Soc. 86, 3901 (1964).
1936. W. R. Hertler and M. S. Raasch, J. Am. Chem. Soc. 86, 3661-3668 (1964).
1937. S. S. Chang and A. B. Bestul, J. Phys. Chem. 68, 3082-3083 (1964).
1938. J. A. Skarulis, V. N. Darnowski, W. P. Kilroy and T. Milazzo, J. Phys. Chem. 68, 3074-3077 (1964).
1939. J. P. Chan and W. F. Giauque, J. Phys. Chem. 68, 3053-3057 (1964).
1940. M. H. Lietzke and R. W. Stoughton, J. Phys. Chem. 68, 3043-3048 (1964).

1941. E. J. Huber, Jr., E. L. Head and C. E. Holley, Jr., J. Phys. Chem. 68, 3040-3042 (1964).
1942. D. Nakamura and M. Kubo, J. Phys. Chem. 68, 2986-2991 (1964).
1943. E. Rudzitis, H. M. Feder and W. N. Hubbard, J. Phys. Chem. 68, 2978-2981 (1964).
1944. G. B. Barbi, J. Phys. Chem. 68, 2912-2916 (1964).
1945. P. D. Zavitsanos, J. Phys. Chem. 68, 2899-2901 (1964).
1946. A. J. Leffler and N. M. Wiederhorn, J. Phys. Chem. 68, 2882-2889 (1964).
1947. R. Nakane, O. Kurihara and A. Natsubori, J. Phys. Chem. 68, 2876-2882 (1964).
1948. A. A. Antoniou, J. Phys. Chem. 68, 2754-2764 (1964).
1949. P. Sellers, S. Sunner and I. Wadsö, Acta Chem. Scand. 18, 202-206 (1964).
1950. R. J. Irving and I. Wadsö, Acta Chem. Scand. 18, 195-201 (1964).
1951. H. Ohtaki, Acta Chem. Scand. 18, 521-533 (1964).
1952. K. Motzfeldt, Acta Chem. Scand. 18, 495-503 (1964).
1953. I. Grenthe, Acta Chem. Scand. 18, 283-292 (1964).
1954. P. Chartier, Ber. Bunsenges. physik. Chem. 68, 404-410 (1964).
1955. J. J. Myher and K. E. Russell, Can. J. Chem. 42, 1555-1562 (1964).
1956. J. W. Green, G. D. Blue, T. C. Ehlert and J. L. Margrave, J. Chem. Phys. 41, 2245-2250 (1964).
1957. R. C. Eckhardt and T. B. Flanagan, Trans. Faraday Soc. 60, 1289-1298 (1964).
1958. A. E. Pope and H. A. Skinner, Trans. Faraday Soc. 60, 1404-1407 (1964).
1959. A. E. Pope and H. A. Skinner, Trans. Faraday Soc. 60, 1402-1403 (1964).
1960. K. B. Oldham, Trans. Faraday Soc. 60, 1646-1655 (1964).
1961. W. S. Holmes, J. H. E. Jeffes, J. C. McCoubrey and R. H. Tomlinson, Trans. Faraday Soc. 60, 1598-1607 (1964).
1962. M. A. Greenbaum, J. A. Blauer, M. R. Arshadi and M. Farber, Trans. Faraday Soc. 60, 1592-1597 (1964).
1963. T. Sekine, J. Inorg. and Nuclear Chem. 26, 1463-1465 (1964).
1964. D. C. J. Morris, G. L. Reed and K. J. Sutton, J. Inorg. and Nuclear Chem. 26, 1461-1462 (1964).
1965. K. H. Gayer, R. M. Haas and L. C. Thompson, J. Inorg. and Nuclear Chem. 26, 1401-1403 (1964).
1966. C. A. Lutz, D. A. Phillips and D. M. Ritter, Inorg. Chem. 3, 1191-1194 (1964).
1967. M. Lustig, C. L. Bumgardner, F. A. Johnson and J. K. Ruff, Inorg. Chem. 3, 1165-1168 (1964).
1968. L. Lynds and C. D. Bass, Inorg. Chem. 3, 1147-1149 (1964).
1969. S. D. Gokhale and W. L. Jolly, Inorg. Chem. 3, 1141-1143 (1964).
1970. J. P. Fackler, Jr. and I. D. Chawla, Inorg. Chem. 3, 1130-1134 (1964).
1971. L. C. Thompson, Inorg. Chem. 3, 1319-1321 (1964).
1972. M. J. M. Woods, P. K. Gallagher, [illegible] Hugus, Jr. and E. L. King, Inorg. Chem. 3, 1313-1317 (1964).
1973. L. S. D. Glasser and F. P. Glasser, Inorg. Chem. 3, 1228-1230 (1964).

1974. D. Banerjea and I. P. Singh, Z. anorg. u. allgem. Chem. 331, 225-230 (1964).
1975. D. N. Purohit and N. C. Sogani, Z. anorg. u. allgem. Chem. 331, 220-224 (1964).
1976. W. Hirschwald, F. Stolze and I. N. Stranski, Z. physik. Chem. [NF] 42, 96-111 (1964).
1977. E. Nebel and K. Schwabe, Z. physik. Chem. 224, 29-50 (1963).
1978. H. J. Spangenberg and H. Kriegsmann, Z. physik. Chem. 224, 273-277 (1963).
1979. G. Nagarajan, Z. physik. Chem. 224, 256-258 (1963).
1980. W. Kleber and P. Fricke, Z. physik. Chem. 224, 253-263 (1963).
1981. M. Bartusek and L. Sommer, Z. physik. Chem. 226, 309-332 (1964).
1982. H. Kriegsmann and S. Pauly, Z. anorg. u. allgem. Chem. 330, 275-289 (1964).
1983. G. Schott and L. Werner, Z. anorg. u. allgem. Chem. 331, 52-58 (1964).
1984. K. Kohler and W. Franke, Z. anorg. u. allgem. Chem. 331, 27-34 (1964).
1985. K. Kohler and W. Franke, Z. anorg. u. allgem. Chem. 331, 17-26 (1964).
1986. K. Kohler and P. Züske, Z. anorg. u. allgem. Chem. 331, 7-16 (1964).
1987. K. Kohler and P. Züske, Z. anorg. u. allgem. Chem. 331, 1-6 (1964).
1988. R. Steudel and P. W. Schenk, Z. physik. Chem. 43, 33-37 (1964).
1989. N. J. Carrera, R. F. Walker and E. R. Plante, J. Research Natl. Bur. Standards 68A, 325-330 (1964).
1990. L. A. Wood and G. M. Martin, J. Research Natl. Bur. Standards 68A, 259-268 (1964).
1991. V. N. Fadeev and P. I. Fedorov, Zhur. Neorg. Khim. 9, 2028-2029 (1964).
1992. A. A. Grinberg and Z. I. Dobroborskaya, Zhur. Neorg. Khim. 9, 2026-2028 (1964).
1993. S. A. Shchukarev, I. V. Vasil'kova and D. V. Korol'kov, Zhur. Neorg. Khim. 9, 1810-1816 (1964).
1994. S. Krupkowski and J. Golonka, Bull. acad. polon. sci., Ser. sci. tech. 12, 69-74 (1964).
1995. N. A. Volodin, A. A. Chidlovskii and A. A. Voskresenskii, Zhur. Fiz. Khim. 38, 1703-1705 (1964).
1996. A. N. Kirginstev and A. V. Luk'yanov, Zhur. Fiz. Khim. 38, 1603-1606 (1964).
1997. V. I. Pepekin, T. N. Dymova, Yu. A. Lebedev and A. Ya. Apin, Zhur. Fiz. Khim. 38, 1024-1026 (1964).
1998. Z. L. Leshchinskaya and N. M. Selivanova, Zhur. Fiz. Khim. 38, 972-974 (1964).
1999. A. Ya. Nashel'skii, V. Z. Ostrovskaya and S. V. Yakobson, Zhur. Fiz. Khim. 38, 891-895 (1964).
2000. E. F. Ivanova and V. V. Aleksandrov, Zhur. Fiz. Khim. 38, 878-884 (1964).
2001. K. A. Sharifov and S. N. Gadzhiev, Zhur. Fiz. Khim. 38, 2070-2072 (1964).
2002. A. N. Kornilov, V. Ya. Leonidov and S. M. Skuratov, Zhur. Fiz. Khim. 38, 2013-2018 (1964).
2003. A. N. Kornilov, V. Ya. Leonidov and S. M. Skuratov, Zhur. Fiz. Khim. 38, 2008-2012 (1964).

2004. L. L. Makarov, Yu. G. Vlasov and R. Kopunets, Zhur. Fiz. Khim. 38, 1938-1941 (1964).
2005. T. V. Kuznetsova, L. F. Egorova and A. V. Pankratova, Zhur. Fiz. Khim. 38, 1860-1862 (1964).
2006. Yu. Kh. Shaulov, V. S. Tubyanskaya, E. V. Evstegneeva and G. O. Shmyreva, Zhur. Fiz. Khim. 38, 1779-1783 (1964).
2007. A. A. Antonov, Zhur. Fiz. Khim. 38, 1713-1717 (1964).
2008. P. I. Protsenko and G. K. Shurdumov, Zhur. Neorg. Khim. 9, 1692-1695 (1964).
2009. V. V. Safonov, B. G. Korshunov, Z. N. Shevtsova and S. I. Bakum, Zhur. Neorg. Khim. 9, 1687-1691 (1964).
2010. G. I. Novikov and A. K. Baev, Zhur. Neorg. Khim. 9, 1669-1675 (1964).
2011. A. M. Golub and G. B. Pomerants, Zhur. Neorg. Khim. 9, 1624-1629 (1964).
2012. O. E. Zvyagintsev and V. P. Tikhonov, Zhur. Fiz. Khim. 9, 1597-1605 (1964).
2013. K. B. Yatsimirskii and V. E. Romanov, Zhur. Neorg. Khim. 9, 1578-1583 (1964).
2014. S. A. Shchukarev and G. A. Kokovin, Zhur. Neorg. Khim. 9, 1565-1569 (1964).
2015. V. N. Eremenko and G. M. Lukashenko, Zhur. Neorg. Khim. 9, 1552-1555 (1964).
2016. V. A. Sokolov and G. A. Sharpataya, Zhur. Neorg. Khim. 9, 1542-1546 (1964).
2017. D. M. Anderson and G. Sposite, Soil Sci. 97, 214-219 (1964); CA 61-3754.
2018. A. A. Babanov, M. A. Kaganov, A. I. Lazarev and M. A. Chernyakova, Tr. Leningrad. Politekhn. Inst. No. 224, 203-216 (1963); CA 61-6727.
2019. F. H. Ellinger, C. C. Land and V. O. Struebing, J. Nuclear Mater. 12, 226-236 (1963); CA 61-6723.
2020. J. Kucera, Cesk. Casopis Fys. 14, 176-185 (1964); CA 61-8025.
2021. K. Schwerdtfeger and A. Muan, Acta Met. 12, 905-909 (1964); CA 61-8025.
2022. M. Shimizu and E. P. Wohlfarth, Phys. Letters 11, 108-109 (1964); CA 61-8024.
2023. M. G. Chasanov, I. Johnson and R. V. Schablaske, J. Less-Common Metals 7, 127-132 (1964); CA 61-8020.
2024. V. N. Eremenko and G. M. Lukashenko, Fiz.-Khim. Osnovy Met. Protsessov, Komis. po Fiz.-Khim. Osnovam Proizv. Stali, Sb. Statei 1964, 179-189; CA 61-8024.
2025. H. K. Liang, Wu Li Hsueh Pao 17, 569-586 (1961); CA 61-5018.
2026. L. B. Pankratz, W. W. Weller and K. K. Kelley, U. S. Bur. Mines, Rept. Invest. 6446, 9pp (1964); CA 61-5017.
2027. V. G. Bamburov, Tr. Inst. Khim., Akad. Nauk S.S.S.R., Ural'sk. Filial No. 7, 27-31 (1963); CA 61-5017.
2028. M. Rolin and A. Ducouret, Bull. soc. chim. France 1964, 790-794; CA 61-5201.
2029. M. Rolin and A. Ducouret, Bull. soc. chim. France 1964, 794-797; CA 61-5201.

2030. G. De Maria, R. Gigli and L. Malaspina, SIPS, Sci. tec. 7, 26-32 (1963); CA 61-5022.
2031. G. De Maria, L. Malaspina and V. Piacente, SIPS, Sci. tec. 7, 33-38 (1963); CA 61-5022.
2032. A. E. Sheindlin and N. I. Gorbunova, Teploenergetika 11, No. 5, 86-89 (1964); CA 61-5020.
2033. H. Schaefer and F. Liedmeier, J. Less-Common Metals 6, 307-312 (1964); CA 61-5020.
2034. E. M. Barrall, II. and L. B. Rogers, Anal. Chem. 36, 1405-1406 (1964); CA 61-5016.
2035. L. A. Weber, D. E. Diller, H. M. Roder and R. D. Goodwin, Cryogenics 2, 236-238 (1962); CA 61-4984.
2036. E. A. Gulbransen, K. F. Andrew and F. A. Brassart, J. Electrochem. Soc. 110, 242-243 (1963); CA 61-4984.
2037. B. Budesinsky, Collection Czech. Chem. Communs. 28, 2902-2913 (1963).
2038. I. Slama, Collection Czech. Chem. Communs. 28, 2810-2813 (1963).
2039. R. V. G. Rao, C. D. Das and H. V. Keer, Indian J. Chem. 2, 29-30 (1964).
2040. A. I. Moskvin, V. P. Zaitseva and A. D. Gel'man, Radiokhimiya 6, 214-230 (1964); CA 61-2694.
2041. Z. Jabransky, Collection Czech. Chem. Communs. 24, 3075-3083 (1959); CA 61-2732.
2042. H. A. Berman and E. S. Newman, Am. Soc. Testing Mater., Proc. 63, 830-851 (1963); CA 61-5191.
2043. J. Drowart and R. Colin, U. S. Dept. Comm., Office. Tech. Serv., AD 426,801, 15pp (1963); CA 61-1287.
2044. I. Kiss, L. Matus and I. Opauszky, Kernenergie 5, 329-331 (1962); CA 61-1293.
2045. M. Ebert and Z. Pacl, Chem. Zvesti 18, 172-177 (1964); CA 61-1314.
2046. R. Cohen-Adad and C. Ferlin, Compt. rend. 258, 4057-4060 (1964); CA 61-1314.
2047. J. Gittins and O. F. Tuttle, Am. J. Sci. 262, 66-75 (1964); CA 61-1314.
2048. R. Gut, E. Iberson and D. M. Gruen, U. S. AEC ANL 6803, 21pp (1963); CA 61-1313.
2049. V. S. Podgornova, Sh. T. Talipov and N. I. Yunaeva, Nekotorye Vopr. Khim. Tekhnol. i Fiz.-Khim. Analiza Neorgan. Sistem, Akad. Nauk Uz. S.S.R., Otd. Khim. Nauk 1963, 120-127; CA 61-1316.
2050. T. Horibe and S. Kuwabara, Kogyo Kagaku Zasshi 67, 276-281 (1964); CA 61-1315.
2051. M. Faiziev and V. Rasuleva, Dokl. Akad. Nauk Uz. S.S.R. 1961, No. 7, 41-43; CA 61-1317.
2052. L. P. Reshetnikova, A. V. Novoselova and B. S. Zakharova, Vestnik Moskov. Univ., Ser. II, Khim. 19, No. 2, 30-32 (1964); CA 61-1317.
2053. J. E. Gordon, C. W. Dempesy and T. Soller, Proc. Conf. Rare Earth Res., 2nd, Glenwood Springs, Colo. 1961, 203-212 (Pub. 1962); CA 61-1323.
2054. R. L. Peters, Mater. Design Eng. 59, No. 5, 87 (1964); CA 61-1323.
2055. G. I. Kalishevich, P. V. Gel'd and R. P. Krentis, Teplofiz. Vysokikh Temperatur, Akad. Nauk S.S.S.R. 2, 16-20 (1964); CA 61-1323.

2056. R. W. Haskell and R. C. De Vries, J. Am. Ceram. Soc. 47, 202-203 (1964); CA 61-1324.
2057. V. A. Kirillin, A. E. Sheindlin and V. Ya. Chekhovskoi, Teplofiz. Vysokikh Temperatur, Akad. Nauk S.S.S.R. 2, 9-15 (1964); CA 61-1324.
2058. G. N. Zviadadze and V. G. Rtskhiladze, Soobshch. Akad. Nauk Gruz. S.S.R. 33, 175-181 (1964); CA 61-1321.
2059. B. Sarkar, P. Saltman, S. Benson and A. Adamson, J. Inorg. and Nuclear Chem. 26, 1551-1554 (1964).
2060. T. E. Gardner and A. R. Taylor, Jr., U. S. Bur. Mines, Rept. Invest. 6435, 8pp (1964); CA 61-1322.
2061. E. F. Westrum, Jr. and H. Justice, Proc. Conf. Rare Earth Res., 2nd, Glenwood Springs, Colo. 1961, 156-162 (Pub. 1962); CA 61-1322.
2062. R. C. Paul, J. Singh, S. C. Ahluwalia and S. S. Pahil, Indian J. Chem. 2, 134-137 (1964); CA 61-1322.
2063. A. Ferrier, E. Uebelacker and E. Wachtel, Compt. rend. 258, 5424-5427 (1964); CA 61-5289.
2064. G. H. Bannister and J. R. Thomson, J. Nucl. Mater. 12, 16-23 (1964); CA 61-5310.
2065. A. Willgallis and K. J. Range, Glastech. Ber. 34, 194-200 (1964); CA 61-5333.
2066. I. A. Novokhatskii and L. M. Lenev, Izvest. Akad. Nauk S.S.S.R., Met. i Gorn. Delo 1963, No. 6, 47-51; CA 61-5270.
2067. K. Burger, Magyar Kem. Folyoirat 70, 179-184 (1964); CA 61-1315.
2068. A. W. Taylor and E. L. Gurney, Soil Sci. Soc. Am. Proc. 28, 63-64 (1964); CA 61-1317.
2069. T. G. Toropova and A. D. Pogorelyi, Tr. Severo-Kavkazsk. Gornomet. Inst. 1961, No. 7, 38-45; CA 61-1293.
2070. J. F. Nachman, C. E. Lundin and [illegible]. S. Yamamoto, Proc. Conf. Rare Earth Res., 2nd, Glenwood Springs, Colo. 1961, 163-173(Pub. 1962); CA 61-1294.
2071. H. Schuetze, K. Wetzel and L. Kaden, Kernenergie 5, 331 (1962); CA 61-1292.
2072. I. E. Flis, K. P. Mishchenko, V. A. Kustodina and K. Yu. Salnis, Khim. Perekisnykch Soedin., Akad. Nauk S.S.S.R., Inst. Obshch. i Neorgan. Khim. 1963, 50-52; CA 61-3753.
2073. R. L. Altman, J. Phys. Chem. 68, 3425-3426 (1964).
2074. E. H. P. Cordfunke, J. Phys. Chem. 68, 3353-3356 (1964).
2075. T. J. Wydeven and N. W. Gregory, J. Phys. Chem. 68, 3249-3252 (1964).
2076. T. Yokokawa and O. J. Kleppa, J. Phys. Chem. 68, 3246-3249 (1964).
2077. R. A. Fisher, H. Chon and J. G. Aston, J. Phys. Chem. 68, 3240-3246 (1964).
2078. R. R. Hammer and N. W. Gregory, J. Phys. Chem. 68, 3229-3233 (1964).
2079. R. R. Richards and N. W. Gregory, J. Phys. Chem. 68, 3089-3093 (1964).
2080. H. C. Duus and D. P. Mykytiuk, J. Chem. Eng. Data 9, 585-588 (1964).
2081. R. R. Thais and J. P. Kohn, J. Chem. Eng. Data 9, 546-547 (1964).
2082. E. P. Egan, Jr. and Z. T. Wakefield, J. Chem. Eng. Data 9, 544-545 (1964).
2083. E. P. Egan, Jr. and Z. T. Wakefield, J. Chem. Eng. Data 9, 541-544 (1964).

2084. J. H. Stern and J. J. Jasnosz, J. Chem. Eng. Data 9, 534-536 (1964).
2085. H. Eding and D. Cubicciotti, J. Chem. Eng. Data 9, 524-525 (1964).
2086. D. T. Hawkins and R. L. Orr, J. Chem. Eng. Data 9, 505-507 (1964).
2087. E. S. Watson, M. J. O'Neill, J. Justin and N. Brenner, Anal. Chem. 36, 1233-1238 (1964).
2088. C. E. Habermann and A. H. Daane, J. Chem. Phys. 41, 2818-2827 (1964).
2089. N. A. Hill and O. B. Cavin, J. Am. Ceram. Soc. 47, 360-361 (1964); CA 61-10118.
2090. S. Hafner and F. Laves, J. Am. Ceram. Soc. 47, 362 (1964); CA 61-10118.
2091. H. M. N. H. Irving and P. K. Khopkar, J. Inorg. and Nuclear Chem. 26, 1561-1569 (1964).
2092. D. J. M. Bevan and J. Kordis, J. Inorg. and Nuclear Chem. 26, 1509-1523 (1964).
2093. M. A. Tucker, C. B. Colvin and D. S. Martin, Jr., Inorg. Chem. 3, 1373-1383 (1964).
2094. M. S. Foster, S. E. Wood and C. E. Crouthamel, Inorg. Chem. 3, 1428-1431 (1964).
2095. A. S. L'vova and N. N. Feodos'ev, hur. Neorg. Khim. 9, 2251-2252 (1964).
2096. V. I. Kumok and V. V. Serebrennikov, Zhur. Neorg. Khim. 9, 2148-2152 (1964).
2097. V. E. Mironov, F. Ya. Kul'ba, V. A. Fedorov and A. V. Fedorova, hur. Neorg. Khim. 9, 2138-2141 (1964).
2098. V. E. Mironov, F. Ya. Kul'ba, A. V. Fokina, V. S. Golubeva and V. A. Nazarov, hur. Neorg. Khim. 9, 2133-2137 (1964).
2099. L. M. aitsev and G. S. Bochkarev, hur. Neorg. Khim. 9, 2122-2125 (1964).
2100. P. G. Maslov, hur. Neorg. Khim. 9, 2076-2078 (1964).
2101. D. A. Johnson and . G. Sharpe, J. Chem. Soc. 1964, 3490-3492.
2102. E. A. V. Ebsworth and M. J. Mays, J. Chem. Soc. 1964, 3450-3454.
2103. B. J. Aylett and L. K. Peterson, J. Chem. Soc. 1964, 3429-3436.
2104. D. W. Archer and C. B. Monk, J. Chem. Soc. 1964, 3117-3122.
2105. P. L. E. de la Praudiere and L. A. K. Staveley, J. Inorg. and Nuclear Chem. 26, 1713-1719 (1964).
2106. A. Finch and P. J. Gardner, J. Chem. Soc. 1964, 2985-2990.
2107. J. C. Slater, J. Chem. Phys. 41, 3199-3204 (1964).
2108. J. R. Van Wazer and K. Moedritzer, J. Chem. Phys. 41, 3122-3126 (1964).
2109. T. C. Ehlert, R. A. Kent and J. L. Margrave, J. Am. Chem. Soc. 86, 5093-5095 (1964).
2110. R. A. Kent, T. C. Ehlert and J. L. Margrave, J. Am. Chem. Soc. 86, 5090-5093 (1964).
2111. G. T. Furukawa, M. L. Reilly and J. H. Piccirelli, J. Research Natl. Bur. Standards 68A, 381-389 (1964).
2112. R. C. King and G. T. Armstrong, J. Research Natl. Bur. Standards 68A, 661-668 (1964).
2113. G. T. Furukawa, M. L. Reilly and J. H. Piccirelli, J. Research Natl. Bur. Standards 68A, 651-659 (1964).
2114. E. S. Newman, J. Research Natl. Bur. Standards 68A, 645-650 (1964).

2115. R. H. Sherman, S. G. Sydoriak and T. R. Roberts, J. Research Natl. Bur. Standards 68A, 579-588 (1964).
2116. T. R. Roberts, R. H. Sherman and S. G. Sydoriak, J. Research Natl. Bur. Standards 68A, 567-578 (1964).
2117. S. G. Sydoriak, T. R. Roberts and R. H. Sherman, J. Research Natl. Bur. Standards 68A, 559-565 (1964).
2118. S. G. Sydoriak and R. H. Sherman, J. Research Natl. Bur. Standards 68A, 547-558 (1964).
2119. T. Nozaki, Y. Nakamura, M. Shimoji and K. Niwa, Ber. Bunsenges. physik. Chem. 68, 568-571 (1964).
2120. M. Idemori, Nippon Kagaku Zasshi 85, 331-335 (1964); CA 61-4963.
2121. D. N. Purohit and N. C. Sogani, Z. Anal. Chem. 203, 97-101 (1964); CA 61-4961.
2122. E. Jozefowicz and J. Maslowska, Zeszyty Nauk. Politech. Lodz., Chem. 13, 13-25 (1963); CA 61-5180.
2123. W. W. Wendlandt, Chemist-Analyst 53, No. 3, 71-72 (1964); CA 61-10117.
2124. M. W. Wadley, Dissertation Abstr. 24, 4986 (1964); CA 61-10316.
2125. R. Kohlmuller and N. Leitner, Rev. Chim. Minerale 1, 275-277 (1964); CA 61-10289.
2126. L. H. Adami and E. G. King, U. S. Bur. Mines, Rept. Invest. 6495, 10pp (1964); CA 61-10109.
2127. S. Utsuno and K. Sone, Bull. Chem. Soc. Japan 37, 1038-1043 (1964); CA 61-10185.
2128. D. L. Johnson, U. S. AEC NAA-SR-8381, 39pp (1964); CA 61-10109.
2129. P. E. Hart, U. S. AEC UCRL 11124, 17pp (1964); CA 61-10110.
2130. A. S. Abbasov, A. V. Nikol'skaya, Ya. I. Gerasimov and V. P. Vasil'ev, Doklady Akad. Nauk S.S.S.R. 156, 1399-1401 (1964); CA 61-10106.
2131. N. M. Selivanova, Z. L. Leshchinskaya, A. I. Maier and E. Yu. Muzalev, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 7, 209-216 (1964); CA 61-10106.
2132. B. F. Markov and S. V. Volkov, Ukrain. Khim. Zhur. 30, 545-553 (1964); CA 61-10104.
2133. F. Maslan, Nucleonics 20, 53 (1962); CA 61-10104.
2134. A. Kawase, Bunseki Kagaku 13, 553-559 (1964); CA 61-10099.
2135. D. M. Czakis-Sulikowska, Roczniki Chem. 38, 533-543 (1964); CA 61-10099.
2136. V. S. Azikov, V. F. Begunova, S. N. Zagrebel'nyi and V. V. Serebrennikov, Tr. Tomskogo Gos. Univ., Ser. Khim. 157, 81-85 (1963); CA 61-10095.
2137. I. M. Bataev and M. S. Zakhar'evskii, Vestnik Leningrad. Univ. 19, No. 10, Ser. Fiz. i Khim. No. 2, 84-89 (1964); CA 61-10094.
2138. Y. Fujino, D. Shinoda, S. Asanabe and Y. Sasaki, Japan. J. Appl. Phys. 3, 431-435 (1964); CA 61-10093.
2139. M. Nakagawa, Kogyo Kagaku Zasshi 67, 523-527 (1964); CA 61-10092.
2140. I. A. Bondar and N. V. Vinogradova, Izvest. Akad. Nauk S.S.S.R., Ser. Khim. 1964, 785-790; CA 61-10089.
2141. J. J. Brown and F. A. Hummel, J. Electrochem. Soc. 111, 1052-1057 (1964); CA 61-10089.
2142. N. Pessall, K. P. Gupta, C. H. Cheng and P. A. Beck, J. Phys. Chem. Solids 25, 993-1003 (1964); CA 61-10070.

2143. M. Maurin and P. Silber, Rev. Chim. Minerale 1, 11-112 (1964); CA 61-10069.
2144. P. H. Gore and P. J. Newman, Anal. Chim. Acta 31, 111-120 (1964); CA 61-10030.
2145. A. Cabbage, F. H. Welch and J. B. Trice, U. S. Dept. Comm., Office Tech. Serv., PB 162,012, 11pp (1949); CA 59-9540.
2146. H. Powers, F. Welch and J. B. Trice, U. S. Dept. Comm., Office Tech. Serv., PB 162,011, 16pp (1949); CA 59-9540.
2147. D. B. Novotny and J. F. Smith, U. S. AEC IS 589, 6pp (1963); CA 61-9254.
2148. L. A. Hiller, Jr. and I. J. Brink, Rev. Sci. Instr. 33, 323-330 (1962); CA 61-9179.
2149. I. Sheft, T. M. Spittler and F. H. Martin, Science 145, 701-702 (1964); CA 61-9162.
2150. V. I. Shlenskaya and A. A. Biryukov, Vestnik Moskov Univ., Ser. II, Khim. 19, No. 3, 65-68 (1964); CA 61-9043.
2151. R. R. Hake and J. A. Cape, Phys. Rev. [2] 135, A1151-A1160 (1964); CA 61-9010.
2152. J. C. Ahluwalia, Dissertation Abstr. 24, 5018-5019 (1964); CA 61-8962.
2153. S. Atallah, J. Astronaut. Sci. 9, 107 (1962); CA 61-8962.
2154. J. P. Franck, Phys. Letters 11, 208-210 (1964); CA 61-8961.
2155. D. Saehr, Bull. Soc. Chim. France 1964, 1287-1289; CA 61-8961.
2156. S.-Y. Yeh and R. E. Peterson, J. Pharm. Sci. 53, 822-824 (1964); CA 61-8945.
2157. E. R. Grilly, Cryogenics 2, 226-229 (1962); CA 61-8919.
2158. C. R. Barber, Comite Consultatif Thermometrie, Comite Intern. Poids Mesures, 6e, Sevres, France 1962, 94-96 (Pub. 1964); CA 61-8913.
2159. W. Pessel and J. Ranachowski, Szklo Ceram. 15, No. 2, 50-52 (1964); CA 61-10420.
2160. E. F. Stroganov, G. M. Matveev and Kh. B. Khokonov, Sovrem. Metody Issled. Silikatov i Stroit. Materialov, Vses. Khim. Obshchestvo, Sb. Statei 1960, 52-66; CA 61-10416.
2161. E. Bonnier, F. Durand and G. Massart, Compt. rend. 259, 380-383 (1964); CA 61-10397.
2162. R. E. Siemens, H. R. Babitzke and H. Kato, U. S. Bur. Mines, Rept. Invest. 6492, 11pp (1964); CA 61-10394.
2163. S. P. Bag, Q. Fernando and H. Freiser, Arch. Biochem. Biophys. 106, 379-380 (1964); CA 61-5178.
2164. H. Voelz-Fladrich, Freiberger Forschungsn. 134, 1-85 (1962); CA 61-10094.
2165. J. D. Hafley, Dissertation Abstr. 24, 5023 (1964); CA 61-10316.
2166. P. D. Pavitsanos, Rev. Sci. Instr. 35, 1061-1063 (1964).
2167. K. E. Jabalpurwala, K. A. Venkatachalam and M. B. Kabadi, J. Inorg. and Nuclear Chem. 26, 1027-1043 (1964).
2168. S. N. Dubey and R. C. Mehrotra, J. Inorg. and Nuclear Chem. 26, 1543-1550 (1964).
2169. S. Hietanen and L. G. Sillen, Acta Chem. Scand. 18, 1018-1019 (1964).
2170. S. Hietanen and L. G. Sillen, Acta Chem. Scand. 18, 1015-1016 (1964).

2171. Y. Sasaki and L. G. Sillen, Acta Chem. Scand. 18, 1014 (1964).
2172. I. Danielsson, B. Nelander, S. Sunner and I. Wadsö, Acta Chem. Scand. 18, 995-998 (1964).
2173. I. Lundqvist, Acta Chem. Scand. 18, 858-870 (1964).
2174. J. Bjerrum, Acta Chem. Scand. 18, 843-857 (1964).
2175. H. Martin, W. Seidel, H. G. Cnotka and W. Hellmayr, Z. anorg. u. allgem. Chem. 331, 333-343 (1964).
2176. G. Gattow and G. Heinrich, Z. anorg. u. allgem. Chem. 331, 275-288 (1964).
2177. G. Gattow and G. Heinrich, Z. anorg. u. allgem. Chem. 331, 256-274 (1964).
2178. H. Schäfer and H. Heine, . anorg. u. allgem. Chem. 332, 25-34 (1964).
2179. N. G. Schmahl and F. Müller, Z. anorg. u. allgem. Chem. 332, 12-24 (1964).
2180. J. C. Barnes, J. Chem. Soc. 1964, 3880-3885.
2181. D. D. Perrin, J. Chem. Soc. 1964, 3644-3648.
2182. H. Yoneda, G. R. Choppin, J. L. Bear and J. V. Quagliano, Inorg. Chem. 3, 1642-1644 (1964).
2183. A. D. Craig, Inorg. Chem. 3, 1628-1633 (1964).
2184. J. F. Allen and H. M. Neumann, Inorg. Chem. 3, 1612-1618 (1964).
2185. S. Katz, Inorg. Chem. 3, 1598-1600 (1964).
2186. P. A. Rock and R. E. Powell, Inorg. Chem. 3, 1593-1597 (1964).
2187. R. M. Izatt, J. J. Christensen and V. Kothari, Inorg. Chem. 3, 1565-1567 (1964).
2188. J. L. Wood and M. M. Jones, Inorg. Chem. 3, 1553-1556 (1964).
2189. C. W. Koch and S. M. Williamson, J. Am. Chem. Soc. 86, 5439-5444 (1964).
2190. E. C. Jekel, C. M. Criss and J. W. Cobble, J. Am. Chem. Soc. 86, 5404-5407 (1964).
2191. R. E. Mitchell and J. W. Cobble, J. Am. Chem. Soc. 86, 5401-5403 (1964).
2192. J. W. Cobble, J. Am. Chem. Soc. 86, 5394-5401 (1964).
2193. C. M. Criss and J. W. Cobble, J. Am. Chem. Soc. 86, 5390-5393 (1964).
2194. C. M. Criss and J. W. Cobble, J. Am. Chem. Soc. 86, 5385-5390 (1964).
2195. J. C. Ahluwalia and J. W. Cobble, J. Am. Chem. Soc. 86, 5381-5384 (1964).
2196. J. C. Ahluwalia and J. W. Cobble, J. Am. Chem. Soc. 86, 5377-5381 (1964).
2197. D. G. Clifton, J. Chem. Phys. 41, 3656-3657 (1964).
2198. L. P. Theard and D. L. Hildenbrand, J. Chem. Phys. 41, 3416-3420 (1964).
2199. R. P. Krentsis and P. V. Gel'd, Sb. Nauchn. Tr., Ural'sk. Politekhn. Inst. No. 126, 95-99 (1963); CA 61-7772.
2200. G. A. Bergman and E. I. Shmuk, Izvest. Akad. Nauk S.S.S.R., Met. i Gorn. Delo 1964, No. 3, 91-99; CA 61-7771.
2201. G. M. Matveev and M. A. Matveev, hur. Vses. Khim. Obshchestva im. D. I. Mendeleeva 9, 354-355 (1964); CA 61-7770.
2202. A. I. Efimov, I. V. Vasil'kova, E. K. Smirnova, N. D. aitseva, T. S. Shemyakina and I. L. Perfilova, Khim. Redkikh Elementov, Leningr. Gos. Univ. 1964, 38-43; CA 61-7761.

2203. D. F. Howard, G. P. Bowman, R. K. Saxer and J. R. Myers, Trans. AIME 230, 850-853 (1964); CA 61-7760.
2204. N. A. Skorik and V. V. Serebrennikov, Tr. Tomskogo Gos. Univ., Ser. Khim. 157, 198-201 (1963); CA 61-7759.
2205. P. G. Rustamov and B. N. Mardakhaev, Azerb. Khim. Zh. 1963, 131-140; CA 61-7758.
2206. N. A. Kostromina, Redkozem. Elementy, Akad. Nauk S.S.S.R., Inst. Geokhim. i Analit. Khim. 1963, 160-165; CA 61-5010.
2207. N. K. Davidenko, Redkozem. Elementy, Akad. Nauk S.S.S.R., Inst. Geokhim. i Analit. Khim. 1963, 149-155; CA 61-5011.
2208. F. Achenza, Ann. chim. (Rome) 54, 240-245 (1964); CA 61-5189.
2209. N. S. Fortunatov and V. S. Kublanovskii, Ukrain. Khim. Zhur. 30, 436-441 (1964); CA 61-5183.
2210. D. Dyrssen, Trans. Roy. Inst. Technol., Stockholm No. 220, 14pp (1964); CA 61-1317.
2211. A. Ferrier, Compt. rend. 258, 3288-3291 (1964); CA 61-2539.
2212. G. Popa, C. Luca and E. Josif, Analele Univ. "C. I. Parhon" Bucuresti, Ser. Stiint. Nat., Chim. 11, 45-57 (1962); CA 61-2532.
2213. C. Liteanu and G. Boda, Studia Univ. Babes Bolyai Cluj., Ser. Chem. No. 1, 35-40 (1962); CA 61-2531.
2214. M. Ebert and F. Skvara, Collection Czech. Chem. Communs. 29, 1413-1417 (1964); CA 61-2529.
2215. G. G. Babayan, E. B. Oganesyan, A. P. Gyunashyan and E. A. Sayamyan, Izvest. Akad. Nauk Arm. S.S.R., Khim. Nauki 16, 539-545 (1963); CA 61-2528.
2216. E. Campi, G. Ostacoli and M. Meirone, Ann. chim. (Rome) 54, 639-646 (1964); CA 61-7158.
2217. H. Deelstra and F. Verbeek, Bull. soc. chim. Belges 73, 597-614 (1964); CA 61-9158.
2218. T. A. Bohigian, Jr. and A. E. Martell, U. S. AEC TID 20015, 27pp (1963); CA 61-9157.
2219. M. Husain, R. Haque and W. U. Malik, J. Indian Chem. Soc. 41, 394-395 (1964); CA 61-9155.
2220. K. Aotani, Denki Kagaku 28, No. 2, 48-49 (1960); CA 61-8946.
2221. B. D. Jain and H. B. Singh, Indian J. Chem. 2, 245-246 (1964); CA 61-8895.
2222. . A. Sheka, E. E. Kriss and E. I. Sinyavskaya, Redkozem. Elementy, Akad. Nauk S.S.S.R., Inst. Geokhim. i Analit. Khim. 1963, 240-245; CA 61-3671.
2223. J. L. Mackey and J. E. Powell, Proc. Conf. Rare Earth Res., 2nd, Glenwood Springs, Colo. 1961, 47-58 (Pub. 1962); CA 61-2534.
2224. R. Näsänen, P. Meriläinen and S. Lukkari, Suomen Kemistilehti B37, 1-5 (1964); CA 61-2532.
2225. R. M. Shellenbarger, Ph. D. thesis, Univ. of N. Carolina, taken from Dissertation Abstr. 24, 3119 (1964).
2226. R. Näsänen, P. Meriläinen and M. Koskinen, Suomen Kemistilehti B37, 41-44 (1964); CA 61-2532.
2227. R. Näsänen and P. Meriläinen, Suomen Kemistilehti B37, 54-56 (1964); CA 61-6455.

2228. K. Pan, Z. F. Lin, S. H. Lin and P. J. Sun, Proc. Intern. Symp. Mol. Struct. Spectry., Tokyo 1962 B311, 3pp; CA 61-6455.
2229. A. Lewandowski and B. Hurnik, Roczniki Chem. 38, 357-360 (1964); CA 61-6456.
2230. E. Svarcs, M. E. Tomilova and A. Ievins, Latvijas PSR Zinatnu Akad. Vestis., Khim. Ser. 1964, 135-136; CA 61-6612.
2231. N. P. Komar, Uch. Zap. Khar'kovsk. Gos. Univ. 133, Tr. Khim. Fak. i Nauchn.-Issled. Inst. Khim. No. 19, 66-94 (1963); CA 61-6611.
2232. E. Svarcs, M. E. Tomilova and A. Ievins, Latvijas PSR Zinatnu Akad. Vestis., Khim. Ser. 1964, 3-6; CA 61-6611.
2233. A. Jayaraman, Phys. Rev. [2] 135, A1056-A1059 (1964); CA 61-6475.
2234. C. B. Finch, L. A. Harris and G. W. Clark, Am. Mineralogist 49, 782-785 (1964); CA 61-6475.
2235. Mrs. J. Boros, K. Szepesi and T. Takacs, Epitoanyag 14, 364-372 (1962); CA 61-6474.
2236. B. S. Tambiev, Uch. Zap. Kabardino-Balkarsk. Univ. 1962, 263-267; CA 61-6466.
2237. B. F. Markov and S. V. Volkov, Ukrain. Khim. Zhur. 30, 341-347 (1964); CA 61-6466.
2238. J.-J. Cheng and Y. W. Klucharoff, Kuei Suan Yes Hsueh Pao 1, 91-97 (1962); CA 61-10091.
2239. L. Bosio and A. Defrain, Compt. rend. 258, 4929-4931 (1964); CA 61-6469.
2240. A. E. Sheindlin, V. Ya. Chekhovskoi and V. A. Petrov, Inzh.-Fiz. Zh., Akad. Belorussk. S.S.R. 7, No. 5, 63-65 (1964); CA 61-6468.
2241. W. S. Fyfe and M. A. Hollander, Am. J. Sci. 262, 709-712 (1964); CA 61-6468.
2242. G. Busch, P. Junod, R. G. Morris, J. Muheim and W. Stutius, Phys. Letters 11, 9-10 (1964); CA 61-6468.
2243. D. L. Martin, Phys. Rev. Letters 12, 723-724 (1964); CA 61-6468.
2244. B. J. C. Van der Hoeven, Jr. and P. H. Keesom, Phys. Rev. [2] 135, A631-A637 (1964); CA 61-6467.
2245. R. Cohen-Adad and C. Ruby, Compt. rend. 258, 6163-6166 (1964); CA 61-6448.
2246. R. Cohen-Adad, A. Tranquard, R. Peronne, P. Negri and A. P. Rollet, Compt. rend. 251, 2035-2037 (1960); CA 61-6448.
2247. N.-M. Ch'ang and A. V. Novoselova, Vestnik Moskov. Univ., Ser. II, Khim. 19, No. 3, 37-39 (1964); CA 61-6451.
2248. A. Gergely, P. Szarvas and L. Maczay, Magyar Kem. Folyoirat 70, 235-242 (1964); CA 61-6453.
2249. S. N. Khodeskar and D. D. Khanolkar, Current Sci. (India) 33, 399-400 (1964); CA 61-6454.
2250. G. Gawalek, H. Trautmann and H. G. Koennecke, Chem. Tech. (Berlin) 16, 409-413 (1964); CA 61-13215.
2251. T. R. Bhat and T. V. Rao, Z. anorg. u. allgem. Chem. 332, 204-208 (1964).
2252. S. Pawlenko, Z. anorg. u. allgem. Chem. 332, 149-158 (1964).
2253. E. Amberger and W. Dietze, Z. anorg. u. allgem. Chem. 332, 131-139 (1964).

2254. A. D. Mah, U. S. Bur. Mines, Rept. Invest. 6518, 8pp (1964); CA 61-13026.
2255. M. K. Murthy and J. Ip, J. Am. Ceram. Soc. 47, 328-331 (1964); CA 61-13025.
2256. J. F. Nachman, C. E. Lundin and A. S. Yamamoto, U. S. AEC ARL 63-15, 68pp (1962); CA 61-13017.
2257. B. Dobovisek, N. Smajic and B. Korousic, Rudarsko-Met. Zbornik 1964, 7-17; CA 61-13016.
2258. T. N. Stoyanovskaya, G. P. Khomchenko and G. D. Vovchenko, Vestnik Moskov. Univ., Ser. II, Khim. 19, No. 3, 44-46 (1964); CA 61-11617.
2259. E. F. Westrum, Jr., Progr. Sci. Technol. Rare Earths 1, 310-350 (1964); CA 61-11589.
2260. K. N. Munshi and A. K. Dey, J. Indian Chem. Soc. 41, 340-342 (1964); CA 61-11596.
2261. D. F. Smith, W. G. Schwab and T. G. Burke, Appl. Opt. 2, 1165-1167 (1963); CA 61-11483.
2262. M. W. Goheen and R. J. Robinson, Anal. Chim. Acta 31, 71-80 (1964); CA 61-7694.
2263. B. Sharan, Indian J. Pure Appl. Phys. 2, 173-175 (1964); CA 61-11474.
2264. M. Kroutil and M. Vender, Chem. Prumysl 14, 412-415 (1964); CA 61-11396.
2265. L. C. Harrington and G. H. Rowe, U. S. AEC PWAC-426, 14pp (1964); CA 61-11396.
2266. H. Ellison and A. E. Martell, J. Inorg. and Nuclear Chem. 26, 1555-1560 (1964).
2267. R. W. Bain, Steam tables 1964: Physical properties of water and steam 0-800°C., 0-1000 bars, 147pp (H. M. Stationery Office, London, 1964); CA 61-11396.
2268. P. I. Fedorov, V. V. Tsimbalist and G.-Y. Lyu, Zhur. Neorg. Khim. 9, 1681-1683 (1964).
2269. G. Anderegg, Experientia, Suppl. No. 9, 75-83 (1964); CA 61-11395.
2270. H. P. Boehm and R. W. Coughlin, U. S. AEC CONF 73-21, 12pp (1963); CA 61-11395.
2271. W. M. Fairbank, Proc. Intern. School Phys. "Enrico Fermi" 21, 293-304 (1963); CA 61-11395.
2272. H. Hartmann and G. Wagner, Abhandl. Braunschweig. Wiss. Ges. 14, 13-34 (1962); CA 61-11393.
2273. S. R. Gunn, U. S. AEC UCRL 7301-T, 10pp (1962); CA 61-11393.
2274. J. B. Goldmann, U. S. AEC NP 12938, 80pp (1963); CA 61-11392.
2275. G. I. Tsoiman, Izvest. Vysshikh Ucheb. Zavedenii, Neft i Gaz 7, 111 (1964); CA 61-11392.
2276. M. Takahashi, Denki Kagaku 28, 313-317 (1960); CA 61-11391.
2277. Yu. N. Surovoi, V. I. Alekseev and L. A. Shvartsman, Doklady Akad. Nauk S.S.S.R. 157, 951-953 (1964); CA 61-11391.
2278. J. W. Vogt, NASA Doc. N63-22167, 77pp (1962); CA 61-11391.
2279. G. I. Novikov and A. K. Baev, Khim. Redkikh Elementov Leningr. Gos. Univ. 1964, 57-62; CA 61-11391.
2280. S. R. Gunn, U. S. AEC UCRL 7325-T, 11pp (1963); CA 61-11391.
2281. N. Ya. Fedorov, S. I. Sklyarenko and E. S. Petrov, Izvest. Sibirsk. Otd. Nauk S.S.S.R., Ser. Khim. Nauk 1964, 104-107; CA 61-11389.

2282. G. I. Novikov, A. K. Baev and O. G. Polyachenkok, Khim. Redkikh Elementov, Leningr. Gos. Univ. 1964, 63-67; CA 61-11389.
2283. A. S. Abbasov, A. V. Nikol'skaya, Ya. I. Gerasimov and V. P. Vasil'ev, Doklady Akad. Nauk S.S.S.R. 156, 1140-1142 (1964); CA 61-11389.
2284. V. P. Mashovets and V. P. Poddyamov, Zhur. Priklad. Khim. 37, 1268-1272 (1964).
2285. D. Deveze and P. Rumpf, Compt. rend. 258, 6135-6138 (1964); CA 61-11381.
2286. E. I. Vail, A. L. Gershuns and L. Z. Kalmykov, Ukrain. Khim. Zhur. 30, 452-457 (1964); CA 61-11378.
2287. L. V. Gurvich and V. G. Ryabova, Teplofiz. Vysokikh Temperatur. Akad. Nauk S.S.S.R. 2, 401-405 (1964); CA 61-11349.
2288. T. Morimoto, M. Yamaguchi, T. Matsumoto and K. Juna, Rept. Res. Lab. Surface Sci., Fac. Sci., Okayama Univ. 2, No. 2, 65-70 (1963); CA 61-13954.
2289. T. A. Sazykina and N. M. Selivanova, Tr. Mosk. Khim.-Tekhnol. Inst. 1963, 14-17; CA 61-13952.
2290. J. Nilsenrath and M. Klein, U. S. Dept. Comm., Office Tech. Serv. AD 432,210, 169pp (1964); CA 61-13951.
2291. P. Vallet, C. Carel and P. Raccah, Compt. rend. 258, 4028-4031 (1964); CA 61-13951.
2292. R. P. Krentsis and P. V. Gel'd, Fiz.-Khim. Osnovy Proizv. Stali, Akad. Nauk S.S.S.R., Inst. Met. Tr. 6-oi [Shestoi] Konf., Moscow 1961, 400-403 (Pub. 1964); CA 61-13950.
2293. E. L. Pace and J. S. Mosser, U. S. AEC WRU 202, 16pp (1962); CA 61-13949.
2294. M. Takahashi, Denki Kagaku 28, 656-660 (1960); CA 61-13948.
2295. M. Takahashi, Denki Kagaku 28, 660-664 (1960); CA 61-13947.
2296. V. A. Pavlova, M. I. Fainshtein and G. P. Faerman, Tr. Leningr. Inst. Kinoinzhenerov 1963, No. 9, 79-87; CA 61-13944.
2297. G. A. Kataev and B. A. Kulikov, Tr. Tomskogo Gos. Univ., Ser. Khim. 157, 221-223 (1963); CA 61-13941.
2298. R. S. Saxena and M. L. Mittal, Indian J. Chem. 2, 332-333 (1964); CA 61-13940.
2299. B. S. Azikov and V. V. Serebrennikov, Tr. Tomskogo Gos. Univ., Ser. Khim. 157, 12-14 (1963); CA 61-13942.
2300. R. P. Rafal'skii and A. D. Vlasov, Vopr. Prikl. Radiol. Sb. 1963, 189-193; CA 61-13939.
2301. M. Eigen, G. Geier and W. Kruse, Experientia, Suppl. No. 9, 164-178 (1964); CA 61-13926.
2302. F. C. Mijlhoff and R. Block, Rec. trav. chim. 83, 799-809 (1964); CA 61-13899.
2303. R. Rowland and C. E. Meloan, Anal. Chem. 36, 1997-1998 (1964).
2304. G. J. Janz and J. L. Perano, Trans. Faraday Soc. 60, 1742-1744 (1964).
2305. A. Ben-Naim and S. Baer, Trans. Faraday Soc. 60, 1736-1741 (1964).
2306. D. Grant and D. S. Payne, J. Inorg. and Nuclear Chem. 26, 1985-1990 (1964).
2307. H. N. Farrer and F. J. C. Rossotti, J. Inorg. and Nuclear Chem. 26, 1959-1965 (1964).

2308. H. M. N. H. Irving and J. P. Conesa, J. Inorg. and Nuclear Chem. 26, 1945-1957 (1964).
2309. K. S. Rajan and A. E. Martell, J. Inorg. and Nuclear Chem. 26, 1927-1944 (1964).
2310. V. S. K. Nair, J. Inorg. and Nuclear Chem. 26, 1911-1917 (1964).
2311. E. A. Arbit and V. V. Serebrennikov, Tr. Tomskogo Gos. Univ., Ser. Khim. 157, 311-313 (1963); CA 61-11377.
2312. B. A. Chertkov and N. S. Dobromyslova, Zhur. Priklad. Khim. 37, 1718-1723 (1964); CA 61-11358.
2313. G. G. Babayan, S. S. Muradyan and E. B. Oganesyan, Izvest. Akad. Nauk Arm. S.S.R., Khim. Nauki 17, 290-295 (1964); CA 61-11358.
2314. V. N. Chernyaev and S. . Ershov, Izvest. Vysshikh Ucheb. Zavedenii, Tsvetnaya Met. 7, 76-83 (1964); CA 61-11357.
2315. V. E. Mironov, F. Ya. Kul'ba and Yu. E. Ivanov, Zhur. Neorg. Khim. 9, 1633-1637 (1964).
2316. R. Barany, L. B. Pankratz and W. W. Weller, U. S. Bur. Mines, Rept. Invest. 6513, 19pp (1964); CA 61-11662.
2317. A. K. Shurin and G. P. Dmitrieva, Sb. Nauchn. Rabot Inst. Metallofiz., Akad. Nauk Ukr. S.S.R. No. 18, 175-177 (1964); CA 61-11697.
2318. A. K. Shurin and G. P. Dmitrieva, Sb. Nauchn. Rabot Inst. Metallofiz., Akad. Nauk Ukr. S.S.R. No. 18, 170-174 (1964); CA 61-11697.
2319. S. M. Kapelner and R. E. Cleary, U. S. AEC CNLM 4094, 21pp (1964); CA 61-11701.
2320. H. G. McAdie, Mater. Res. Std. 4, 413-417 (1964); CA 61-11730.
2321. D. F. Weil and W. S. Fyfe, Geochim. Cosmochim. Acta 28, 1243-1255 (1964); CA 61-11385.
2322. Z. A. Munir and A. W. Searcy, J. Electrochem. Soc. 111, 1170-1173 (1964); CA 61-11358.
2323. D. G. Edwards, U. S. AEC UCRL 7167, 151pp (1963); CA 61-11357.
2324. M. M. Karavaev, I. M. Kaganskii and V. A. Zhantalai, Zhur. Priklad. Khim. 37, 1689-1695 (1964); CA 61-11357.
2325. H. F. P. Knaap, U. S. AEC NP 12800, 68pp (1962); CA 61-11351.
2326. G. Nagarajan, Acta Phys. Austriaca 18, 11-19 (1964); CA 61-11351.
2327. G. Nagarajan, Acta Phys. Austriaca 18, 1-10 (1964); CA 61-11351.
2328. L. V. Gurvich and V. G. Ryabova, Teplofiz. Vysokikh Temperatur, Akad. Nauk S.S.S.R. 2, 215-218 (1964); CA 61-11349.
2329. B. D. Martin, D. A. Lych and C. V. Heer, Phys. Rev. [2] 135, A671-A679 (1964); CA 61-7769.
2330. R. de Hartoulari, Compt. rend. 258, 4989-4992 (1964); CA 61-7764.
2331. R. R. Hammer and J. A. Pask, J. Am. Ceram. Soc. 47, 264-267 (1964); CA 61-7731.
2332. N. I. Mel'nichenko, Teploenerg. 11, No. 6, 63-64 (1964); CA 61-7731.
2333. A. van Itterbeek, O. Verbeke, F. Theewes, K. Staes and J. de Boelpaep, Physica 30, 1238-1244 (1964); CA 61-7731.
2334. W. A. Heusinkveld and K. Schurer, Comite Consultatif Thermometrie, Comite Intern. Poids Mesures, 6e, Sevres, France 1962, 50-51 (Pub. 1964); CA 61-7728.
2335. G. Schorsch, Bull. soc. chim. France 1964, 1449-1455; CA 61-10306.
2336. H. A. C. Montgomery, M. S. Thom and A. Cockburn, J. Appl. Chem. London 14, 280-296 (1964); CA 61-8058.

2337. M. E. Levina, Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 7, 7-9 (1964); CA 61-5019.
2338. M. O. Kostryukova, Zhur. Eksperim. i Teor. Fiz. 46, 1601-1604 (1964); CA 61-5019.
2339. B. W. Veal and J. A. Rayne, Phys. Rev. [2] 135, A442-A446 (1964); CA 61-5019.
2340. A. Vaivads and T. Millers, Latvijas PSR Zinatnu Akad. Vestis, Kim. Ser. 1963, 701-703; CA 61-5019.
2341. V. Ya. Chekhovskoi, Teplofiz. Vysokikh Temperatur, Akad. Nauk S.S.S.R. 2, 296-302 (1964); CA 61-6465.
2342. A. S. Abbasov, A. V. Nikol'skaya, Ya. I. Gerasimov and V. P. Vasil'ev, Doklady kad. Nauk S.S.S.R. 156, 118-120 (1964); CA 61-6465.
2343. A. Kueffer, Papir Celulosa 17, 125-126 (1962); CA 61-6460.
2344. T. Ishino and A. Matsumoto, Technol. Rept. Osaka Univ. 13, 487-493 (1963); CA 61-6449.
2345. W. Heyne, Exptl. Tech. Physik 12, No. 2, 287-289 (1964); CA 61-6420.
2346. C. M. Iserentant, G. G. Robbrecht and R. J. Doclo, Phys. Letters 11, 14-15 (1964); CA 61-6420.
2347. J. Bernard and F. Remy, Compt. rend. 258, 4563-4566 (1964); CA 61-6418.
2348. V. T. Burtsev, R. A. Karasev and A. M. Samarin, Fiz.-Khim. Osnovy Proizv. Stali, Akad. Nauk S.S.S.R., Inst. Met., Tr. 6-oi [Shestoi] Konf., Moscow 1961, 366-371 (Pub. 1964); CA 61-6418.
2349. I. P. Palyura and A. P. Palkin, Zhur. Neorg. Khim. 9, 2668-2669 (1964).
2350. J. R. Perumareddi, Ph. D. thesis, Univ. of S. California 1962), taken from Dissertation Abstr. 24, 3519 (1964).
2351. V. P. Isaev and A. N. Morozov, Izvest. Akad. Nauk S.S.S.R.,., Met. i Gorn. Delo 1964, No. 2, 13-16; CA 61-2777.
2352. R. Knuetter, Tech.-Wiss. Abhandl. Osram-Ges. 8, 112-114 (1963); CA 61-4021.
2353. A. V. Suvorov, G. I. Novikov, R. B. Dobrotin and A. V. Tarasov, Khim. Redkikh Elementov, Leningr. Gos. Univ. 1964, 26-32; CA 61-8958.
2354. A. Duquesnoy and F. Marion, Compt. rend. 258, 5657-5659 (1964); CA 61-8958.
2355. S. A. Shchukarev, I. V. Vasil'kova and D. V. Korol'kov, Khim. Redkikh Elementov, Leningr. Gos. Univ. 1964, 68-74; CA 61-8958.
2356. R. L. Seth and A. K. Dey, Indian J. Chem. 2, 291-292 (1964); CA 61-9160.
2357. H. Yamamoto, S. Tanaka, T. Nagai and T. Takei, Denki Kagaku 32, 43-48 (1964); CA 61-10317.
2358. N. I. Kolbin, V. M. Samoilov and A. N. Ryabov, Khim. Redkikh Elementov, Leningr. Gos. Univ. 1964, 50-56; CA 61-10106.
2359. V. K. olotukhin, L. V. Yablons'ka, T. V. Romanova and S. G. Guk, Visn. L'vivsk., Derzh. Univ., Ser. Khim. 1963, No. 6, 77-81; CA 61-13944.
2360. G. Verhaegen, S. Smoes and J. Drowart, U. S. AEC W DD-TR-60-782, (Pt. XIX) 8pp (1963); CA 61-11349.
2361. M. A. Azizov and K. S. Khakimova, Tr. Tashkentsk. Farm. Inst. 3, 364-369 (1962); CA 61-9158.

2362. A. Schellenberger and G. Lueders, Ber. 97, 2251-2259 (1964); CA 61-14163.
2363. C. G. Macarovici and R. Micu-Semenuic, Rev. Roumaine Chim. 9, 127-130 (1964); CA 61-14162.
2364. I. V. Kolosov and Z. F. Andreeva, Izv. Timiryazevsk. Sel'skokoz. Akad. 1962, No. 2, 211-216; CA 61-14158.
2365. W. J. Silva and R. C. Smith, Jr., U. S. Dept. Comm., Office Tech. Serv., AD 431,182, 47pp (1963); CA 61-13964.
2366. G. Somsen and L. Weeda, Rec. trav. chim. 83, 810 (1964); CA 61-13955.
2367. B. Stalinski and . Bieganski, Bull. acad. polon. sci., Ser. sci. chim. 12, 331-334 (1964); CA 61-13954.
2368. H. E. Flotow and D. W. Osborne, U. S. AEC CONF 20-23, 18pp (1963); CA 61-13954.
2369. K. A. Sharifov, S. N. Gadzhiev and M. Ya. Agarunov, Izv. Akad. Nauk zerb. S.S.R., Ser. Fiz.-Tekhn. i Mat. Nauk 1964, No. 2, 85-87; CA 61-13954.
2370. G. Petit and F. Delbove, Compt. rend. 254, 1388-1390 (1962); CA 61-13956.
2371. V. I. Altynov and B. V. Ptitsyn, Zhur. Neorg. Khim. 9, 2407-2410 (1964).
2372. F. Z. Dzhabarov and S. V. Gorbachev, Zhur. Neorg. Khim. 9, 2399-2402 (1964).
2373. T. S. Shemyakina, E. K. Smirnova, T. I. Popova and V. M. Kuptsova, Zhur. Neorg. Khim. 9, 2387-2390 (1964).
2374. A. Ya. Sychev, Zhur. Neorg. Khim. 9, 2343-2346 (1964).
2375. I. I. Chernyaev and A. V. Babkov, Zhur. Neorg. Khim. 9, 2307-2312 (1964).
2376. G. M. Lukashenko and V. N. Eremenko, Zhur. Neorg. Khim. 9, 2295-2296 (1964).
2377. V. B. Spivakovskii and L. P. Moisa, Zhur. Neorg. Khim. 9, 2287-2294 (1964).
2378. A. D. Zorin, G. G. Devyatykh, E. F. Krupnova and S. G. Krasnova, Zhur. Neorg. Khim. 9, 2280-2283 (1964).
2379. M. S. Stakhanova, M. Kh. Karapet'yants, V. A. Vasil'ev and Yu. A. Epikhin, Zhur. Fiz. Khim. 38, 2420-2429 (1964).
2380. L. L. Makarov, Yu. G. Vlasov and V. I. Izotov, Zhur. Fiz. Khim. 38, 2403-2407 (1964).
2381. A. A. Vasserman, Zhur. Fiz. Khim. 38, 2386-2391 (1964).
2382. I. S. Morozov, . N. Shevtsova and Li Chi Fa, Zhur. Neorg. Khim. 9, 2606-2612 (1964).
2383. F. Ya. Kul'ba, Yu. B. Yakovlev and V. E. Mironov, Zhur. Neorg. Khim. 9, 2573-2577 (1964).
2384. G. I. Kurnevich and G. A. Shagisultanova, Zhur. Neorg. Khim. 9, 2559-2563 (1964).
2385. Yu. A. Koz'min, L. P. Shul'gin and V. D. Ponomarev, Zhur. Neorg. Khim. 9, 2532-2535 (1964).
2386. A. B. Nikol'skii, Zhur. Neorg. Khim. 9, 2511-2517 (1964).
2387. S. A. Shchukarev, T. A. Tolmacheva and Yu. L. Pazukhin, Zhur. Neorg. Khim. 9, 2507-2510 (1964).

2388. S. A. Shchukarev, T. A. Tolmacheva and G. M. Slavutskaya, Zhur. Neorg. Khim. 9, 2501-2506 (1964).
2389. F. P. Bundy, J. Chem. Phys. 41, 3809-3814 (1964).
2390. C. Fischer and E. Wolf, Z. anorg. u. allgem. Chem. 333, 46-53 (1964).
2391. O. Glemser, A. Müller and U. Stöcker, Z. anorg. u. allgem. Chem. 333, 25-28 (1964).
2392. J. Y. Tong, Inorg. Chem. 3, 1804-1805 (1964).
2393. G. P. Haight, Jr., D. C. Richardson and N. H. Coburn, Inorg. Chem. 3, 1777-1780 (1964).
2394. H. R. O'Neal, N. M. Senozan and N. E. Phillips, Proc. Intern. Conf. Low Temp. Phys., 8th, London 1962, 403-404 (Pub. 1963); CA 61-15420.
2395. T. Shinoda, H. Chihara and S. Seki, J. Phys. Soc. Japan 19, 1088 (1964); CA 61-15420.
2396. Y. Makita, J. Phys. Soc. Japan 19, 576 (1964); CA 61-15420.
2397. J. L. Robin, Bull. Union Physiciens 58, 788-789 (1964); CA 61-15419.
2398. A. W. Lemmon, Jr., H. W. Deem, E. A. Eldridge, E. H. Hall, J. Matolich, Jr. and J. F. Walling, NASA CR-54018, BATT 4673-T7, 39pp (1964); CA 61-15419.
2399. B. Weinstock, E. F. Westrum, Jr. and G. L. Goodman, Proc. Intern. Conf. Low Temp. Phys., 8th, London 1962, 405-406 (Pub. 1963); CA 61-15420.
2400. R. F. Kubin and L. L. Presley, NASA Rept. No. NASA SP-3002, 69pp (1964); CA 61-15418.
2401. W. J. Little, U. S. Dept. Comm., Office Tech. Serv., AD 434,368, 129pp (1964); CA 61-15418.
2402. J. W. Leech and J. A. Reissland, Proc. Intern. Conf. Low Temp. Phys., 8th, London 1962, 409-410 (Pub. 1963); CA 61-15418.
2403. Ya. I. Gerasimov, A. M. Evseev and G. V. Pozhirskaya, Invest. Heat Resistant Alloys 1963, 94-102; CA 61-15415.
2404. J. H. E. Jeffes and H. McKerrell, J. Iron Steel Inst. (London) 202, 666-676 (1964); CA 61-15415.
2405. D. L. Cochran, NASA Rept. No. AT(04-3)-251, AT(04-3)-368, 19pp (1962); CA 61-15416.
2406. P. Fauchais and N. Manson, Compt. rend. 259, 1023-1026 (1964); CA 61-15416.
2407. G. Brunisholz, J. P. Quinche and A. M. Kalo, Helv. Chim. Acta 47, 14-27 (1964); CA 61-15407.
2408. D. V. Owens, E. H. Swift and D. M. Smith, Talanta 11, 1521-1532 (1964); CA 61-15404.
2409. C.-K. Kuo and T.-S. Yen, Hua Hsueh Hsueh Pao 30, 381-387 (1964); CA 61-15401.
2410. T. R. Roberts and R. H. Sherman, Proc. Intern. Conf. Low Temp. Phys., 8th, London 1962, 437-438 (Pub. 1963); CA 61-15383.
2411. N. M. Karnaukhova, hur. Tekh. Fiz. 34, 1906-1910 (1964); CA 61-15381.
2412. M. Thackray, Nature 203, 1278-1279 (1964); CA 61-15381.
2413. A. S. Darling, Platinum Metals Rev. 8, No. 4, 134-140 (1964); CA 61-15381.
2414. Yu. A. Prisilkov, Yu. A. Sapozhnikov and A. V. Tseplyaeva, Vestnik Moskov. Univ., Ser. II, Khim. 19, No. 5, 74-76 (1964); CA 61-15381.

2415. H. L. Schlaefer and W. Tausch, Experientia, Suppl. No. 9, 179-200 (1964); CA 61-12698.
2416. N. A. Skorik and V. V. Serebrennikov, Tr. Tomskogo Gos. Univ., Ser. Khim. 157, 307-310 (1963); CA 61-12696.
2417. M. Suryanarayana, Current Sci. 33, 520-521 (1964); CA 61-12699.
2418. K. Sekiguchi, T. Yotsuyanagi and S. Mikami, Chem. Pharm. Bull. 12, 994-1004 (1964); CA 61-15935.
2419. . Wojtaszek and J. Dubowy, eszyty Nauk. niw. Jagiel., Ser. Nauk. Chem. 6, 169-174 (1961); CA 61-15775.
2420. S. Banya and S. Matoba, Tetsu To Hagane 49, 666-672 (1963); CA 61-15719.
2421. . Kozuka, J. Moriyama and I. Kushima, Denki Kagaku 28, 523-526 (1960); CA 61-14293.
2422. G. Stephen, P. Powell and J. E. Powell, U. S. AEC IS 634, 34pp (1963); CA 61-12933.
2423. J. J. Fardy, U. S. AEC AAECE 94, 27pp (1962); CA 61-12927.
2424. J. E. Powell and J. L. Ferrell, U. S. AEC IS 445, 12pp (1963); CA 61-12924.
2425. L. M. Vincent and J. Gillardeau, Comm. Energie At. (France), Rappt. CEA No. 2360, 107pp (1963); CA 61-14168.
2426. R. C. Linares, Solid State Commun. 2, 229-231 (1964); CA 61-12710.
2427. G. Nagarajan, Bull. soc. chim. Belges 73, 655-672 (1964); CA 61-12781.
2428. A. R. Miedema, H. van Kempen and W. J. Huiskamp, Proc. Intern. Conf. Low Temp. Phys., 8th, London 1962, 228-229 (Pub. 1963); CA 61-12778.
2429. T. McConville and B. Serin, Phys. Rev. Letters 13, 365-367 (1964); CA 61-12768.
2430. H. Hayashi, N. Nakayama, T. Kozuka, M. Yoshida, K. Hasegawa, S. Mizukusa, T. Hata, S. Ogiso and M. Mizuno, Nagoya Kogyo Gijutsu Shikensho Hokoku 13, 291-295 (1964); CA 61-12720.
2431. H. Hayashi, N. Nakayama, M. Yoshida, T. Kozuka, M. Mizuno, K. Yamamoto, T. Yamamoto and T. Noguchi, Nagoya Kogyo Gijutsu Shikensho Hokoku 13, 285-290 (1964); CA 61-12720.
2432. U. Piesbergen, . Naturforsch. 19a, 1075-1079 (1964); CA 61-12710.
2433. A. E. Sheindlin and N. I. Gorbunova, Teplofiz. Vysokikh Temperatur, Akad. Nauk S.S.S.R. 2, 484-487 (1964); CA 61-12710.
2434. W. W. Weller and K. K. Kelley, U. S. Bur. Mines, Rept. Invest. 6511, 7pp (1964); CA 61-12709.
2435. T. Shinoda, H. Chihara and S. Seki, J. Phys. Soc. Japan 19, 1637-1648 (1964); CA 61-12708.
2436. G. A. Grachev and V. I. Rigin, Tr. Sibirsk. Tekhnol. Inst. No. 36, 73-74 (1963); CA 61-12708.
2437. I. T. Sryvalin and O. A. Esin, Fiz.-Khim. Osnovy Proizv. Stali, Akad. Nauk S.S.S.R., Inst. Met., Tr. 6-oi [Shestoi] Konf., Moscow 1961, 395-399 (Pub. 1964); CA 61-12708.
2438. J. F. Walling, Proc. High-Temp. Liquid-Metal Heat Transfer Technol. Meeting, Brookhaven Natl. Lab. 64-76 (1962); CA 61-12708.
2439. M. J. M. Leask, W. P. Wolf and A. F. G. Wyatt, Proc. Intern. Conf. Low Temp. Phys., 8th, London 1962, 230-231 (Pub. 1963); CA 61-12708.
2440. J. Bousquet and J. C. Remy, Bull. soc. chim. France 1964, 211-214; CA 61-12708.

2441. K. P. Gupta, C. H. Cheng and P. A. Beck, J. Phys. Chem. Solids 25, 1147-1149 (1964); CA 61-12708.
2442. L. S. Levinson, U. S. AEC LADC 5930, 12pp (1963); CA 61-12707.
2443. E. J. Wheelwright, D. M. Fleming and F. P. Roberts, U. S. AEC HW 77344, 7pp (1963); CA 61-12707.
2444. Yu. A. Afanas'ev, Radiokhimiya 6. 499-500 (1964); CA 61-12707.
2445. P. A. Rice, D. A. Ragone and J. A. Craig, U. S. AEC TID 17348, 138pp (1962); CA 61-12705.
2446. L. M. Lenev and I. A. Novokhatskii, Izvest. Akad. Nauk S.S.S.R., Met. i Gorn Delo 1964, No. 4, 87-90; CA 61-12705.
2447. P. E. Lapat and R. B. Holden, U. S. AEC UNC 5060, 27pp (1963); CA 61-12705.
2448. H. Rittwagen, NASA Doc. N64-15030, 55pp (1963); CA 61-12705.
2449. Ya. I. Gerasimov and A. V. Nikol'skaya, Vopr. Met. i Fiz. Polyprov., Akad. Nauk S.S.S.R., Tr. 4-go Soveshchaniya 1961, 22-25 (Pub. 1963); CA 61-12704.
2450. M. M. Jones, R. V. Dilts and J. A. Hirsch, J. Tenn. Acad. Sci. 38, No. 3, 91-94 (1863); CA 61-14163.
2451. E. K. Astakhova, V. M. Savostina and V. M. Peshkova, Vestnik Moskov. Univ., Ser. II, Khim. 19, No. 3, 62-64 (1964); CA 61-14167.
2452. E. Sh. Ganelina, hur. Priklad. Khim. 37, 1358-1361 (1964); CA 61-7917.
2453. G. D'Amore and G. Sergi, Ann. chim. (Rome) 54, 327-335 (1964); CA 61-7949.
2454. G. D'Amore and G. Sergi, Ann. chim. (Rome) 54, 424-430 (1964); CA 61-7948.
2455. M. L. N. Reddy and U. V. Seshaiah, J. Indian Chem. Soc. 41, 289-294 (1964); CA 61-7922.
2456. L. S. Serdyuk and V. S. Smirnova, Zhur. Anal. Khim. 19, 451-456 (1964); CA 61-3676.
2457. J. Pomerantz and R. Piacesi, NASA Doc. N63-22236, 140pp (1963); CA 61-12704.
2458. C.-P. Chang and L.-S. Liu, K'o Hsueh T'ung Pao 1964, 435-438; CA 61-12699.
2459. R. Hugel, Bull. soc. chim. France 1964, 1462-1469; CA 61-12700.
2460. C.-P. Chang and L.-S. Liu, K'o Hsueh T'ung Pao 1964, 250-252; CA 61-12698.
2461. S. S. Zavodnov, Zh. Vses. Khim. Obshchestva im. D. I. Mendeleeva 9, 472-473 (1964); CA 61-12696.
2462. D. N. Astrov, M. P. Orlova and D. I. Sharevskaya, Comite Consultatif Thermometrie, Comite Intern. Poids Mesures, 6e, Sevres, France 1962, 102-124 (Pub. 1964); CA 61-12668.
2463. H. M. Roder, L. A. Weber and R. D. Goodwin, NASA Doc. N64-11637, 5pp (1963); CA 61-12666.
2464. M. Durieux and H. van Dijk, Comite Consultatif Thermometrie, Comite Intern. Poids Mesures, 6e, Sevres, France 1962, 166-170 (Pub. 1964); CA 61-12666.
2465. C. R. Barber, Comite Consultatif Thermometrie, Comite Intern. Poids Mesures, 6e, Sevres, France 1962, 97 (Pub. 1964); CA 61-12668.
2466. Y. Yamanaka, Denki Kagaku 28, 427-432 (1960); CA 61-12666.

2467. [illegible] Yamanaka, Denki Kagaku 28, 501-503 (1960); CA 61-12665.
2468. [illegible] Matsuo, H. Kuniyoshi and [illegible] Miyake, Science 145, 1454-1455 (1964); CA 61-12665.
2469. M. G. Shakhtakhtinskii, A. A. Kuliev and G. B. Abdullaev, Vopr. Met. i [illegible]. Poluprov., Akad. Nauk S.S.S.R., Tr. 4-go [Chetvertogo] Soveshchaniya, Moscow 1961, 29-32 (Pub. 1963); CA 61-12665.
2470. [illegible] G. Sydoriak and R. H. Sherman, U. S. AEC LADC 5711, 51pp (1962); CA 61-12665.
2471. M. Yamaguchi, [illegible] Mizushima and M. Toda, J. Phys. Soc. Japan 19, 580-581 (1964); CA 61-12665.
2472. A. A. Wasapis, A. J. Melveger, M. B. Panish, L. Reif and C. L. Rosen, U. S. AEC WADD-TR-60-463, (Pt. II), 85pp (1961); CA 61-10422.
2473. K. E. Mironov, Khim. Perekisnykh Soedin., Akad. Nauk S.S.S.R., Inst. Obshch. i Neorgan. Khim. 1963, 80-84; CA 61-3737.
2474. V. R. Klokman and N. S. Kolesnikova, Radiokhimiya 6, 11-18 (1964); CA 61-3737.
2475. J. Kocher, Compt. rend. 258, 4061-4064 (1964); CA 61-3740.
2476. T. [illegible]kerlak, B. Nikov and V. Sislov, Glasnik Drustva Hemicara Technol. S.R. Bosne Hercegovine 11, 39-42 (1962); CA 61-3749.
2477. I. A. Murav'eva, K. B. Zaborenko, O. G. Nemkova and T.-P. Hang, Radiokhimiya 6, 124-127 (1964); CA 61-3751.
2478. J. Kepinski and J. Trzeszczynski, Roczniki Chem. 38, 201-211 (1964); CA 61-3751.
2479. M. I. Ravich and [illegible] E. Borovaya, Doklady Akad. Nauk S.S.S.R. 155, 1375-1378 (1964); CA 61-3752.
2480. N. O. Smith, S. Kelemen and B. Nagy, Geochim. Cosmochim. Acta 26, 921-926 (1962); CA 61-3753.
2481. V. I. Ermolenko and S. A. Shevchenko, Redkozem. Elementy, Akad. Nauk S.S.S.R., Inst. Geokhim. i Analit. Khim. 1963, 107-112; CA 61-3750.
2482. N. N. Mironov and L. M. Trofimova, Tr. po Khim. i Khim. Tekhnol. 1963, 235-237; CA 61-3752.
2483. I. Leden and T. Ryhl, Acta Chem. Scand. 18, 1196-1201 (1964).
2484. S. Sunner and S. Thoren, Acta Chem. Scand. 18, 1528-1532 (1964).
2485. R. Näsänen and M. Koskinen, Acta Chem. Scand. 18, 1337-1340 (1964).
2486. W. A. Glickman, Ph. D. thesis, Penn. State Univ. (1964), taken from Dissertation Abstr. 25, 2253-2254 (1964).
2487. R. A. Kent, Ph. D. thesis, Michigan State Univ. (1963), taken from Dissertation Abstr. 25, 89-90 (1964).
2488. T. B. Warner, Ph. D. thesis, Indiana Univ. (1963), taken from Dissertation Abstr. 25, 139 (1964).
2489. J. [illegible] Barkman, Jr., Ph. D. thesis, Rice Univ. (1964), taken from Dissertation Abstr. 25, 1593 (1964).
2490. W. R. Stagg, Ph. D. thesis, Iowa State Univ. of Sci. Technol. (1963), taken from Dissertation Abstr. 25, 4014 (1964).
2491. D. M. Vaught, Ph. D. thesis, Univ. of Utah (1964), taken from Dissertation Abstr. 25, 1555 (1964).
2492. J. D. Hale, Ph. D. thesis, Brigham Young Univ. (1963), taken from Dissertation Abstr. 25, 1550 (1964).
2493. J. D. Nutter, Ph. D. thesis, Univ. of Nebraska (1964), taken from Dissertation Abstr. 25, 1604 (1964).

2494. C. F. Gale, Ph. D. thesis, Univ of Colorado (1964), taken from Dissertation Abstr. 25, 1600 (1964).
2495. M. L. Nebel, Ph. D. thesis, Wayne State Univ. (1959), taken from Dissertation Abstr. 25, 4373-4374 (1964).
2496. R. A. Gerber, Ph. D. thesis, Univ. of California (1964), taken from Dissertation Abstr. 25, 2218-2219 (1964).
2497. D. F. Anthrop, Ph. D. thesis, Univ. of California (1963), taken from Dissertation Abstr. 25, 3999-4000 (1964).
2498. C. E. Lebermann, Ph. D. thesis, Iowa State Univ. of Sci. Technol. (1963), taken from Dissertation Abstr. 25, 4[illegible] (1964).
2499. R. R. Hammer, Ph. D. thesis, Univ. of Washington (1963), taken from Dissertation Abstr. 25, 862-863 (1964).
2500. O. T. Hajicek, Ph. D. thesis, Wayne State Univ. (1[illegible]), taken from Dissertation Abstr. 25, 2222-2223 (1964).
2501. T. J. Wydeven, Ph. D. thesis, Univ. of Washington (1964), taken from Dissertation Abstr. 25, 2791-2792 (1964).
2502. T. H. Ramsey, Jr., Ph. D. thesis, Univ. of Texas (1964), taken from Dissertation Abstr. 25, 2900 (1964).
2503. F. Tivin, Ph. D. thesis, Univ. of Illinois (1964), taken from Dissertation Abstr. 25, 794 (1964).
2504. E. D. Weed, Ph. D. thesis, Ohio State Univ. (1964), taken from Dissertation Abstr. 25, 795-796 (1964).
2505. J. D. Oster, Ph. D. thesis, Purdue Univ. (1964), taken from Dissertation Abstr. 25, 869 (1964).
2506. W. B. Rose, Ph. D. thesis, Kansas State Univ. (1964), taken from Dissertation Abstr. 25, 872 (1964).
2507. N. G. Rhode, Ph. D. thesis, Oklahoma State Univ. (1963), taken from Dissertation Abstr. 25, 871 (1964).
2508. H. A. Taylor, Ph. D. thesis, Princeton Univ. (1963), taken from Dissertation Abstr. 25, 3952 (1964).
2509. D. F. Brewer and J. R. Keyston, Proc. Intern. Conf. Low Temp. Phys., 8th, London 1962, 27-28 (Pub. 1963); CA 61-15421.
2510. W. T. Siegler and J. C. Mullins, Georgia Inst. of Technol., Atlanta Eng. Expt. Sta., Contract No. CST 7494 MR 15, 71pp (1963); CA 61-15422.
2511. B. Fisher and D. C. Tannhauser, J. Electrochem. Soc. 111, 1194-1196 (1964); CA 61-15648.
2512. L. Ya. Markovskii and N. V. Vekshina, Zhur. Prikl. Khim. 37, 2126-2133 (1964); CA 61-15649.
2513. Kh. M. Takubov and S. V. Pal'chevskii, Doklady Akad. Nauk Tadzh. S.S.R. 7, No. 4, 16-19 (1964); CA 61-15662.
2514. C. K. Moeller, Kgl. Danske Videnskab. Selskab., Mat.-Fys. Skrifter 32, No. 15, 21pp (1960); CA 61-15651.
2515. J. C. Ahluwalia, Ph. D. thesis, Purdue Univ. (1963), taken from Dissertation Abstr. 25, 5018-5019 (1964).
2516. I. Mahadeviah, Ph. D. thesis, Univ. of Cincinnati (1963), taken from Dissertation Abstr. 25, 820-821 (1964).
2517. J. D. Hefley, Ph. D. thesis, Univ. of Arkansas (1963), taken from Dissertation Abstr. 25, 5023 (1964).

2518. B. Budesinsky and E. Antonescu, Collection Czech. Chem. Communs. 28, 3264-3270 (1963).
2519. I. Gainar and K. W. Sykes, J. Chem. Soc. 1964, 4452-4459.
2520. D. P. N. Satchell and J. L. Wardell, J. Chem. Soc. 1964, 4300-4302.
2521. D. P. N. Satchell and J. L. Wardell, J. Chem. Soc. 1964, 4296-4300.
2522. D. W. Cushen and R. Hulme, J. Chem. Soc. 1964, 4162-4166.
2523. D. P. N. Satchell and J. L. Wardell, J. Chem. Soc. 1964, 4134-4142.
2524. R. Cigen and N. Mannerstrand, Acta Chem. Scand. 18, 1755-1766 (1964).
2525. C. W. F. T. Pistorius and H. C. Snyman, Z. physik. Chem. [NF] 43, 1-10 (1964).
2526. P. Feschotte and O. Kubashewski, Trans. Faraday Soc. 60, 1941-1946 (1964).
2527. J. D. Filby and J. N. Pratt, Trans. Faraday Soc. 60, 1934-1940 (1964).
2528. K. H. Gayer and O. T. ajicek, J. Inorg. and Nuclear Chem. 26, 2123-2125 (1964).
2529. I. Johnson and M. G. Chasanov, J. Inorg. and Nuclear Chem. 26, 2059-2067 (1964).
2530. G. V. Bakore and S. D. Bhardwaj, Z. physik. Chem. 227, 26-32 (1964).
2531. W. Fischer, T. Petzel and S. Lauter, Z. anorg. u. allgem. Chem. 333, 226-234 (1964).
2532. S. Misumi and Y. Masuda, J. Electroanal. Chem. 6, 434-442 (1963).
2533. I. N. Belyaev and N. N. Chikova, Zhur. Neorg. Khim. 9, 2754-2760 (1964).
2534. A. S. Barabanova and B. A. Voitovich, Zhur. Neorg. Khim. 9, 2698-2700 (1964).
2535. B. I. Panfilov and N. N. Feodos'ev, Zhur. Neorg. Khim. 9, 2693-2697 (1964).
2536. B. I. Panfilov and N. N. Feodos'ev, Zhur. Neorg. Khim. 9, 2685-2692 (1964).
2537. V. V. Sychev and V. V. Andrianov, Teplofiz. Vysokikh Temperatur 1, 50-55 (1963); CA 61-8962.
2538. P. I. Fedorov and V. V. Tsimbalist, Zhur. Neorg. Khim. 9, 1676-1680 (1964).
2539. V. E. Mironov, F. Ya. Kul'ba and V. A. Federov, hur. Neorg. Khim. 9, 1641-1644 (1964).
2540. O. E. Zvyagintsev and V. P. Tikhonov, Zhur. Neorg. Khim. 9, 1588-1596 (1964).
2541. N. K. Davidenko, Zhur. Neorg. Khim. 9, 1584-1587 (1964).
2542. S. P. Sangal and A. K. Dey, J. Indian Chem. Soc. 41, 306-308 (1964).
2543. J. L. Boivin, Can. J. Chem. 42, 2744-2748 (1964).
2544. J. Thonstad, Can. J. Chem. 42, 2739-2743 (1964).
2545. O. Glemser, A. Müller and H. Schwarzkopf, Z. anorg. u. allgem. Chem. 334, 21-26 (1964).
2546. R. Kuthe and K. K. Neumann, Ber. Bunsenges. physik. Chem. 68, 692-702 (1964).
2547. A. Capotosto, Jr., Ph. D. thesis, Univ. of Rhode Island (1963), taken from Dissertation Abstr. 25, 789 (1964).
2548. S. G. Sydoriak, T. R. Roberts, R. H. Sherman and F. G. Brickwedde, Comite Consultatif Thermometrie, Comite Intern. Poids Mesures, 6e, Sevres, France 1962, 183-189 (Pub. 1964); CA 61-11346.

2549. W. P. Jensen, Ph. D. thesis, State Univ. of Iowa (1964), taken from Dissertation Abstr. 25, 819-820 (1964).
2550. J. R. Marquart, Ph. D. thesis, Univ. of Illinois (1963), taken from Dissertation Abstr. 25, 5027 (1964).
2551. B. L. Bruner, Ph. D. thesis, Iowa State Univ. of Sci. Tech (1963), taken from Dissertation Abstr. 25, 4002 (1964).
2552. C. R. Barber, Comite Consultatif Thermometrie, Comite Intern. Poids Mesures, 6e, Sevres, France 1962, 19-21 (Pub. 1964); CA 61-12962.
2553. J. A. Hull, R. H. Davies and L. A. K. Staveley, J. Chem. Soc. 1964, 5422-5425.
2554. L. D. Pettit and H. M. N. H. Irving, J. Chem. Soc. 1964, 5336-5343.
2555. D. J. Alner and M. A. A. Kahn, J. Chem. Soc. 1964, 5265-5268.
2556. C. F. Timberlake, J. Chem. Soc. 1964, 5078-5085.
2557. P. Paoletti and A. Vacca, J. Chem. Soc. 1964, 5051-5057.
2558. L. Sacconi, P. Paoletti and M. Ciampolini, J. Chem. Soc. 1964, 5046-5051.
2559. C. C. Addison, R. J. Pulham and R. J. Roy, J. Chem. Soc. 1964, 4895-4901.
2560. C. C. Addison and J. A. Manning, J. Chem. Soc. 1964, 4887-4895.
2561. L. A. D'Orazio, Ph. D. thesis, Univ. of Delaware (1964), taken from Dissertation Abstr. 25, 3285-3286 (1964).
2562. H. C. H. King, E. Körös and S. M. Nelson, J. Chem. Soc. 1964, 4832-4839.
2563. N. N. Greenwood, J. H. Morris and J. C. Wright, J. Chem. Soc. 1964, 4753-4761.
2564. O. Glemser and A. Müller, Z. anorg. u. allgem. Chem. 334, 150-154 (1964).
2565. H.-J. Seifert and K. Klatyk, Z. anorg. u. allgem. Chem. 334, 113-124 (1964).
2566. E. Yu. Silina and M. Kh. Karapet'yants, Zhur. Fiz. Khim. 38, 2733-2735 (1964).
2567. A. S. Pashinkin, Zhur. Fiz. Khim. 38, 2690-2693 (1964).
2568. L. N. Erbanova, S. I. Drakin and M. Kh. Karapet'yants, Zhur. Fiz. Khim. 38, 2670-2674 (1964).
2569. V. I. Lebed' and V. V. Aleksandrov, Zhur. Fiz. Khim. 38, 2608-2613 (1964).
2570. A. L. Lomov and A. N. Kreslovnikov, Zhur. Fiz. Khim. 38, 2569-2574 (1964).
2571. G. C. Wake and I. K. Walker, New Zealand J. Sci. 7, 227-241 (1964); CA 61-10105.
2572. J. M. Smith, B. Caswell and P. V. Shaw, Ind. Eng. Chem. 56, 41-52 (1964); CA 61-12703.
2573. S. R. Gunn, Nucl. Instr. Methods 29, 1-24 (1964); CA 61-9134.
2574. W. W. Dunning and D. S. Martin, U. S. AEC IS 822, 69pp (1964); CA 61-15410.
2575. H. T. Chen, Ph. D. thesis, Polytech. Inst. of Brooklyn (1964), taken from Dissertation Abstr. 25, 2897 (1964).
2576. D. Negoiu and M. Nasea, Studia Univ. Babes-Bolyai, Ser. Chem. 8, 39-48 (1963); CA 61-13868.

2577. S. Sen, Z. anorg. u. allgem. Chem. 333, 160-164 (1964).
2578. R. J. Baltisberger, Ph. D. thesis, Univ. of Wisc. (1963), taken from Dissertation Abstr. 25, 4978-4979 (1964).
2579. J. Fajer, Ph. D. thesis, Brandeis Univ. (1963), taken from Dissertation Abstr. 25, 5021-5022 (1964).
2580. R. F. Schmalz, J. Geophys. Res. 46, 575-579 (1959); CA 60-5061.
2581. V. A. Kogan and V. E. Lyusternik, Sb. Nauchn. Rabot, Vses. Nauchn.-Issled. Inst. Poligr. Prom. No. 13, 11-23 (1961); CA 60-7753.
2582. S. A. Shchukarev, E.K. Smirnova and A. R. Kurbanov, Doklady Akad. Nauk Tadzh. S.S.R. 5, No. 4, 14-17 (1962); CA 59-2228.
2583. D. L. Hildenbrand, L. P. Theard and F. Ju, Aeronutronic, Newport Beach, Calif., Contract No. AF 04(611)-8523, ARPA Order 348-62, Publ. U-2485, RPL-TDR-64-36, 20pp (1964); CA 61-15418.
2584. C. Liteanu and G. Boda, Studia Univ. Babes-Bolyai, Ser. Chem. 7, 139-150 (1962); CA 61-13855.
2585. J. Nölting, Ber. Bunsenges. physik. Chem. 68, 939-944 (1964).
2586. J. Nölting, Ber. Bunsenges. physik. Chem. 68, 932-939 (1964).
2587. A. V. Potapov and G. V. Babkin, Zhur. Fiz. Khim. 38, 3005-3007 (1964).
2588. Yu. B. Nadzhafov and Yu. Kh. Shaulov, Zhur. Fiz. Khim. 38, 2975-2979 (1964).
2589. An. N. Nesmeyanov and G. Trapp, Zhur. Fiz. Khim. 38, 2931-2937 (1964).
2590. A. N. Golubenko and T. N. Rezukhina, Zhur. Fiz. Khim. 38, 2920-2923 (1964).
2591. Yu. I. Gryzin, Zhur. Fiz. Khim. 38, 2834-2839 (1964).
2592. S. Drakin and Yu. Chzhan, Zhur. Fiz. Khim. 38, 2800-2806 (1964).
2593. K. S. Math, Q. Fernando and H. Freiser, Anal. Chem. 36, 1762-1767 (1964); CA 61-12932.
2594. A. V. Lapitskii, V. P. Vizgin and L. N. Pankratova, Vestnik Moskov. Univ., Ser. II, Khim. 19, No. 4, 39-44 (1964); CA 61-12942.
2595. V. M. Tolmachov and O. F. Boberov, Uch. Zap. Khar'kovsk. Gos. Univ. 133, Tr. Khim. Fak. i Nauchn.-Issled. Inst. Khim. No. 19, 147-152 (1963); CA 61-4963.
2596. L. A. Hall, J. G. Hust and A. L. Gosman, Natl. Bur. Standards, Tech. Note 217, 102pp (1964).
2597. N. P. Komar, Uch. Zap. Khar'kovsk. Gos. Univ. 133, Tr. Khim. Fak. i Nauchn.-Issled. Inst. Khim. No. 19, 28-32 (1963); CA 61-6611.

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