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NATIONAL BUREAU OF STANDARDS REPORT

7192

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

(Supplement to NBS Reports 6297, 6484, 6645, 6928, and 7093)

1 July 1961

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U. S. DEPARTMENT OF COMMERCE

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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, and 7093)

Sixth Technical Summary Report
to the Advanced Research Projects Agency
on the Thermodynamic Properties
of Light-Element Compounds

Reference: ARPA Order No. 20-61

NBS

U. S. DEPARTMENT OF COMMERCE
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ABSTRACT

This is the sixth report on the current experimental, theoretical, and evaluative program, at the National Bureau of Standards, on the thermodynamic properties of selected light-element and other compounds of primary interest in high-temperature research. The emphasis in the NBS work has been on the simpler substances--metals and alloys, a few of the oxidizer compounds, and especially the combustion products. The first part of the report discusses the accomplishments of the various NBS groups in the program during the past year and their plans for the coming year. The development of new apparatus and special techniques is fast approaching the stage where they can yield original data. A method recently developed in the program is described for the calibration, to an accuracy of 1 to 2%, of the electrical-energy input to an exploding wire.

During its first two years the program was limited in scope to the compounds of Li, Be, Mg, Aℓ, and Ti with the elements H, O, F, Cℓ, N, and C. During the past year practical considerations have made it desirable to expand the coverage to include (a) "mixed" systems of the simpler compounds of interest (principally, compounds containing pairs of the above metallic elements), and (b) compounds of a number of other elements (especially Zr, Hg, Pb, W, K, Br, I, B, and Si).

Several surveys of the existing thermodynamic data on the expanded ensemble of substances were initiated. These are up-to-date, but in most cases critical evaluation is still lacking. Preliminary results were given six months ago (in NBS Report 7093). The coverage in the present report includes: (a) the borates of Li, Na, K, Ca, and Pb (with "best" values for the heats of formation of about 25); (b) heats of formation of "mixed" oxides (with data on about 25); (c) the heats of formation of inorganic fluorine compounds of all the elements (covering several hundred substances); (d) low-temperature heat-capacity data on various compounds containing W, Pb, Br, or I (with discussions of about 20); (e) high-temperature heat-content data (references and temperature ranges for several hundred substances); and (f) phase relations, x-ray parameters, and heats of formation of intermetallic compounds in about 12 binary systems of the elements Aℓ, Li, Mg, Si, Ti, and Zr. Also included are tables of ideal-gas thermodynamic functions of NF_2, N_2F_4, and (up to 10,000° K) the single-charge positive ions of approximately 25 monatomic gases.

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PART A. SUMMARY OF RESEARCH ACCOMPLISHMENTS AND PLANS FOR FUTURE WORK

INTRODUCTION

From the first the NBS program was planned and implemented to evaluate and provide, so far as possible, all the major thermodynamic properties contributing to chemical propulsion under equilibrium conditions. The first phase of the program, now largely completed, is the evaluation of existing data and the computation of the best tables possible therefrom. The second phase, active from the beginning and now the principal one, is the measurement of new data, both with existing apparatus and with new apparatus that has had to be developed.

With the aim of maximizing the number of important chemical systems for which there will exist a complete set of satisfactory thermodynamic properties, the experimental program is with few exceptions being deliberately limited to the simpler compounds involving Be, Aℓ, Li, Zr, H, F, O, Cℓ, and N (potential fuel components such as hydrides and free metals, potential oxidizer components, and resulting combustion products such as metal fluorides and oxides). As the data status on two-element compounds has improved, the NBS program has been shifting its scope of research to include an increasing number of the numerous compounds of "mixed" type (such as intermetallic compounds, double fluorides, and oxyfluorides) which are inevitably important when, as is often the case, the fuel or oxidizer contains two oxidizable or two oxidizing elements.

The behavior of a given substance in propulsion depends on the simultaneous operation of a number of complementary thermodynamic properties, with no regard to the different techniques by which these properties are separately measured in the laboratory. For this reason the following summary of plans for further NBS work during the next fifteen months is subdivided by class of substance instead of by property or method of measurement. In this summary, the plans for future work are described in relation to the most important data gaps believed to exist at present. Following the summary is a more detailed account of the accomplishments during the past year of each working group, and of its plans for the next fifteen months.

Metal Hydrides and Intermetallic Compounds

Except with discriminating methods like spectroscopy, accurate measurements are of limited value except on samples which are either highly pure or else well characterized. This problem has been most acute with some of the metal hydrides. A series of NBS measurements of the heat of formation of one hydride, probably the most accurate presently in existence for this compound, is nearly completed and will be extended only in the event that better samples become available. It is planned to make a systematic survey of the available data on light-metal hydrides to see where further research is most needed. Those of next priority seem to be the "two-metal" hydrides. Previously unknown entropies of relatively stable hydrides will be available through NBS low-temperature calorimetry almost completed on LiH and $LiAlH_4$, and were recently calculated for several zirconium-hydride compositions from earlier NBS work in another program.

The four metals being emphasized (Li, Be, Al, Zr) form six possible pairs, but the available data indicate that Be forms no intermetallic compounds or solid alloys with Al or Li. Upon completion of the current survey, priority will be assigned to two of the remaining four pairs (Al-Zr and Al-Li). The corresponding intermetallic compounds will be studied, with analysis and possibly density measurements on those samples which can be procured.

Oxidizer Compounds

Accurate heats of formation were measured earlier in the program for several solid perchlorates (those of ammonium, lithium, sodium, and potassium), and that of nitronium perchlorate (NO_2ClO_4) is expected to be completed soon. Proposed plans for subsequent work on a few additional compounds which may be classed as oxidizers include not solids, but rather, typical simple substances in the N-O-F system. There are several practical reasons why their heats of formation need careful determination, especially the following: (1) In the absence of actual data, the heats of formation of larger molecules containing N-F or O-F bonds must often be estimated and compared using bond energies derived from the simpler molecules. (2) For many of the simpler compounds in the N-O-F system, no data exist or those that do exist disagree seriously--e.g., the values for OF_2 cover a range of 14 kilocalories per mole.

It is planned that after the combustion calorimetry on aluminum and beryllium in fluorine discussed below have been completed, the heat of formation of the gas OF_2 will be measured by flame calorimetry. However, if a sample of OF_2 is unavailable the compound NOF may be substituted. Two important simple N-F compounds are NF_3 and N_2F_4. Their heats of formation were measured at the Bureau in other programs, which will sponsor further measurements on N_2F_4 (heat of formation, low-temperature heat capacity and entropy, and the microwave spectrum of the NF_2 produced by its dissociation) when purer samples become available. However, shock-wave techniques have already reached a state of refinement at the Bureau, and the present program plans to include during the next year an extension of this method to the rate of dissociation of a simple N-F compound such as N_2F_4 or NF_3, with accompanying spectroscopic determinations of the composition.

Metal Fluorides and Chlorides

The planned continuation of this phase of the experimental program is based on priority of materials to be measured in the order (a) one-metal fluorides (as $A\ell F_3$), (b) two-metal fluorides (as $Li_3A\ell F_6$), and (c) chlorides (as $BeC\ell_2$). Work on these substances involves four different apparatuses and methods already in use to measure heats of formation, entropies, and heat capacities of solids (and liquids), and three in the last stages of testing before being ready for measurements to define the composition and the heat and free energy of formation of the corresponding vapors. While individual problems (such as the tendency of BeF_2 to solidify as a glass, and the common complexity of most of the metal-halide vapors) create difficulties, the above techniques are virtually capable of giving a complete set of thermodynamic properties for this class of substances.

The one-metal fluorides and chlorides whose heats of formation have been seriously in doubt have been $A\ell F_3$, BeF_2, and $BeC\ell_2$. Earlier experimental work in the program provided what seems to be an accurate value for $BeC\ell_2$, and is expected to do so very soon for $A\ell F_3$. The existing published values for BeF_2 cover a range of 17 kilocalories per mole. It is planned to measure the heat of formation of this compound by direct combustion of the metal in fluorine, with the prospect that the technique successfully developed earlier for $A\ell F_3$ will yield so near complete combustion as to give an unambiguous result for BeF_2.

The low- and high-temperature heat capacities of the one-metal fluorides and chlorides are generally well-known except for those of beryllium. (The accepted high-temperature results for LiF and $LiC\ell$ resulted from NBS measurements several years ago.) Low-temperature measurements are planned on $A\ell C\ell_3$, and also on BeF_2 and $BeC\ell_2$ if samples can be obtained. Heat-capacity measurements on some two-metal fluorides also are tentatively planned: At low temperatures, on $Li_3A\ell F_6$ or Li_2BeF_4; at high temperatures, $Li_3A\ell F_6$ is expected to be completed soon. These mixed fluorides will be synthesized by melting together their components unless, as seems likely, an external source of pure samples becomes available. Although the important $A\ell F_3$-ZrF_4 system is believed to form no stable "mixed-metal" compound, an effort is being made to verify this fact.

With the above types of thermal data available, the vapor-pressure curves form the most reliable source of the heats of formation of the vapors of such relatively involatile compounds as the metal halides when the vapor composition is unambiguous or can be determined independently. A new vapor-pressure apparatus of the transpiration type, now being tested, will be used. The vapor pressure of BeF_2 and LiF have been measured with fairly good precision elsewhere, although the composition of LiF vapor is complex and still in considerable doubt. Measurements are planned on $A\ell F_3$ in inert atmospheres and also in an atmosphere of HF, to detect and measure the possible formation of $A\ell$-H-F gas species. If the latter search gives negative results, it is planned to make measurements on ZrF_4, because there are serious discrepancies in the existing data.

The extension of the thermodynamic properties of metal-halide vapors to very high temperatures requires an accurate knowledge of their molecular structure, and for this purpose a microwave spectrometer which will operate up to about 1200°K is being constructed. If high-temperature tests in the near future show as satisfactory sensitivity as the instrument has shown at room temperature, measurements will be made on fluorides and chlorides of aluminum and beryllium. Diatomic species such as ℓF are believed to be within the range of the apparatus, and the spectra of more complex molecules such as $A\ell C\ell F_2$ and corresponding beryllium species will be sought for study.

Metal Oxides, Hydroxides, and Oxyfluorides

The heats of formation of $A\ell_2O_3$, ZrO_2, Li_2O, and LiOH are believed to be known reliably. It is planned, however, to measure that of BeO, since it is presently uncertain by several kilocalories per mole. Although some attention has been devoted to the possibility of obtaining values for the "two-metal" oxides (such as $A\ell_2O_3 \cdot BeO$, for which a rather uncertain value is available by an indirect method), no plans were made for such work owing to the apparent lack of straightforward techniques and the priority of other tasks. The entropies and heat capacities of the one-metal oxides are generally well known to near the respective melting points. It is planned to measure the heat capacity of BeO from 1200° to 1800°K, and that of $BeO \cdot A\ell_2O_3$ from room temperature to 1800°K, as recent attempts to procure pure samples of macroscopic particle-size promise to be successful. The entropies of these two compounds are in doubt, so that heat-capacity measurements may be carried out over the low-temperature range too.

The properties of oxide, hydroxide, and oxyfluoride gaseous species of the above metals are unknown or far more uncertain, and several apparatuses are being developed to measure them at the high temperatures required. High priority will be given to obtaining results with a newly acquired mass spectrometer, with investigation first of the Be-O-F system. If beryllium oxyfluoride molecules are detected, it should be possible to evaluate their relative importance at different temperatures and pressures. Since such gaseous systems will almost certainly contain also Be-O and Be-F species, it is planned to perform similar complementary experiments on BeF_2 alone and BeO alone. Some work on these two compounds has appeared in the literature; further work on BeF_2 will serve to check the apparatus and method, and work on BeO is expected to be more reliable than the earlier results by allowing the vapors to diffuse from relatively inert rhenium containers. If definitive results are obtained on the Be-O-F system soon enough, additional tasks undertaken will be (1) measurement of the rate of vaporization of $A\ell_2O_3$ in vacuo and in the presence of water vapor under pseudo-equilibrium conditions, using the existing arc-image furnace, and (2) mass-spectrometric studies of the $A\ell$-O-F system. Important gaseous aluminum-hydroxide species would undoubtedly be present in the former system.

The exploding-wire experiment is another method currently under development to study metal-oxide gas systems (such as Aℓ-O and Zr-O) at still higher temperatures (2000° - 6000°K) and up to pressures as high as 100 atmospheres. The apparatus has been built and is now in operation, but before measurements on the extremely transient and unusually complex hot system can be converted into reliable thermodynamic data, the detailed instrumentation and conditions of operation must be carefully investigated along several separate lines. High-speed photographic observations and pressure measurements are now well in hand, and during the past year a major goal was achieved when the accuracy of measuring the total electrical energy entering an exploding wire was verified. Two independent types of comparison with the heat energy produced gave agreement to better than 2 percent, which is considered unusually good for such short time intervals (a few microseconds). The additional phases of measurement also have been under study, but need much more work which is expected to occupy the next year. These phases are as follows: (1) Time- and space-resolved vapor-density measurements will be undertaken with X-rays (both soft and hard to accommodate systems containing different metals). (2) The metal vapor and surrounding gas must mix thoroughly. The hydrodynamic and diffusion aspects of this problem are being investigated theoretically. The experimental approach will seek empirically the conditions of power input, wire shape, etc. needed for uniform explosion, using photographic, X-ray, and chemical analytical criteria. (3) To determine the chemical composition of the vapor, it is planned to modify an existing type of grating spectrograph to provide adequate time and space resolution.

Other Substances; Additional Tables

Light-metal compounds containing B, N, C, Mg, and Ti will receive considerably less priority than those discussed above. Among the nitrides and carbides, Be_3N_2 and $A\ell_4C_3$ are two of the most important lacking heat-capacity data, and there are tentative plans for a series of measurements on each. In addition, heats of reaction of certain beryllium alkyls are planned in order to determine the strength of the Be-C bond. Methods for preparing pure samples were reviewed earlier in the program. The thermodynamic properties of numerous non-metal boron compounds have been measured and reviewed thoroughly in earlier programs at the Bureau; and in a new program supported by the Air Force the heats of formation of the borides of aluminum and other metals will be measured by fluorine calorimetry. Tables of the thermodynamic functions of approximately 125 solids, liquids, and gases have been computed and issued earlier in the present program, and those for which better data become available will be revised.

1. THERMOCHEMISTRY

Experimental Thermochemical Studies:

Measurement of the heat of hydrolysis of nitronium perchlorate, NO_2ClO_4, has been started. These results will be combined with data previously determined in this Laboratory on other perchlorates to yield the heat of formation of nitronium perchlorate.

Future plans include measurements on the heat of solution of $BeCl_2$ in order to resolve the apparent discrepancy in the heat of formation of the solid compound between the work of this Laboratory and unpublished data from Dow Chemical Company. Planned for measurement are also heats of reaction of certain beryllium alkyls to determine the strength of the Be-C bond, and the heat of formation of beryllium oxide.

Tables of Thermodynamic Properties and of Heats of Formation:

The available thermochemical and thermodynamic data on the compounds of boron with hydrogen, oxygen, fluorine, chlorine, and bromine were reviewed, and a revised set of selected "best" heats of formation prepared. In addition, 49 tables of thermodynamic functions were calculated for individual boron compounds as either ideal gases or condensed phases. A critical discussion of the data used was included, to serve as a guide to the reliability of the values, and to indicate areas where additional work is needed.

Future activities of the compilation group will be directed toward a comprehensive review of the available thermochemical data for a complete revision of NBS Circular 500. This will include all of the compounds of the elements of interest, as part of the systematic coverage of the data. Special reports covering particular substances will be prepared as the data are reviewed.

2. FLUORINE CALORIMETRY

The heats of combustion of teflon and of aluminum-teflon mixtures in fluorine have been determined in a series of experiments. At the present, only preliminary values can be cited for the heats of these reactions as some calculations remain to be made and some of the corrections are not completely under control. The energy in the bomb process (constant volume) for the reaction of fluorine with the teflon used was found to be 10.344 kj/gram as the mean of five experiments with a standard deviation of the mean of 0.007 kj/gram. For these reactions fluorine was initially present at about 21 atm pressure and the product was CF_4 with no higher fluorocarbons being observed. About 4 grams of teflon in the form of a powder were burned in each experiment.

For the combustion of aluminum-teflon mixtures, powdered materials were mixed in a proportion of about 1 part aluminum to 4 parts teflon by weight, the amounts being sufficient to cause a total heat release of about 43 kj. In these experiments, the teflon is burned essentially completely to CF_4. The solid product ($A\ell F_3$) is white except for scattered traces of gray material. It is found on all the bomb walls, indicating that at least part of the reaction occurs in the vapor phase. The product is a fine powder, of which the particle size has not been determined. The most successful combustions have been carried out with the pellet of aluminum-teflon mixture in a shallow recess in a nickel or monel plate resting on the bottom of the bomb. Rapid thermal equilibration was found to occur in this system, whereas in some earlier arrangements, the equilibration had been very slow. Using the energy of combustion of teflon described above, the energy of combustion of aluminum in fluorine under the bomb conditions (i.e., constant volume, and 21 atm of F_2) is in the neighborhood of 1,490 kj/mole (357 kcal/mole). Because of uncertainties in some of the corrections, at the time of writing, an uncertainty of about one percent must be attached to this value. The principal uncertainty appears to be in a determination of the heat to be attributed to combustion of the fuse. A nichrome fuse with aluminum supports was used, and combustion of the fuse was not complete in every case. The quantity of reaction is based upon the sample weight. Our preliminary value, which is the average of six measurements, agrees with that determined by Gross and co-workers within the experimental errors as known at this time.

Material of value to the work of this project in the critical evaluation of heats of formation of fluorine compounds, has been obtained in an independent project, in which a complete survey of material related to the heats of formation of inorganic fluorine compounds of all elements has been made, covering the period since 1948. That is, it begins at the close of the literature compiled for NBS Circular 500.

The combustion of aluminum in fluorine and the determination of the heat of formation of aluminum fluoride has proceeded to a point where it can be stated definitely that the work will be completed by September 30, 1961. The study of beryllium combustion will then begin, and the heat of formation of beryllium fluoride will be determined by a similar approach. The heat of formation of lithium fluoride (crystal) is not subject to uncertainties as large as those which we have named, and we will not expect to determine it. If time and personnel assignments permit, we shall undertake a study of the heat of formation of OF_2(g) or of NOF(g), depending partly upon the availability of samples.

3. LOW-TEMPERATURE CALORIMETRY

The primary functions of the low-temperature heat-capacity phase of the program are the accurate measurement of the heat capacity of substances of interest in the condensed phases from about 15° to 400°K and the calculation of the thermal functions from the results of the measurements. During the period July 1, 1960 to July 31, 1961, the efforts of the group have been directed also, with the increase in the number of elemental species important to the program, to literature survey. Investigations of methods of preparation and of sources of procurement were made of those substances where heat data were lacking or considered questionable. Low-temperature heat-capacity data were analyzed wherever available and joined smoothly with high-temperature heat-content data, and the thermal functions were calculated from the results of the analysis.

Measurements were completed on a high-purity (99.9 percent) BeO sample in the form of pellets prepared by compressing and sintering a powder of "sub-micron" size. The material did not sinter as well as materials of lower purity are known to sinter. The pellets were very fragile and broke readily into fine particles. The analysis of the heat data showed significant deviation from results previously published. In order to ascertain whether the difference is caused by the effect of particle size, further measurements are planned on BeO of larger particle size as soon as a sample becomes available.

Gross (sample-plus-container) measurements on $LiAlH_4$ have been completed from 15° to 320°K, and the measurements on the empty container are in progress. Similar to $LiBH_4$, no solid-phase transition was observed. Heat measurements on $KAlH_4$, if available, would be interesting since KBH_4 as well as other alkali borohydrides are known to have solid phase transitions. The gross measurements on a LiH sample have also been completed. Measurements on the empty container are expected to start soon. Apparatus was designed for the purification of $AlCl_3$ and for the subsequent transfer in the liquid phase to a platinum sample container. The purification of $AlCl_3$ is in progress.

Recently published low-temperature heat-capacity data on Li and LiCl were analyzed and revised tables of their thermal functions were obtained. Analysis and calculation of thermal functions were extended to the following compounds: TiO, Ti_2O_3, Ti_3O_5, TiO_2 (rutile and anatase), Zr, ZrO_2, ZrN, and $ZrCl_4$. These tables were issued in NBS Report No. 7093 (January 1, 1961).

The phase behavior of binary systems of Li, Al, Be, Mg, and Zr fluorides and chlorides was investigated preparatory to possible procurement of mixed binary compounds of these halides for heat measurements. The results of this study were given in NBS Report No. 7093. Literature survey of heat data has been extended to compounds of lead and tungsten, and these results are given elsewhere in this report.

During the next year heat-capacity measurements in progress on LiH and $LiAlH_4$ will be completed. Measurements will be completed on $AlCl_3$ which is now being prepared for the measurements. A sample of BeO of large crystal size will be investigated whenever it becomes available. Measurements will also be made on an Al_4C_3 sample now on hand. Depending upon the complexity of each task about two to four of the following substances are planned for study:

a) <u>Li_3AlF_6</u>. This substance may be prepared by heating stoichiometric portions of LiF and AlF_3 to a temperature above the melting point of LiF (848° C). The melting point of Li_3AlF_6 is 790° C. The subsequent cooling of the melt should yield crystalline Li_3AlF_6. To save time it is hoped that this material could be prepared elsewhere for us. Meanwhile, samples of AlF_3 and LiF will be obtained for possible preparation of Li_3AlF_6. A furnace for this purpose has been obtained.

b) <u>$BeCl_2$</u>. A group willing to supply a vacuum-sublimed sample free of $AlCl_3$, $FeCl_3$, and BeO was located. As soon as the total purity of the sample that group intends to supply can be firmly established, a sample will be purchased.

c) <u>BeF_2</u>. The commercial process used to obtain BeF_2 by thermal decomposition of $(NH_4)_2BeF_4$ at about 1000°C yields a glassy material. Sublimation of BeF_2 and decomposition of $(NH_4)_2$ BeF_4 below the melting point of BeF_2 (548°C) are known to yield crystalline BeF_2. Crystallization from a melt containing alkali fluoride is also known to yield crystalline BeF_2. A possible source of crystalline BeF_2 is being contacted.

d) <u>$BeO \cdot Al_2O_3$</u>. Work is in progress at NBS to prepare this material, probably by heating a stoichiometric mixture to about 1900°C.

e) <u>$2LiF \cdot BeF_2$</u>. This material can be prepared by heating a stoichiometric mixture to about 500° to 600°C. Efforts are being made to have a sample prepared. If unavailable, the substance will be prepared in the furnace mentioned earlier. Samples of LiF and BeF_2 are available.

f) <u>AlF_3-ZrF_4 and Al_2O_3-ZrO_2</u>. Compounds of these binary systems are not known. Eutectic mixtures of these systems may be investigated.

g) <u>Be_3N_2 and Li_3N</u>. These substances can be prepared directly from the elements. Efforts will be made to prepare Be_3N_2 and, if time permits, Li_3N for heat measurements.

h) <u>Others.</u> The interest of the program has extended to compounds of K, Br, I, Hg, Pb, and W. Possible heat measurements on some of these compounds are being considered with, however, a low priority in mind.

4. HIGH-TEMPERATURE CALORIMETRY

These measurements supplement low-temperature calorimetry in providing enthalpy-temperature data on which the thermodynamic functions of solids and liquids are based and, in many cases, estimated by extrapolation to still higher temperatures if the actual data are reliable. In contrast to the work at low temperatures, the high-temperature calorimetry conducted in the present program uses the "drop method" exclusively. The two available apparatuses are adapted to two adjoining temperature ranges (300°-1200°K and 1200°-1800°K). Although some work was done with both apparatuses during the past year, no new final data were obtained owing to difficulties of the three most formidable types commonly encountered in high-temperature measurements of this kind. These three problems, which are discussed below under separate headings, are believed to be under sufficient control for reliable measurements soon.

Finding Inert Container Materials:

Measurements on Li_3AlF_6 over the range 273°-1200°K were undertaken. Since it had proved difficult to procure a sample of this congruently melting compound, samples were synthesized by melting together, directly in the sealed calorimetric container, high-purity LiF and sublimed AlF_3 in stoichiometric proportions. The thermodynamic properties indicate that a silver container would be inert to the sample. The apparatus did not permit exceeding the high melting point of AlF_3. But there was good reason to believe that in a reasonable time at 1173°K this solid would completely dissolve in the molten LiF to form the pure liquid mixed fluoride, and that completion of this process would be verified by lack of upward drift with time of subsequent enthalpy measurements, owing to the considerable heat of fusion of aluminum fluoride.

After a few hours of such heating, three subsequent enthalpy measurements at the same temperature showed no appreciable drift and thus indicated success in forming the pure sample. However, a welded seal of the silver container opened, so that a considerable amount of the sample escaped by vaporization during each run, making the corrections too large to be reliable. A Pt-10%Rh container, next tried, was tight for awhile, but sprang a leak before any measurements could be made. This parallels a report in the literature that this alloy failed to contain molten Na_3AlF_6 above 1373°K, as well as earlier difficulties in this laboratory in containing molten NaOH, and is believed to be due to intergranular penetration of the metal without the occurrence of chemical corrosion. Further work with Li_3AlF_6 has been postponed till a pre-formed sample can be procured that requires no prolonged heating in the calorimetric apparatus.

Accurate Measurement of Sample Temperatures in the Furnace:

This is no problem with the lower-temperature apparatus, owing to the large isothermal region afforded by a massive silver core. In the case of the higher-temperature furnace, where silver cannot be used for this purpose, an alumina insert was procured and installed in the center of the core to reduce to 1 mm or less the gap between wall and suspended sample. While no tests of the modified arrangement have yet been made, it is believed that the improved heat conduction will hold the sample much closer to the measured wall temperature than earlier tests had shown.

During the past year this apparatus (for enthalpy measurements up to 1800°K) was described in very extensive detail in an NBS publication.* The top of the ice calorimeter had been constructed of an Fe-Co-Ni alloy to approximate the thermal expansion of the glass container, but on standing for many months in ice or cold water, this alloy began to corrode seriously. The rate of corrosion was recently reduced considerably by the well-known expedient of setting up a permanent electrical potential which keeps the alloy cathodic.

Procurement and Analysis of Pure Samples:

The availability of pure samples, or accurately analyzed ones whose impurities can be corrected for, is necessary for accurate measurements. The NBS Applied Analytical Research Section has recently been able to begin the careful analysis of samples of AlF_3 and Al_4C_3. An extensive search was recently made for sources of the best samples of the substances listed in the next section. Members of the Reactor Chemistry Division, Oak Ridge National Laboratory, have kindly offered to assist so far as possible in the problem of obtaining pure samples of metal fluorides and mixed metal fluorides for this program. In a long-term program of their own they have had extensive experience in determining the exact phase relations of metal fluoride systems, and may be able to make a few tests soon for the existence of stable mixed fluorides in some of the heretofore uninvestigated systems of primary chemical-propulsion interest. In addition, the Oak Ridge National Laboratory has recently been able to produce BeO of relatively large particle size which may be available on a limited scale for NBS measurements. The NBS Engineering Ceramics Section is cooperating by investigating alternative methods of preparing the pure mixed oxide $BeO \cdot Al_2O_3$ from the two binary oxides, with x-ray examination as a criterion of complete compound formation. It appears feasible to use similar tests to look for compound formation in the Al_2O_3-ZrO_2 system.

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*T. B. Douglas and W. H. Payne, "New Apparatus for the Precise Measurement of Heat Content and Heat Capacity from 0° to 1500°C" (in National Bureau of Standards Handbook 77, "Precision Measurement and Calibration. Vol. II: Selected Papers on Heat and Mechanics," U. S. Government Printing Office, Washington, D. C., Feb. 1, 1961, pp. 241-276). (Most of this report was originally published as "Wright Air Development Center Technical Report 57-374, Part I.")

Plans for the Next Fifteen Months:

If present tests of apparatus performance progress as expected, the enthalpy of Al_4C_3 over the range 273°-1200°K will be measured within the next three months. The high-temperature measurements of enthalpy planned for the following year consist of $BeO \cdot Al_2O_3$ (273°-1800°K), Li_3AlF_6 (273°-1200°K), and BeO (1200°-1800°K). But in the unlikely event that tests described in the preceding section reveal stable compounds in the AlF_3-ZrF_4 and Al_2O_3-ZrO_2 systems, enthalpy measurements on them will be given high priority if samples can be obtained.

5. HYDRIDES AND INTERMETALLIC COMPOUNDS OF LIGHT ELEMENTS

The work on the light metal hydrides was continued. Improvements in synthetic and analytical techniques have provided a better insight into the nature of the structure of these materials. However, there are still some disturbing facts which indicate that the presently accepted structures are not perfect. Most of the samples of the light-metal hydrides were used by the group making heat-of-formation measurements. This work will be summarized completely in a separate report.

The studies of the aluminum hydride-trimethylamine adducts were reported suspended as of June 1960. However, one preparation was made of aluminum hydride-bis-trimethylamine, but the product was not considered pure enough for further vapor-equilibrium studies.

A survey has been made of the alloys and intermetallic compounds of aluminum, beryllium, lithium, and magnesium with each other and with silicon, titanium and zirconium. This survey contains primarily phase-composition relations, crystallographic data, density and volume data, and heats of formation. The material on the beryllium alloys was reported in the last semi-annual report (NBS Report 7093, January 1, 1961). The data on the other systems is included as a separate chapter in this report.

Due to activation of projects elsewhere, the preparation of binary light-metal hydrides will be deemphasized at the Bureau. Small amounts of these materials will be prepared as required by other groups in the Bureau or by the over-all ARPA program. Searches will be continued for better methods of preparing and analyzing the light hydrides, and liaison will be maintained with other laboratories with the aim of finding realistic structures for these materials. As an aid to the calculation of heats of formation of these materials, samples of the related organometallic compounds, free of polar adduct, will be prepared for heat-of-formation studies. Research will be performed on the preparation of mixed hydrides of the light elements.

Since a satisfactory heat of formation has not been obtained for aluminum hydride, it has been suggested that a study be made of the trimethylamine adducts of aluminum hydride using mass-spectrometric techniques. By this means, vapor and decomposition pressures may be obtained, along with decomposition potentials and mass data for the adduct. By using the heat of addition of the trimethylamine moiety to the aluminum hydride it should be possible to arrive at a heat of formation of aluminum hydride. It will be the responsibility of this group to prepare or procure, purify, and analyze the aluminum-hydride adduct, and to coordinate the program on this compound.

The survey of alloys and intermetallic compounds of the light elements will continue. The study of specific systems will be pursued. This phase of the program will include procurement and analysis of samples, and determination and calculation of properties. For the present, these studies will be limited to one system.

Purification work as required by other groups will be carried out on request.

6. LIGHT-ELEMENT EQUATION OF STATE

The over all objective of this project is to determine, by experimental measurements, the equation of state of selected elements (Be, Aℓ and Zr) and their compounds at temperatures between 2000 and 6000°K and pressures up to 100 atmospheres. The immediate objective is the systematic exploration of the exploding wire method as the means for producing a two-component (e.g. Aℓ vapor and oxygen), high temperature, high pressure system so that the thermodynamic properties of the system under quasi-equilibrium conditions may be measured. Thus far, this study of the feasibility of the exploding wire method has entailed the design, construction and instrumentation of an experimental apparatus. It has also required the exploration and development of techniques of high-speed observation and measurement, so as to permit a time-resolved study of the state of the exploding wire system. These tasks are in various stages of completion, and will be continued during the next year.

<u>Activity Summary - July 1, 1960 to June 30, 1961</u>

The basic design of the experimental setup and the experimental method are described in some detail in NBS Report 6484 (July 1, 1959). During the past year, because of difficulties with unreliable triggering, the experimental setup was modified in several ways. The two parallel spark gaps used earlier were replaced with a new, single gap which is housed in a sealed chamber. This chamber is charged with nitrogen or argon in order to reduce the problem of electrode erosion by oxidation.

The new electrodes are made of a copper alloy, tipped with a tungsten-copper material known as "elkonite". Tests showed that these electrodes withstood the high current (220,000 amps peak) discharges somewhat better than the smaller tungsten-tipped electrodes used earlier. The electronic triggering circuit was also modified. The trigger spark gap and the trigger condensers were removed, and a high-energy pulse from a thyratron-triggered, 15 kv pulse generator is now used directly for breaking down the spark gap. Test results show this new setup to be more reliable. The jitter is about 1 to 2 microseconds.

The main effort during the past year was concentrated on the development of techniques of high-speed measurement for determining the state of the exploding wire system under transient conditions. The techniques for measuring the current and the voltage in the discharge circuit received the major attention. A new coaxial shunt and a special low inductance voltage divider, designed and constructed for this experiment by Mr. John H. Park of the Electrical Instruments Section of this Bureau, were installed. In addition, a calorimetric method for calibrating the total electrical energy dissipated in the discharge was developed. Using this method, we were able to achieve agreement to within 1 to 2 percent between the measured electrical energy (obtained from the voltage and current measurements) and the measured calorimetric heating energy. This work is described in detail in Part B of this report. A full report is soon to be submitted for publication in the NBS Journal of Research.

Considerable effort was also devoted to the development of techniques suitable for high-speed photographic observation of the exploding wire. A Beckman and Whitley, Model 189 Framing Camera was installed, and has been used to make preliminary observations of the explosion phenomena. The problem of multiple exposure imposed by the camera's slow (1/25 sec) mechanical shutter has been overcome by the development of a high-speed shutter. This shutter is made up of two parts: a fast-opening part and a fast-closing part. The fast-closing action is obtained from the blackening of a window by exploding a series of parallel lead wires. This was first developed by H. E. Edgerton (Review of Scientific Instruments, Vol. 27, No. 3, March, 1956). The fast-opening part of the shutter was developed specifically for this experiment and represents an original contribution. It consists of a piece of aluminum foil (approximately 1 in. X 3 in.) placed directly in front of the framing camera's diamond-shaped stop so that no light may pass into the camera. The opening action is obtained when a capacitor, charged to high voltage, is suddenly discharged through the foil. During the discharge the magnetic forces set up by the passage of current compress the foil toward its center line, thus allowing light to pass into the camera. Experiments showed that the shutter is 75% open in 60-80 microseconds. At the present time, another shutter of this type is under development. In this case two slightly overlapping foils are used to prevent passage of light into the camera. The foils are arranged to form the two arms of a loop circuit. Here the increased magnetic forces inside the foil loop may be expected to give still faster opening action. The use of this combination fast-opening, fast-closing shutter with the framing camera will permit high-speed, time-resolved photographic observation of any portion of the exploding wire phenomenon.

For the pressure measurement, the transient pressure in the exploding wire vessel during the explosion was measured by means of a water-cooled, strain-gauge type pressure transducer. Although there was some difficulty with arcing from the exploding wire to the transducer, this technique may be considered fairly well developed.

For the density measurements, a simulated x-ray system was set up for working out the various problems associated with measuring the density of the exploded wire vapor by soft x-ray absorption. In this system, different thicknesses of Al foil are used to simulate the variable-density Al vapor. The time features of the experiment are simulated by passing the x-ray beam through a hole in a rotating wheel. The intensity of the transmitted beam is detected by means of a NaI crystal bonded to a photomultiplier, the output of which is displayed on an oscilloscope. This system has not progressed to a point where it can be applied to the exploding wire experiment. In addition to this soft x-ray work, a four-channel flash x-ray system was ordered. This unit will be used to study the density distribution of heavier vapors (such as zirconium and titanium) and the breakup process of the wire in the solid and liquid states.

Some work has also been done toward modifying a Jarrell-Ash spectrograph for the time-resolved determination of composition in the exploding wire system by spectrographic studies.

Another phase of our work, a theoretical study of the hydrodynamic aspect of the exploding wire system, was initiated during the past year. This study will concentrate primarily on the analysis of the flow field surrounding the exploding wire and the diffusion at the interface between the expanding wire vapor and the surrounding gas. Thus far this work has included a review of the open literature on related problems with cylindrical shocks.

Plans for Period July 1, 1961 to September 30, 1962

The work in this next period will be a continuation of all phases of the work described above. Special attention will be given to the remaining problems in the determination of the density and composition of the wire vapor as a function of space and time, by means of x-ray and spectrographic measurements. Concentrated effort will also be devoted to the problem of mixing of the metal vapor and the surrounding gas. It is hoped that the solution to these problems can be worked out in sufficient detail in the next 15 months, so that a full-scale effort may later be made in the determination of the data of state of the mixed system under conditions of high temperature and high pressure.

7. SHOCK WAVE DETERMINATION OF THERMODYNAMIC DATA

The objective of the NBS shock tube program is the determination of thermodynamic and rate data for atmospheric gases (air, O_2, N_2, NO) by the method of shock wave compression. In the next fiscal year part of the effort will be devoted to research on one of the simple N-F compounds such as N_2F_4 or NF_3. Most of the previous activity in this program has been concerned with the refinement of techniques for the measurement of data for the gas behind the shock wave. In preliminary experiments with Mach 1.6 to 2.0 shocks in air the density (interferometric) and shock velocity (with light screens) were determined with an accuracy of 1 percent; pressure measurements (with a pressure transducer) were accurate to 3 percent. Similar measurements along with spectroscopic composition determinations will be employed in an investigation of the rate of dissociation of N_2F_4 behind weak shock waves. Plans were made to set-up the spectroscopic equipment soon after July 1, 1961.

8. HIGH-TEMPERATURE MICROWAVE SPECTROSCOPY

Microwave spectroscopy offers considerable promise for obtaining detailed structural information on some of the simpler molecular species which exist in high-temperature systems. The microwave spectrum provides very accurate values of the moments of inertia of a molecule, as well as information on vibrational energy levels and other molecular properties. A microwave spectrometer which will operate up to 800°-1000°C has been under construction for this project. The spectrometer consists of a folded nickel waveguide suspended in an evacuated tank. The nickel Stark electrodes are supported by ceramic spacers. Resistance heating elements are mounted parallel to the waveguide. The various components have been assembled and tested at room temperature. The spectrometer showed satisfactory sensitivity and resolution in these room-temperature tests, which indicates that the waveguide design is probably suitable for high-temperature operation.

As soon as the final engineering details are taken care of, preliminary heating tests will be made. The spectrometer performance at high temperatures will be checked by observing the known spectra of suitable salts. The first new systems to be studied will probably involve the halides of aluminum and beryllium. The three most promising systems for the initial studies are: (1) the Al-$AlCl_3$ system, where it should be possible to detect the spectrum of $AlCl$, and possibly that of $AlCl_2$; (2) the Al-AlF_3 system, where similar studies could be made; (3) the $BeCl_2$-BeF_2 system, where there is a chance of detecting the spectrum of $BeFCl$.

9. HALIDE SOLID-VAPOR EQUILIBRIA (TRANSPIRATION METHOD)

Construction of a transpiration apparatus and associated controlling mechanisms has been completed. Preliminary measurements of the vapor pressure of Calorimetry-Conference Standard-Sample benzoic acid at 100°C have been started. These measurements will permit evaluation of the behavior of the flow apparatus independently of the furnace.

It is the purpose of this section to describe the new apparatus with special emphasis on those features by which it differs from previous transpiration equipment.

Furnace:

The Pt-20% Rh wire wound resistance furnace is one meter long with a 42-cm copper cylinder at the center designed to minimize temperature gradients. Preliminary experiments indicate that the gradients over this 42 cm region can be held to about 0.5°C by supplying heat to the ends of the furnace by other heaters associated with 5 cm-long-copper cylinders. The copper is contained in an inert gas to prevent corrosion and consequent reduction in thermal conductivity and melting point. An alternative nickel core has been made to permit furnace operation up to 1700°K. Furnace temperatures are measured by Pt/Pt-10% Rh thermocouples and controlled to ±0.15° by Leeds and Northrop three-mode controllers feeding to magnetic amplifiers.

Flow System:

The inert gas flow into the transpiration apparatus is monitored qualitatively by two National Instrument Laboratories Vol-O-Flo meters with ranges of 3 to 100 and 10 to 300 ml/min. These meters can be read to about 0.2% of the full scale deflection.

After passing through the vapor cell and condenser the inert gas is collected in an American Meter Company 60-liter "meter prover" which measures the total volume continuously at a pressure within 0.002% of atmospheric pressure. The "prover" volume can be measured with a precision of 0.03% or better for a normal experiment. The gas is collected over vacuum-pump oil, with precautions to minimize absorption of gas by the oil.

Vapor Cell Condenser:

The vapor cell and condenser are made of Pt-10% Rh. The essential features of the design are concentric construction (after Beusman*) and the use of pyrolytic graphite to prevent sticking of metal surfaces at high temperatures. The vapor cell is 20 cm long and 1.1 cm in diameter. The two sample boats are made of Pt-10% Rh.

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*C. Beusman, "Activities in the KCl-$FeCl_2$ and $LiCl$-$FeCl_2$ Systems", Oak Ridge National Laboratory, ORNL-2323 (1957).

The concentric design aids in bringing the flow gas to the furnace temperature. A 1-mm-I. D. capillary of 10 cm length separates the vapor cell from the condenser and minimizes vapor transport by diffusion and heat loss out the ends by radiation. The major features of the apparatus are illustrated in the accompanying figure.

Measurements on Benzoic Acid:

The few preliminary measurements which have been made on benzoic acid indicate the following advantageous features of the present design.

(1) The sample mass lost from the boats can be compared with the mass gained by the condenser. Preliminary experiments indicate that these two methods agree within the precision of weighing the condenser.

(2) The use of two boats of nearly identical dimensions permits extrapolation to low flow rates for measurements at flow rates too high for attainment of saturation. This may eliminate the need for complete saturation in an actual experiment if this is inconvenient to achieve.

(3) The vapor cell design will permit saturation of the flow gas at flow rates which are relatively high for a transpiration measurement. The present measurements indicate that 99% of saturation is achieved for benzoic acid at 100°C (vapor pressure about 1 mm) with an argon flow rate of 35 ml/min.

The values for the vapor pressure of benzoic acid determined by these measurements agree with those obtained by Davies and Jones* within the estimated precision of either experiment (about 1%). The tests on benzoic acid will be continued in order to evaluate other features of the apparatus such as reproducibility of measurements and starting and stopping errors. Certain improvements in the apparatus are already planned as a result of these preliminary tests.

Future Plans:

Following completion of the benzoic acid tests the system ($A\ell F_3$ + argon) will be studied between 1150° and 1400°K. It is believed that this study may help to clarify the problem of association in saturated aluminum fluoride vapor.

Modifications in the existing flow system will precede study of the ($A\ell F_3$ + HF) system. Preliminary order-of-magnitude experiments are planned. If these indicate appreciable reaction, quantitative measurements will be made. It is anticipated that empirical volatility data itself would have practical utility, but in addition it is hoped that such data would be interpretable in terms of heats and equilibrium constants of specific chemical reactions.

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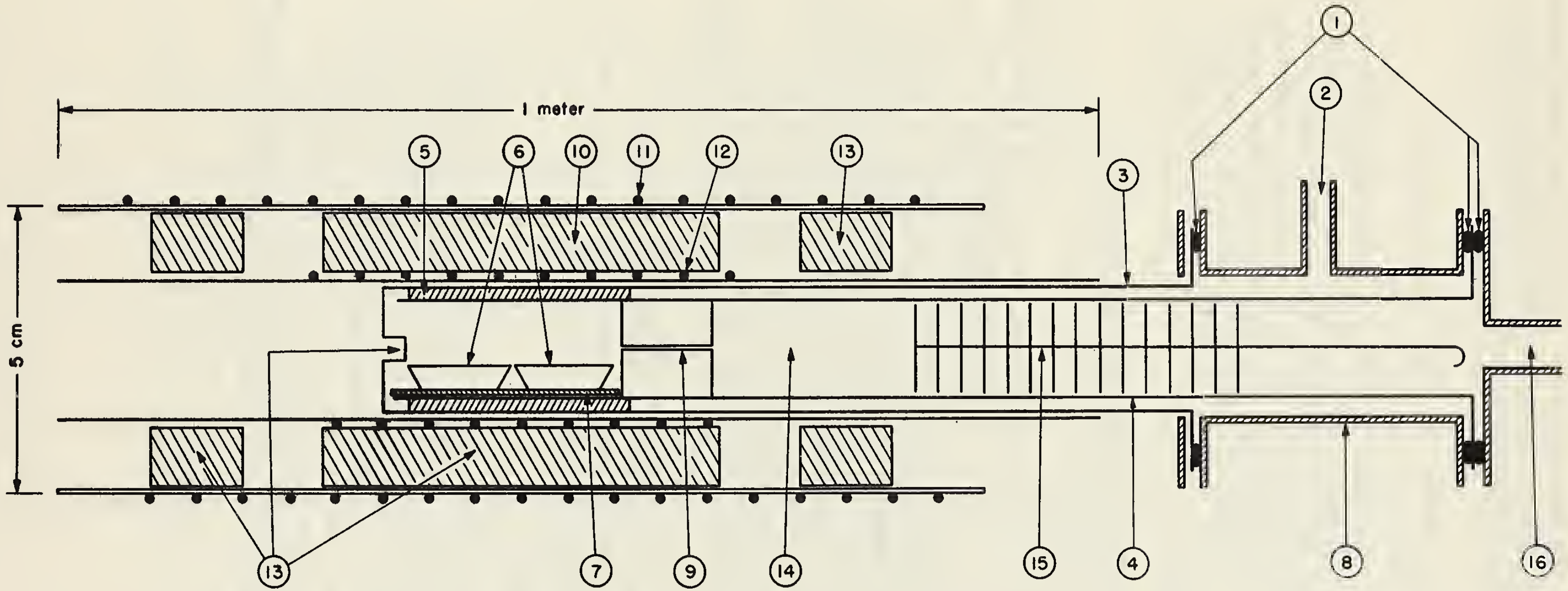
*M. Davies and J. Ifor Jones, Trans. Faraday Soc. 50, 1042 (1954).



1	O-rings	9	Capillary
2	Gas inlet	10	Ni or Cu cylinder
3	Pt-Rh outer casing	11	Main heaters
4	Pt-Rh inner casing	12	Auxiliary heater
5	Pyrolytic graphite cylinder	13	Thermocouple locations
6	Sample boats	14	Condenser
7	Pyrolytic graphite sled	15	Condenser baffle
8	Base metal connector	16	Gas outlet

SCHEMATIC DRAWING OF TRANSPIRATION APPARATUS (Note that horizontal and vertical scales differ.)

Since the existing vapor pressure data for ZrF_4 indicate considerable uncertainty as to pressure and vapor composition, it is planned to study the system (ZrF_4 + argon) between 925° and 1200°K.

10. VAPORIZATION OF REFRACTORY SUBSTANCES

The general philosophy of the experimental program to study the vaporization of refractory oxides and similar substances was discussed in the Fourth Technical Summary Report, NBS Report No. 6928, page 12 (July 1, 1960). The discussion centered around four measuring techniques which were under development at that time. Progress in the development of the techniques and changes of emphasis during the ensuing period are summarized below. Plans for continuing the activity during the forthcoming year are then presented.

Statement of Accomplishments July 1, 1960 - June 30, 1961:

1. Mass Spectrometric Technique.

Owing to the importance of this approach, much of the experimental work of the group has been subordinated to the task of expediting the construction, installation, and testing of this apparatus, and to training personnel. The direction-focussing mass spectrometer, custom built by Nuclide Analysis Associates, State College, Pa., has now been installed at NBS. During the year preliminary testing of the apparatus was carried out at State College, and one member of the group also spent a three-month training period with W. A. Chupka at the Argonne National Laboratory. The last few months since installation have been devoted to a final checking of the instrument, to the removal of minor "bugs" or inconveniences in its operation, and to calibration of the Knudsen-cell inlet system. A temperature controller for use with the Knudsen cell, primarily in the 1800-2500°C temperature range, has yet to be obtained. Data on the power requirements of the electron-bombardment heat source have also been obtained, and will be used as basis for designing the controller. The apparatus is now ready for definitive measurements to be made on selected systems, at least in the temperature range up to 1800°C.

2. Image Furnace Technique.

Initial effort was devoted to the adaption or modification of the commercial arc image furnace in order to make measurements of rate of vaporization within reasonably well defined limits of precision. Two modifications permitted the arc to be operated at 300 amps. without overheating the ellipsoidal mirror. The measurement of the temperature of the heated sample was a major problem, but the overall uncertainty of corrected values has been considerably reduced: Visual flicker when observing the surface with an optical pyrometer has been eliminated by speeding up the beam-chopping mechanism. The rotating shutter and sector disc which form integral parts of the mechanism were redesigned to give a more uniform chopping action. A technique was also developed for obtaining an approximate value of the emittance of the surface and will be useful in converting observed brightness temperatures to true temperatures.

Measurements of the rate of vaporization of aluminum oxide as a function of the pressure and composition of a surrounding gas phase have commenced. Assuming the heated surface is always the same, the precision of measured rates of vaporization in vacuo is about ±50%. Temperature fluctuations account for much of the uncertainty, but better measurement and control of the area of the heated surface can be readily effected and should lead to a significant improvement in the precision. In the meantime, exploration of the problems involved in introducing controlled partial pressures of other gases, such as H_2O, into the system is progressing, and preliminary data is being obtained.

Using the arc image furnace, a technique has also been developed for vacuum-sealing a piece of tungsten inside an aluminum oxide sample. The usefulness of this type of sample is under investigation, as discussed below.

3. Microbalance Technique.

By vacuum-sealing a piece of tungsten inside an aluminum oxide sample (as mentioned above) it has been found possible to obtain rates of vaporization of the sample by suspending it in vacuum from a microbalance and heating it by induction. This method is comparatively free of the errors which were encountered when the sample was enclosed with an external heater, but it is too early to define how far the approach will be limited by diffusion of tungsten through the alumina. Measurements up to about 1700°C have so far been made, but they will be extended to higher temperatures before a full analysis of the data is made.

4. Knudsen Effusion Technique.

Little progress with this technique has been made, owing to the transfer of personnel to the mass spectrometric technique. Measurements of absolute effusion rates of the equilibrium vapors is, however, not outmoded by the mass spectrometric approach, because the accuracy of the latter method is limited by approximate values of the ionization cross-sections of the molecules. Interest in the technique is being maintained, therefore, but an active program is severely restricted by man-power shortages. In particular, the long-standing search for rhenium Knudsen cells has continued. A suitable composition from which to produce the cell is believed to have been found, and fabrication work on a cell is in progress.

Program Plans July 1, 1961 - October 1, 1962

The following summarizes in order of priority the plans for the next 15 months. The plans reflect the current belief that major experimental problems will not restrict progress, except as indicated.

Mass Spectrometric Technique.

1. Identification of gaseous species and determination of their equilibrium partial pressures in the following systems:

(a) Be-F
(b) Be-O-F
(c) Be-O (in W and Re Knudsen cells).

2. Of high priority, but subject to technique development, comparable studies to those listed above on the Al_2O_3-H_2O and BeO-H_2O systems.

3. Similar studies to those given under 1.) on Al-O-F systems.

Arc Image Furnace Technique.

4. Measurements of rates of vaporization of Al_2O_3 under pseudo-equilibrium conditions in

(a) Various partial pressures of $H_2O(g)$
(b) Other gases (A, H_2, O_2, etc.).

Microbalance Technique.

5. Completion of measurements of rate of vaporization of Al_2O_3 in vacuum. It is not anticipated that this activity will continue beyond September 30, 1961.

Knudsen Cell Technique.

6. Absolute effusion measurements of BeO and Al_2O_3 from W and Re cells. Activity to be held in abeyance pending availability of adequate man-power.

PART B. THERMODYNAMIC PROPERTIES OF LIGHT ELEMENT COMPOUNDS

CHAPTER 1

PRELIMINARY REPORT ON THE CALORIMETRIC CALIBRATION OF THE ELECTRICAL ENERGY MEASUREMENT IN AN EXPLODING WIRE EXPERIMENT

by D. H. Tsai and J. H. Park

A discussion is present on the requirements and the methods for measuring the current and voltage during the transient discharge of a capacitor bank employed in an exploding wire experiment (see Part A, Section 6 of this report). A method is described for accurately calibrating the measured current, voltage and electrical energy by comparing the calorimetric heating of a fixed resistance element with the electrical energy dissipated in the element. Preliminary results here show that the accuracy of the energy measurement is about 1-2%. Work is in progress to study the refinement of measurement techniques and sources of error.

1. Introduction

The present investigation has been carried out in connection with an exploding wire experiment, which involves the vaporization and explosion of a thin metallic wire by means of a sudden discharge of electrical energy through the wire. In order to understand and explain the temperature and energy relations in the exploding wire system, the propagation of the shock wave, and other related problems, it is important to be able to measure accurately the energy dissipated during the transient discharge. Such energy measurements are also needed in other applications of capacitor discharge experiments such as: (1) magnetic confinement in plasma experiments, (2) high-speed impact studies, (3) heat capacity measurement using a pulsed technique, (4) high voltage or high current impulse testing, and others.

This report described some results of an investigation of a calorimetric method for calibrating the electrical measurement of total energy dissipated in a fixed resistance element under the transient conditions of a capacitor-bank discharge. This method employed the fixed resistance element as a calorimeter, and compared the total heat energy measured by the calorimeter with the electrical energy obtained from the measured current through the element and the measured voltage drop across the element. Since the current and the voltage drop were measured independently of each other, the calibration also provided a separate check on these measurements. The check on the current measurement was especially interesting, because some confirmatory data were obtained on the performance of a coaxial shunt [1][1] that was used in this investigation.

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[1] Figures in brackets indicate the literature references at the end of this paper.

Since the publication of reference [1], there have been some doubts expressed about the high-frequency performance of a shunt of this design. Although the present experiment was quite limited in frequency range, the method employed here was perfectly general, and obviously could be applied in a higher frequency range.

The present results are of a preliminary nature. Only one sample test will be described to indicate the accuracy of the measurement. Further refinement of the experimental technique is being developed, and a study of the measurement accuracy under different test conditions is in progress. The final results will be given in a full report, and will be submitted for publication in the open literature.

2. Calorimetric Calibration

The basic principle of the calorimetric calibration is straightforward. The energy involved in the calorimetric heating of the resistance element is

$$M\ C_p\ \Delta T,$$

where M is the mass of the element, C_p its specific heat at constant pressure, and ΔT the temperature rise due to heating. The ohmic heating of the element is

$$\int R\ i^2\ dt,$$

where R is the resistance of the element, i the instantaneous current, and t the time of heating, the integration being performed over the entire period of heating, usually from $t=0$ to $t=\infty$ in a discharge experiment. The instantaneous electrical energy involved is

$$e\ i\ dt,$$

where e is the voltage drop across the element. For an oscillatory discharge the area under the curve of ei vs. t goes alternately positive and negative as the energy is stored alternately in the magnetic and electric field. The total energy dissipated in the resistance element is

$$\int_0^\infty e\ i\ dt,$$

i.e., the net algebraic sum of the total area under the ei curve.

It there were no energy loss by heat conduction, convection or radiation, then

$$M\ C_p\ \Delta T = \int_0^\infty R\ i^2\ dt = \int_0^\infty e\ i\ dt.$$

This equation is the basis for the calorimetric calibration investigated. The problems involved are two-fold. First is the achievement of the experimental conditions under which this equation holds true, and second is the accurate measurement of the various parameters. These are discussed below.

Requirements for Calorimeter. The exploding wire apparatus used in this investigation is shown in Fig. 1. This apparatus is similar to the one described in reference [2], except for minor modifications. For the present purpose, the fixed-resistance element (calorimeter) is installed in place of the exploding wire vessel. This arrangement preserves the symmetry of the current path, and allows the study of the problems of voltage measurement under conditions closely similar to those encountered in an actual exploding wire experiment. In addition to the geometrical requirements, the requirements of good calorimetry are: (1) Uniform heating along the entire length of the resistance element so that a representative temperature change may be obtained. (2) Small or known heat loss from the calorimeter. (3) Accurately known mass, heat capacity, and electrical resistance of the resistance element. (4) Accurate temperature measurement.

To satisfy requirements (1) and (2), the resistance element should be of a uniform cross-section, with known current paths along the entire length of the element, including the ends. To minimize the skin effect, (in order to achieve uniform current density over the cross-sectional area) the element should be cylindrical, with a wall thickness small compared to the diameter. To minimize the heat loss by conduction, the length of the element should be long compared to the diameter and the wall thickness, and the temperature should be measured near the mid-point of the length. to minimize the heat loss by radiation and convection, the surface of the resistance element should be smooth and polished. In addition to the above physical characteristics, the mass and the resistance of the element and the energy input to the element should be so chosen that the temperature rise of the element is not too high. A high temperature rise not only would increase the heat loss, but also would, in general, affect the specific heat and resistance (requirement 3) of the element, and thus make it very difficult to determine both the heat energy in the calorimeter and the ohmic heating. On the other hand, too small a temperature rise would result in greater percentage error in the temperature measurement (requirement 4) and adversely affect the accuracy of the calorimetric heat energy measurement. Also, for maximum accuracy, the damping of the discharge circuit as a whole should not be too low, for then the discharge would be more oscillaroty, and it would be correspondingly more difficult to obtain an accurate measurement of the net area under the ei vs. t curve.

The above are some of the more important general requirements in the design of the resistance calorimeter. In the present preliminary experiment, these requirements were only partially satisfied. However, in the experiments being planned, an effort is being made to satisfy these requirements more fully.

One additional point is worth noting. In this investigation, the temperature of the resistance element was measured by means of a pair of thermocouple wires welded individually to the element at two

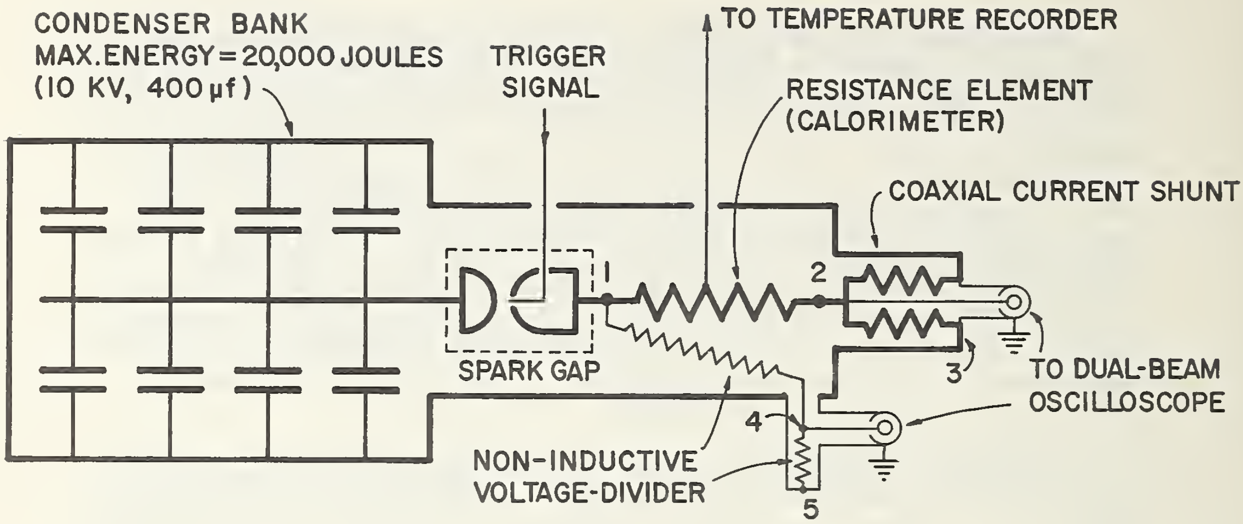

FIGURE 1 SCHEMATIC DIAGRAM OF EXPERIMENTAL APPARATUS

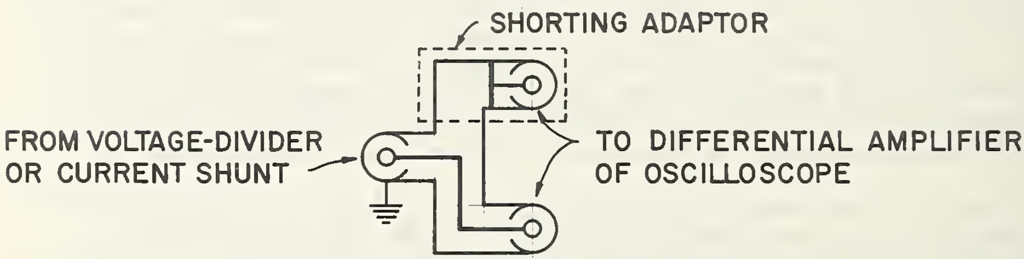

FIGURE 2 BALANCED CABLE CONNECTIONS FOR REDUCING GROUND CURRENT EFFECT

neighboring points at the mid-section of the element. During an oscillatory discharge, the potential at the thermocouple functions could be as high as several thousand volts above or below ground potential. It was therefore necessary to disconnect the thermocouple circuit from the main discharge circuit during the discharge, and to re-connect the thermocouple circuit for temperature measurement after the discharge was over. The measured temperature therefore was not the instantaneous temperature. The maximum temperature rise was obtained by extrapolating the recorded temperature during the cooling period to the time just after the discharge took place. Fortunately, under the experimental conditions encountered, the error introduced by this method was small.

Requirements for current and voltage measurements. The requirements for the accurate measurement of current and of voltage have been studied in detail by Park in references [1] and [3]. For the present purpose, it was convenient to borrow directly from the earlier results, and make use of the coaxial shunt described in [1] for current measurement, and the non-inductive resistance divider described in [3] for voltage measurement.

As in references [1] and [3], the main difficulty in measurement arises from the high current flowing in the main discharge circuit and the high rate of change of this current with time. A part of this current flows through the ground system of the measuring circuits as well, and induces extraneous voltage signals which may be several times higher than the true voltage signals.

The effect of the ground current on a measuring circuit may be tested by disconnecting the center conductor of the coaxial cable at the input end[2] and shorting it to the cable sheath. Then any signal in the measuring circuit produced by the discharge of the main circuit would be an extraneous signal.

It was found that the ground-current effect could be largely eliminated by measuring only the difference between the total voltage and the voltage induced by the ground current. This was done by using two identical cables in the measuring circuit connected to the same point at the input end by means of a "T" connector, except that one cable was connected in the "normal" manner for measuring the total voltage, and the other was connected in the "shorted" manner described above for measuring the induced voltage (see Fig. 2). The signals from these two cables were fed into a differential amplifier (of a cathode ray oscilloscope) which then measured only the difference between the two signals.

The foregoing method of using this "balanced" arrangement of the measuring cables did not completely eliminate the extraneous signals.

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[2]This is the end where the cable is normally connected to the shunt or the voltage divider.

This was probably due to some slight mismatch of the cables, and to the lack of symmetry of the current paths, especially at the input end of the cables. A further source of difficulty was the inter-connected ground system. In the present case a dual-beam oscilloscope was used for simultaneous measurement of the current and the voltage. The current and voltage measuring cables were therefore grounded to a common point at the oscilloscope end. However, at the input end, these cables were grounded to different points of the main discharge circuit, because the construction of the current shunt and of the voltage divider did not permit a common connection. Thus the ground potential at the oscilloscope must fluctuate during a discharge of the main circuit. This would cause ground currents to flow in the chassis of the oscilloscope which could induce extraneous voltages in the amplifier input circuits. In addition to the above mentioned difficulties, the pairs of cables in the two measuring circuits formed two loops which were inductively coupled to the main discharge circuit. The voltages induced in these loops were able to cause currents producing iR drops in the cables which were not self-cancelling in the present balanced arrangement for measuring the differential voltages.

No quantitative data has been obtained on the errors arising from each of these sources (cable mismatch, lack of symmetry of current paths, etc.). However, the total error could be measured rather easily by shorting all the cables at the input ends, and by repeating the discharge under identical conditions.

3. Experimental Apparatus and Instrumentation

The major components of the experimental apparatus are shown schematically in Figure 1. The capacitance of the condenser bank was 400 μf, and at the maximum voltage of 10 kv, the stored energy was 20,000 joules. When installed as in Fig. 1, the natural frequency of the discharge circuit was 11.4 kc.

The spark gap and the triggering system were similar to those described in reference [4]. The electrodes were tipped with a tungsten-copper alloy (Elkonite). The spark gap was assembled in a transparent enclosure, which could be charged with nitrogen or argon at different pressures for better control of the timing of the discharge. The nitrogen or argon atmosphere presumably also cut down the erosion of the electrodes due to oxidation.

The resistance element was made of a Ni-Cr-Fe alloy (inconel) tubing 10 in. long, 1.051 in. o.d., 0.912 in. i.d. The ends of this piece of tubing were silver-soldered to clamps for connection to the main circuit at points 1 and 2 (Fig. 1). The soldered joints were lap joints, each 1/4 in. wide. The effective length of the tubing was taken as the length between the mid-sections of the two lap joints, or 9.75 in. long. The mass of the tubing based on this length was 288.9 grams. The specific heat at constant pressure (C_p) for the inconel was taken from reference [5] as 0.1074 cal/gram-deg C (average of three inconel samples) at 40 deg C average temperature. (This was based on a temperature rise of about 30 deg C from a room temperature of 25 deg C.)

The temperature of the inconel tubing was measured by means of an iron-constantan thermocouple, with No. 28 wires, welded directly to the inconel tubing at two neighboring points, 1/4 in. apart, at the mid-section of the tubing. The temperature recorder was a Leeds and Northrup millivolt recorder, with a full-scale response time of about 1/2 second. The thermocouple circuit was conventional, except for the switching device mentioned earlier for isolating the recorder from the high potential at the resistance element during a discharge.

The resistances of the various parts of the circuit (between points 1 to 5) were determined by the Electricity Division at the NBS by means of a Kelvin double bridge. These resistances were as follows:

Between Points	Component	Resistance, ohms
1-2	Resistance element (calorimeter)	0.001803
2-3	Coaxial shunt	0.000325
1-2-3-5		0.002180
1-4	High-side of voltage divider	202.60
4-5	Low-side of voltage divider	1.1054

The high-side of the voltage divider, made up of a ribbon-wound non-inductive resistor [3], was mounted at an angle relative to the common axis of the inconel tubing and of the outer cylinder (see Fig. 1) which served as the current return passage. This was done in order to reduce the capacitance between this resistor and the rest of the circuit near-by. Except for this part, the main discharge circuit around the inconel element preserved a cylindrical symmetry. The low-side of the voltage divider was made up of low-inductive carbon resistors, arranged symmetrically in a small cylindrical housing in order to keep the inductive effect to a minimum. The voltage measured was the voltage drop between points 1 and 5. If this is denoted by e_{1-5}, then the electrical energy associated with this part of the circuit would be

$$\int_0^\infty e_{1-5} i \, dt.$$

The electrical energy associated with the inconel element would then be

$$\frac{R_{1-2}}{R_{1-2-3-5}} \int_0^\infty e_{1-5} \, i \, dt,$$

where R is the resistance of the part of the circuit denoted by the subscripts.

For the measuring circuit, the cables used were four RG58/U coaxial cables, each 11 ft. in length. These cables were not terminated with matched impedance because of the relatively low frequency (11.4 kc) involved. The oscilloscope was a Tektronix Model 555 Dual-beam oscilloscope, equipped with two type G differential pre-amplifiers. The vertical scales (voltage scales) were calibrated against the calibration signals provided in the oscilloscope, and the horizontal scale (time scale) was calibrated against the NBS Standard 100 kc frequency.

4. Results

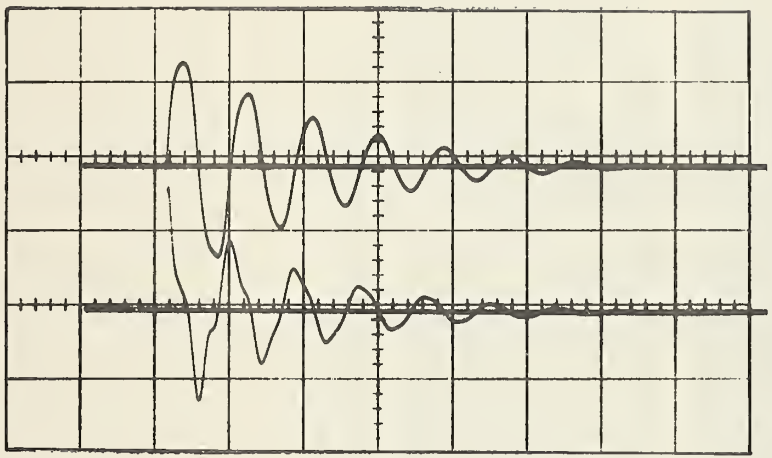
Fig. 3 shows a representative series of measurements obtained on the experimental set-up described in the preceding section. The conditions of the test are given in the figure caption. Fig. 3a was obtained with the balanced arrangement of the measuring cables described earlier. The top trace of Fig. 3a shows the measured current through the circuit, the bottom trace shows the measured voltage drop between points 1 and 5 of Fig. 1. Fig. 3b was obtained with the measuring cables shorted to ground at the input end. The top trace shows the ground current effect in the current measuring circuit, the bottom trace shows the same effect in the voltage measuring circuit. (Note the difference in the vertical scales in these figures.)

From these data, the ohmic heating and the electrical energy were obtained by evaluating the integrals $\int Ri^2dt$ and $\int eidt$. This was done both graphically with the aid of a planimeter, and numerically with the aid of an automatic digital computer (at a step size of 3 μsec in dt). In both cases, the $\int eidt$ integral was evaluated twice: once without the correction for the ground-current effect on the voltage curve, and once with the correction. No correction was made on the current curve, because the ground current effect on the current-measuring circuit appeared to be negligible.

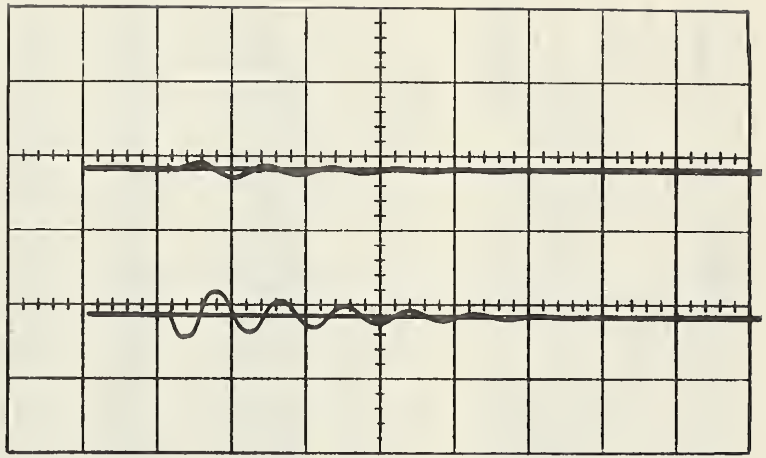
The results are tabulated below. The percentage figures show the percent difference compared with the measured calorimetric heating. The calorimetric heating did not include the heat losses by convection, radiation and conduction. With a temperature rise of about 30 deg C, the convective heat loss was about 4 joules/sec. The radiative and conductive heat losses were both negligible.

	Calorimetric Heating, joules	$\int R\ i^2\ dt$, joules	$\int e\ i\ dt$, joules: Without Correction for Ground Current Effect	$\int e\ i\ dt$, joules: With Correction for Ground Current Effect
Graphical Method	4076	4082 +0.1%	4775 +17.1%	4152 +1.9%
Numerical Method		4171 +2.3%	4615 +13.2%	4019 -1.4%

These results show the importance of the correction for the ground-current effect on the measured voltage. This was somewhat surprising, because Fig. 3b shows that this effect amounted to only about 2% (in maximum amplitude) of the measured voltage shown in Fig. 3a. The differences between the graphical method and the numerical method are not conclusive. Further work is needed to investigate the accuracy of both methods.



(a)



(b)

Figure 3 Typical current and voltage records showing (a) the measured current through the calorimeter and the voltage across it, and (b) the effect of ground current on the current and voltage measuring circuits.

Capacitor bank: 380 µf charged to 7 kv;
Calorimeter: see text for details, temperature rise = 31.4 deg C;
Horizontal scale (time): 100 µsec/large division (cm) for both (a) and (b);
Vertical scale (voltage): (a) top curve 40 v/cm for current shunt, bottom curve 10 v/cm for voltage divider; (b) top curve 1 v/cm for current measuring circuit, bottom curve 1 v/cm for voltage measuring circuit;
Cable connection: balanced connections as described in text.

5. Conclusions

The results so far have indicated that the equipment and the methods described here for meauring the current and voltage during the transient discharge of a capacitor bank are capable of yielding results which are in fair agreement with the result obtained independently from a calorimetric method. These results therefore suggest that it will be worthwhile to refine the experimental technique by a more careful calibration procedure, and a more detailed investigation of the sources of error and the experimental range in which the technique is applicable. These investigations are now in progress, and appropriate reports will be issued as the results become available.

REFERENCES

[1] J. H. Park, NBS J. Research, 39, 191 (1947).

[2] Preliminary report on the thermodynamic properties of lithium, beryllium, magnesium, aluminum and their compounds with hydrogen, oxygen, nitrogen, fluorine, and chlorine, NBS report 6484, chap 4, (1959).

[3] J. H. Park and H. N. Cones, Sphere-gap volt-time curves--reference standards for steep front measurements, AIEE paper no. CP 57-215, 1957.

[4] E. H. Cullington, W. G. Chace and R. L. Morgan, Lovotron--a low voltage triggered gap switch, Instrumentation for geophysical research no. 5, AFCRC-TR-55-227, Sept. 1955.

[5] T. B. Douglas and A. C. Victor, NBS J. Research, 65C, 65 (1961).

CHAPTER 2

EXPLANATORY NOTES FOR TABLES OF IDEAL-GAS THERMODYNAMIC FUNCTIONS OF N_2F_4 AND NF_2

by D. R. Lide, Jr.

Tables of ideal-gas thermodynamic functions are given in Appendix A for N_2F_4 (Table A-71) and for NF_2 (Table A-70). The basis of arriving at each of the molecular constants underlying these two tables is as follows.

Since the microwave spectrum[1] of N_2F_4 shows that the gaushe form (C_2 symmetry, with internal rotation angle of approximately 65°) is a major constituent at ordinary temperatures, and since the infrared spectrum[2] indicates that there is only one form present in significant amounts, we have assumed for purposes of calculation that N_2F_4 exists entirely as the gaushe isomer. The principal moments of inertia (15.0517, 26.2484 and 29.8378 x 10^{-39} gm cm^2) are experimental values determined from the microwave spectrum[1]. The estimated vibrational frequencies are based on infrared measurements of M. K. Wilson[2], which have been confirmed by L. J. Schoen of NBS. While a detailed assignment has not been made, it is reasonable to associate bands at 1011, 962, 933, and 850 cm^{-1} with the NF stretching modes. Infrared bands at 736, 589, 537, 517, 500 (estimated), and 390 cm^{-1} apparently correspond to the NF_2 deformations and to the twisting and wagging modes. In view of the low N-N bond energy[3], the band at 285 cm^{-1} is a reasonable choice for the N-N stretch. The remaining fundamental is the torsion about the N-N bond, which has been estimated as about 100 cm^{-1} from the microwave spectrum[1]. The major uncertainty in the ideal-gas thermal functions results from this frequency; for example, the calculated entropy at 300°K would be off by about 1 eu if the estimated torsional frequency is in error by 50 cm^{-1}, which is entirely possible.

The NF_2 molecule is a bent triatomic with vertex angle of 104° according to the infrared results of Schoen, Lide, and Mann[4]. The stretching frequencies of 1075 and 940 cm^{-1} have been observed, while the bending mode was estimated as 510 cm^{-1} from a force-constant treatment[4]. The moments of inertia (1.2037, 7.3748, and 8.5702 x 10^{-39} gm cm^2) were calculated from the single rotational constant obtained from a resolved infrared band[4] on the assumption that the N-F bond distance is 1.370 A. Since the molecule contains an odd number of electrons, an electronic multiplicity of 2 has been assumed.

The entropy change for the dissociation

$$N_2F_4 \rightarrow 2\ NF_2$$

is calculated from Tables A-70 and A-71 to be 45.6 eu at 400°K. From measurements of the dissociation constant of N_2F_4 in the 350°-450°K region Colburn and Johnson[3] have obtained ΔS values ranging from 38 to 45 eu.

REFERENCES

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

2. M. K. Wilson, private communication.

3. C. B. Colburn and F. A. Johnson, J. Chem. Phys. 33, 1869 (1960) and private communication.

4. L. J. Schoen, D. R. Lide, Jr., and D. E. Mann, NBS Report 7129 (April 1961).

CHAPTER 3

ALLOYS AND INTERSTITIAL COMPOUNDS OF ALUMINUM, LITHIUM, AND MAGNESIUM WITH EACH OTHER AND WITH SILICON, TITANIUM, AND ZIRCONIUM

by Thomas W. Mears

The alloys and interstitial compounds of beryllium with aluminum, lithium, magnesium, silicon, titanium, and zirconium were surveyed in the last semi-annual report (NBS Report 7093, 1 January 1961). In the present survey, the alloys and interstitial compounds of aluminum, lithium, and magnesium with each other and with silicon, titanium, and zirconium are covered. The phase diagrams of most of these systems were reproduced from Hansen [1] in the last semi-annual report and will be alluded to throughout this survey.[a]

When alloy and intermetallic compounds are formed, it is often the case that the material formed will be more dense than that calculated from partial atomic volumes. Unfortunately, it is also true that energy is lost as heat of mixing (formation) of the alloy or interstitial compound. Further, it is generally true that the greater the density of the alloy as compared to the elements, the greater the heat of mixing. This heat of mixing may be partially, completely, or even excessively offset by the heats of mixing of the mixed combustion products. However, if the heats of mixing do not cancel out, there would be no advantage in using an alloy or interstitial compound over the mixture of elements, unless a possible improvement in the kinetics of combustion is to be had.

Aluminum-lithium system

A partially complete phase diagram for the aluminum-lithium system is given in Hansen [1]. This diagram is reproduced as figure 3, p. 189 of the last semi-annual report. This diagram shows two intermediate phases LiAl and Li_2Al. The lattice spacings of aluminum solid solutions in lithium are [2]:

At.% of Li	a (kXat 25°C)
0	4.0413_4
3.44	4.0396_7
4.83	4.0392_7
7.11	4.0382

a. These diagrams were reproduced by permission from <u>Constitution of Binary Alloys</u>, second edition, by Max Hansen. Copyright 1958 by McGraw-Hill Book Co., Inc.

The average coefficient of expansion of an alloy containing 4.83 at. percent lithium is [3].

$\alpha = 24.3 \times 10^{-6}$ (-50°C to 25°C)

Lattice spacings: 4.0319_6 at -50°C
4.0393 at 25°C

AlLi melts at a maximum in the liquidus at approximately 718°C and exists over a range of composition [4]. It exists as a face-centered cube of B32 type structure, a = 6.360KX, and the x-ray density is 1.75g/cm^3 [5]. Its heat of formation[a] is -6.0 Kcal/g. atom (-12Kcal/mole) [6].

$AlLi_2$ forms peritectically at 523°C [5].

Aluminum-magnesium system

The phase diagram for the aluminum-magnesium system has been worked out by Eickhoff and Vosskuhler [7] and augmented by Clark and Rhines [8]. This is attached as figure 1. A similar phase diagram from Hansen [1] is given as figure 4, p.190 of the last semi-annual report. The β-phase, Al_3Mg_2 melts at a maxima from the liquidus at 451.5°C. The γ-phase, $Al_{12}Mg_{17}$ melts at a maxima at 462°C. The ϵ-phase, Al_4Mg_3 (?), exists between a eutectoid at 210°C and a peritectoid at 390°C.

The lattice spacings of solid solutions of magnesium in aluminum have been measured by many workers [2,3,9,10,11,12,13,14,15]. A composite graph of these values is attached as figure 2. The thermal expansion of solutions of approximately the same composition have also been measured [3], and are listed in the following table.

At.%Mg	a (KX) -50°C	+25°C	+200°C	$\alpha^{25}_{-50} \times 10^6$	$\alpha^{200}_{25} \times 10^6$
0	4.0347	4.0414_2			
2.36	4.0427_5	4.0496		22.7	
6.36	4.0614	4.0685	4.0858	23.2	24.7
10.56	4.0782	4.0861	4.1037_5	25.9	26.7

The β-phase, Al_3Mg_2, has a face-centered cubic unit cell, with a=28.16 ± 2KX, Dm = 2.23g/cm^3, Dx= 2.28g/cm^3 for an alloy containing 35 atomic percent magnesium [16, 17]. The heat of formation[a] is -0.37 Kcal/mole [8].

The γ-phase, $Al_{12}Mg_{17}$, occurs in the region 50 to 60 atomic percent (theory 58.6 at. percent) magnesium. It is a body-centered cubic in which a=10.54 ± 2KX, and the macroscopic density is 2.068g/cm^3 at 21°C [18]. The lattice spacings and densities have been determined for this region [19,20] and are shown graphically in figure 3.

The ϵ-phase at approximately 43 atomic percent aluminum has not been characterized. The empirical formula corresponds to about Mg_4Al_3.

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[a] Δ Hf

The lattice spacings of solid solutions of aluminum in magnesium are shown in figure 4 [21,22,23].

The heats of formation of the aluminum-magnesium system have been determined by Kubaschewski and Catterall [6] as follows:

At.%Mg	ΔH_3 (kcal/mole)
10	-.140
40	-.390
50	-.620

Aluminum-silicon system

Not much work has been done on the aluminum-silicon system because of the mutual insolubility in the solid state. There is little evidence of compound formation. The phase diagram is given by Hansen [1]. This diagram was reproduced as figure 5 on p. 191 in the last semi-annual report. This shows a eutectic at 11.3 atom percent silicon at 577°C. There is some slight evidence of terminal solubility. Lattice spacings for silicon concentrations up to 1 percent are reported by Axon and Hume-Rothery [2].

Aluminum-titanium system

The phase diagram from Hansen [1] for the aluminum-titanium system was reproduced in the previous semi-annual report. The α-solid solution transforms into the β-solid solution at temperatures ranging from 882°C for pure titanium to 1240°C for solution containing 42 atom percent (29 weight percent) aluminum. The γ-form, AlTi, forms peritectically at 1460°C. Al_3Ti forms peritectically at 1340°C and has invariant composition [24].

The solid solubility of titanium in aluminum is very small. Supersaturated solutions were obtained by rapid quenching and the lattices determined [25].

At.%Ti	a (kX)
0	4.0415
0.085	4.04054
0.090	4.0405
0.20	4.0395

The solid solution of aluminum in titanium is much broader than the aluminum solutions. Several workers [24,26,27] have prepared these alloys and determined their crystal lattices. These data are combined in figure 5. The humps at 10-14 atomic percent aluminum may be due to oxide or nitride impurities [28].

Al_3Ti is a body-centered, tetragonal DO_{22} type of structure, where a =3.84kX, c =8.579KX, c/a =2.234, Dm =3.31g/cm^3, and Dx-ray =3.37g/cm^3 [29,30].

The alloy may be prepared by heating aluminum with potassium fluotitanate at 1200°C, cooling slowly, and dissolving away the excess aluminum. Calculations have also been made [31] where Al_3Ti is considered as a face-centered tetragonal cell in which case a =5.424Kx, c =8.574Kx, and c/a =1.58. The heat of formation[a] is given as -35.3 $\pm$ 1.2 kcal/mole (-8.8Kcal per atom) [32].

AlTi has an ordered cubic Ll_0 structure where a =3.997 KX, c =4.062KX, c/a =1.02 at the stoichimetric 50 percent point [33). The alloy is prepared by arc melting "iodine" titanium with aluminum. The heat of formation[a] of AlTi is given as -19.3 $\pm$ 0.05 Kcal/mole (-9.7 Kcal/g atom) [32].

Aluminum-zirconium system

The aluminum-zirconium system is quite complex as shown by the phase diagram from Hansen [1] which was reproduced as figure 7 on p. 193 of the last semi-annual report. There are three phases which melt at maxima in the liquidus, namely Al_3Zr at 1580°C, Al_2Zr at 1645°C, and Al_3Zr_4 at 1530°C. Possibly six others form peritectically; Al_3Zr_2(?) at 1595°C, Al_2Zr_3 at 1480°C, Al_3Zr_5 at 1395°C, $AlZr_2$ at 1250°C $AlZr_3$ at 975°C and AlZr at 1250°C [34].

Al_2Zr_3 is a tetragonal unit cell, a= 7.630 $\pm$ 0.001A°, c=6.998 $\pm$0.001A°, c/a =0.9054, Dx =5.34 g/cm^3 on the basis of $4Zr_3A_2$ units per unit cell, and Dm =5.35g/cm^3. The sample was prepared by arc melting under argon and annealing for two weeks at 1100°C [35].

Al_3Zr_5 is an hexagonal structure with an x-ray density of 5.43g/cm^3 [36].

Al Zr_3 has an ordered cubic structure with a=4.372A° and Dx =5.976 $\pm$ 0.013g/cm^3 [37].

Al_3Zr is a body-centered tetragonal (DO_{23}) type of structure, where A°=4.005KX, c =17.285KX, c/a =4.316, Dx =4.11g/cm^3, and D°m =4.11 g/cm^3 [30,35,21]

Al_2Zr has an orthorhombic unit cell, where a = 10.40KX, b =7.21 KX, and c =4.97 KX for an alloy containing 37.6 weight percent aluminum [34]. The heat of formation is given as -30.0 Kcal/mole (-10.0 Kcal/g atom) [6].

$AlZr_2$ was prepared by arc melting and annealing for three weeks at 900°C. It has been indexed as an hexagonal unit cell where a =4.8939 $\pm$ 0.005A, c=5.9283 $\pm$ 0.0005A, c/a =1.211 $\pm$ 0.001 and Dx =5.67g/cm^3. A macroscopic density of 5.78g/cm^3 was obtained, but the sample was contaminated with Zr_3Al whose density is 5.98g/cm^3. [39].

Al_3Zr_4 was also prepared by arc melting under argon. It is indexed as an hexagonal unit cell, where a=5.433 $\pm$ 0.002A and

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[a] Δ Hf

$c=5.390 \pm 0.002A$. On the basis of one Al_3Zr_4 unit per unit cell, $Dx = 5.37 g/cm^3$. The macroscopic density was measured at $5.28 g/cm^3$ [35].

Lithium-magnesium system

The diagram for the lithium-magnesium system given by Hansen [1] was reproduced as figure 12 on p. 198 in the last report. This curve shows a eutectic at 77 atom percent (92 weight percent) magnesium at 588°C. The lithium solid solution extends to 75.5 atomic percent (91 weight percent) magnesium at 588°C and 70.1 atomic percent (89 weight percent magnesium at 100°C. The magnesium solid solution extends to 83.0 atomic percent (94.5 weight percent) magnesium at 588°C and 82 atomic percent (94.3 weight percent) at 300°C. Apparently no intermetallic compounds are formed.

Magnesium-silicon system

The magnesium-silicon phase diagram given by Hansen [1] was reproduced as figure 13 on p. 199 of the last semi-annual report. This shows the existence of a compound Mg_2Si which melts at a maximum at 1102°C. Eutectics occur at 53 atom percent (50.5 weight percent) silicon at approximately 950°C and at 1.16 atom percent (1.34 weight percent) silicon at 637.6°C. There is very little terminal solubility.

The lattice spacing of a two-phase alloy quenched from just below the melting point gave the lattices: a =3.2026, c =5.1998 KX and c/a =1.6236 at 25°C as compared with powdered magnesium metal with lattices a =3.2023, c = 5.1994kx, and c/a =1.6234 [21].

Mg_2Si is a face-centered cubic (C1) type structure with a $=6.338 \pm .002$ KX [40]. The density calculates to $1.95 g/cm^3$. The heat of formation[a] is -19.0 ± 1.0 Kcal/mole (-6.16 Kcal/g atom) [41].

Magnesium-titanium and magnesium-zirconium systems

The systems for both magnesium-titanium and magnesium-zirconium have only been studied slightly. The very limited curves given by Hansen [1] are reproduced as figures 14 and 15 on ps. 200 and 201 of the last semi-annual report.

The lattice spacings of a two-phase alloy containing 1 weight percent titanium and annealed just below the solidus show lattices of a =3.2025, c =5.2017KX and c/a = 1.6242 at 25°C as compared to pure magnesium with a=3.2023, c =5.1994kX, and c/a = 1.6236 at 25°C [21]. Titanium apparently does not dissolve in magnesium [42], but both α- and β-titanium dissolve magnesium to the extent of not more than 1.5 weight percent [43].

No intermediate phases have been found for the magnesium-zirconium system [44]. The lattice spacings for a two-phase alloy containing 1 weight percent zirconium quenched just below the solidus are a =3.1989, c =5.1964KX and c/a = 1.6244 as compared to a =3.2033, c =5.1994 KX and c/a = 1.6236 for pure magnesium [21].

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[a] ΔHf

The various heat, volume, and density data available are tabulated in table 1. For information, the data on the beryllium alloys given in the last semi-annual report is also tabulated. Also included are values for several of the zirconium-silicon alloys, the heat data for which is reported by Robins and Jenkins [45]. The atomic volumes for the elements used in the calculation were taken from Heslop and Robinson [46]. Certain of the molecular volume data for silicon-titanium and silicon-zirconium systems are from VanArkle's recent paper [47]. The percent increase in volume values are probably good to 1 percent in the case of aluminum alloys and 3 percent in the remainder of the cases. It should be stressed that these percent increases are small differences in larger numbers and should be considered accordingly.

REFERENCES

1. M. Hansen, "Constitution of Binary Alloys", second edition, McGraw Hill Book Co., Inc., New York (1958).
2. H.J. Axon and W. Hume-Rothery Proc. Roy. Soc. A193, 1 (1958).
3. W. Hume-Rothery and T.H. Boultbee, Phil. Mag. 40, 71 (1949).
4. K. Schubert, Z. Metallk. 41, 63 (1950).
5. E. Zintl and J. Woltersdorf, Z. Electrochem. 41, 876 (1935).
6. O. Kubaschewski and J.A. Catteral, "Thermochemical Data on Alloys", Pergammon Press, London (1956).
7. K. Eickhoff and H. Vosskühler, Z. Metallk. 44, 223 (1953).
8. J.B. Clark and F.N. Rhines, J. Metals 9, 6 (1957).
9. E.C. Elwood, J. Inst. Metals 80, 605 (1952).
10. D.M. Poole and H.J. Axon, J. Inst. Metals 80, 599 (1952).
11. J.E. Dorn, P. Pietrokowski, and T.E. Tietz, J. Metals 2, 933 (1950)
12. H. Küstner, Z. Metallk. 34, 114 (1942).
13. V.G. Kuznetsov and L.N Guseva, Izv. Akad. Nauk SSSR, 905 (1940)
14. G. Siebel and H. Vosskühler, Z. Metallk. 31, 359 (1939).
15. J.J. Trillat and M. Paic Rev. Aluminum 15, 1109 (1938).
16. H. Perlitz, Nature 154, 606 (1944).
17. H. Perlitz, Trans. Chalmers University of Technology, Gothenberg, Sweden 50 (1946).
18. F. Laves, K. Lohberg, and P. Rahlfs, Nachr. Ges. Wiss. Gottingen, Math. phys. Klasse Fachgruppe 1, 67 (1934).
19. E.C. Makarov, Doklady Akad. Nauk. SSSR 74, 935 (1950).
20. F. Laves and K. Moellor, Z. Metallk. 30, 232 (1938).
21. R.S. Busk, J. Metals 2, 1460 (1950).
22. G.V. Raynor, Proc. Roy. Soc. A180, 107 (1942).
23. W. Hume-Rothery and G.V. Raynor, Proc. Roy. Soc A177, 27 (1940).
24. E.S. Bumps, H.D. Kessler, and M. Hansen, J. Metals 4, 609 (1952).
25. J. Folkenhagen and W. Hofmann, Z. Metallk. 43, 69 (1952).
26. H.R. Ogden, D.J. Maykuth, W.L. Finlay, and R.I. Jaffee, J. Metals 3, 1150 (1951).
27. W. Rostoker, J. Metals 4, 212 (1952).
28. H.J. Clark, Jr., J. Metals 1, 588 (1949).
29. G. Brauer, Z. anorg. u. allgem Chem. 242, 1. (1939).
30. G. Brauer, Naturwis . 26, 710 (1938).
31. W.L. Fink, K.R. vanHorne, and P.M. Budge, Trans. AIMME 93, 421 (1931).
32. O. Kubaschewski and W.A. Dinch, Acta Metallurg. 3, 339 (1955).
33. P. Durez and J.V. Taylor, J. Metals 4, 70 (1952).
34. D.J. McPherson and M. Hansen, Trans. Am . Sec. Metals 46, 354 (1954).
35. C.G. Wilson, D.K. Thomas, and F.J. Sperner, Acta. Cryst. 13 56 (1960).
36. G. Brauer, Z. Electrochem. 49, 208 (1943).
37. J.H. Kieler and J.H. Mallory, J. Metals 7, 394 (1955)

38. W.L. Fink and L.A. Wilby, Trans. AIMME 133, 69 (1939).
39. C.G. Wilson and D. Sams, Acta Cryst. 14,71 (1961)
40. W. Klemm and H. Westlinning, Z. anorg. Chem. 245, 365(1941).
41. O. Kubaschewski and H. Villa, Z. Electrochem. 53, 32 (1949).
42. K.T. Oust and L. M. Pidgeon, J. Metals 1, 585 (1949).
43. J.W. Frederickson J. Metals 7, 368(1955).
44. H. Nowotny, E. Wormnes, and A. Mohrnheim, Z. Metallk. 32, 39 (1940).
45. D.A. Robins and I. Jenkins, Acta Metallurg. 3, 598 (1955).
46. R.B. Heslop and P.L. Robinson, "Inorganic Chemistry", Elsevier Publishing Co., New York (1960).
47. A. VanArkle, "Alloys as Solid Rocket Fuels", report of National Research Corporation, Cambridge, Mass., October 7, 1960.

Table I. Percent increase in volume of alloy or intermetallic as compared to elements,

Compound	Density D (macro) g/cm^3	D (x-ray) g/cm^3	Molecular volume VM $cm^3/mole$	Sum of atomic volumes ΣVA $cm^3/atom$	Percent increase on alloying $\frac{VM - \Sigma VA}{\Sigma VA} \times 100$	Heat of formation ΔHf Kcal/mole	Heat of formation ΔHf Kcal/atom
AlLi		1.75	19.4	23.1	-16.0	-12.0	-6.0
$AlLi_2$							
Al_3Mg_2	2.23	2.28	57.4	57.8	-0.69	-0.37	-0.07
Al_3Mg_4							
$Al_{12}Mg_{17}$	2.07		356.1	356.3	-0.06		
Al_3Ti	3.31	3.37	38.6	40.6	-4.92	-35.3	-8.8
AlTi		3.84	19.5	20.6	-5.34	-19.3	-9.7
Al_3Zr	4.11	4.11	41.9	44.0	-4.78		
Al_2Zr						-30.0	-10.0
Al_3Zr_2							
AlZr							
Al_3Zr_4	5.28	5.37	83.6	86.0	-2.79		
Al_2Zr_3	5.35	5.34	61.2	62.0	-1.29		
Al_3Zr_5		5.43	98.9	100.0	-1.10		
$AlZr_2$	5.78(?)	5.67	36.9	38.0	-2.89		
$AlZr_3$		5.98	50.3	52.0	-3.27		
$Be_{13}Mg$		1.83	77.2	77.0	+0.26		
Be_2Ti		3.28	20.1	20.3	-0.98		
$Be_{12}Ti$	2.30		68.2	68.8	-0.87		
Be_2Zr		4.32	25.5	23.7	+7.59		
Be_5Zr		3.60	37.9	38.3	-1.04		
$Be_{13}Zr$		2.72	76.6	77.1	-0.65		
$Be_{17}Zr_2$		3.08	109.0	110.5	-1.36		
Mg_2Si		1.95	39.3	39.3	0.00	-19.0	-6.3

Table I. p.2

Compound	Density D (macro) g/cm^3	Density D(x-ray) g/cm^3	Molecular volume VM $cm^3/mole$	Sum of atomic volumes ΣVA $cm^3/atom$	Percent increase on alloying $\frac{VM - \Sigma VA}{\Sigma VA} \times 100$	Heat of formation ΔHf Kcal/mole	Heat of formation ΔHf Kcal/atom
Si_3Ti_5		4.32	74.9	87.7	-14.6	-87	-11
Si_2Ti		3.85	27.0	33.6	-19.6	-80	-27
$SiZr_4$							
$SiZr_2$		6.03	34.9	39.5	-11.6	-50.0	-16.7
Si_3Zr_5		6.00	90.1	104.5	-13.8	-146.5	-18.3
Si_3Zr_4							
Si_5Zr_6							
$SiZr$		5.63	21.2	25.5	-16.9	-35.3	-17.7
Si_2Zr		4.90	30.1	37.0	-18.6	-36.0	-12.0

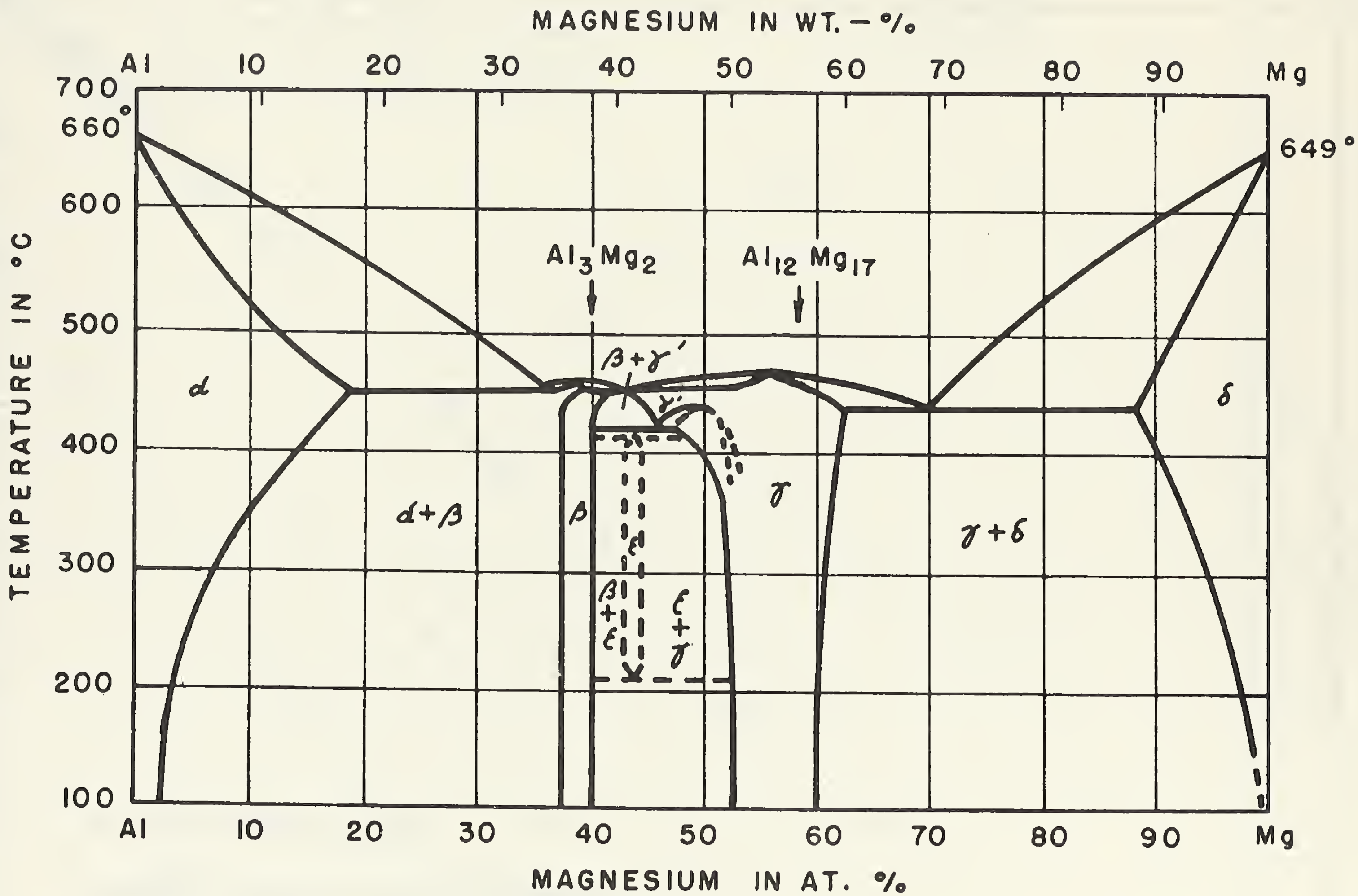

Figure 1. Phase diagram of magnesium-aluminum system.

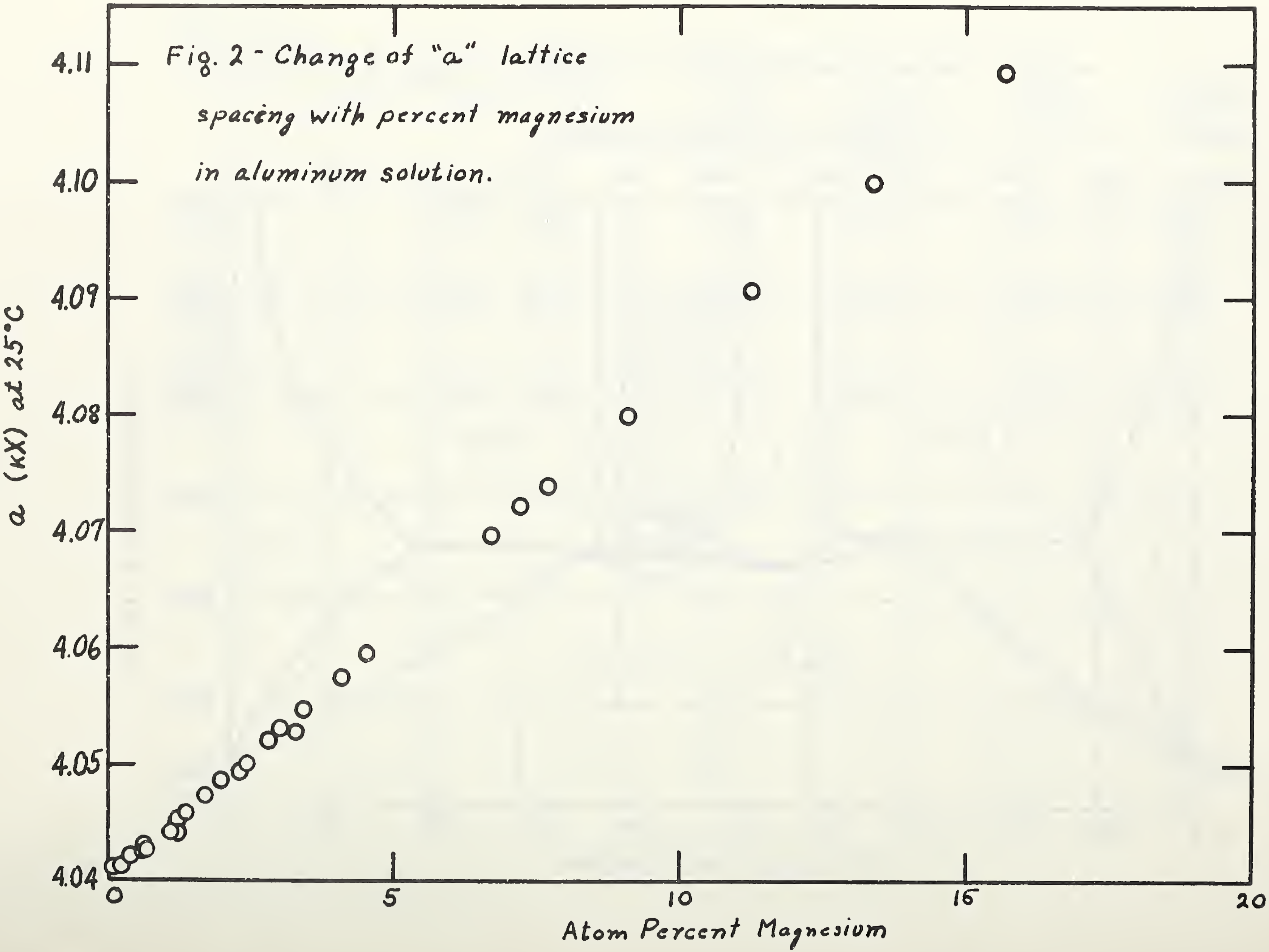

Fig. 2 - Change of "a" lattice spacing with percent magnesium in aluminum solution.

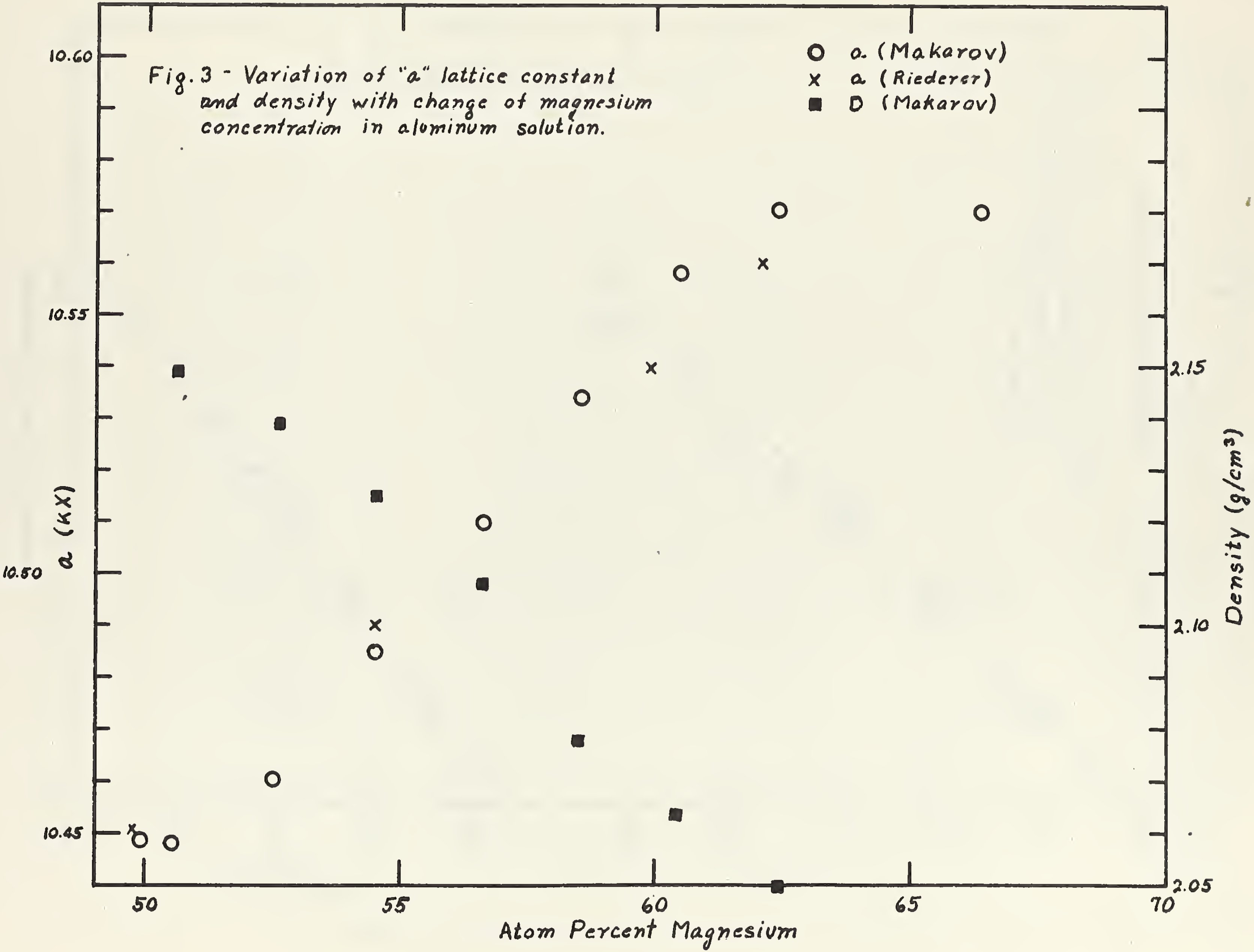

Fig. 3 - Variation of "a" lattice constant and density with change of magnesium concentration in aluminum solution.

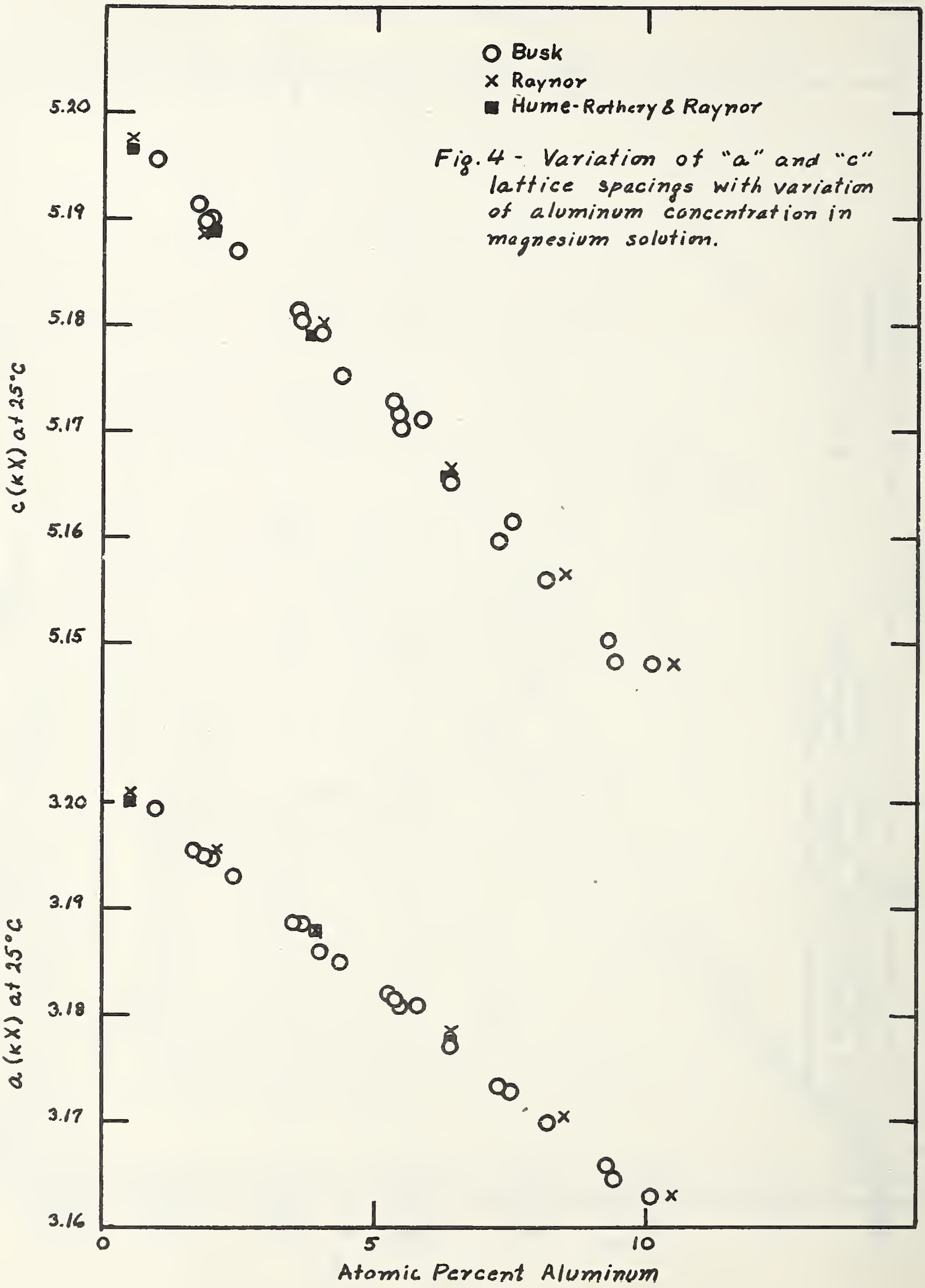

Fig. 4 - Variation of "a" and "c" lattice spacings with variation of aluminum concentration in magnesium solution.

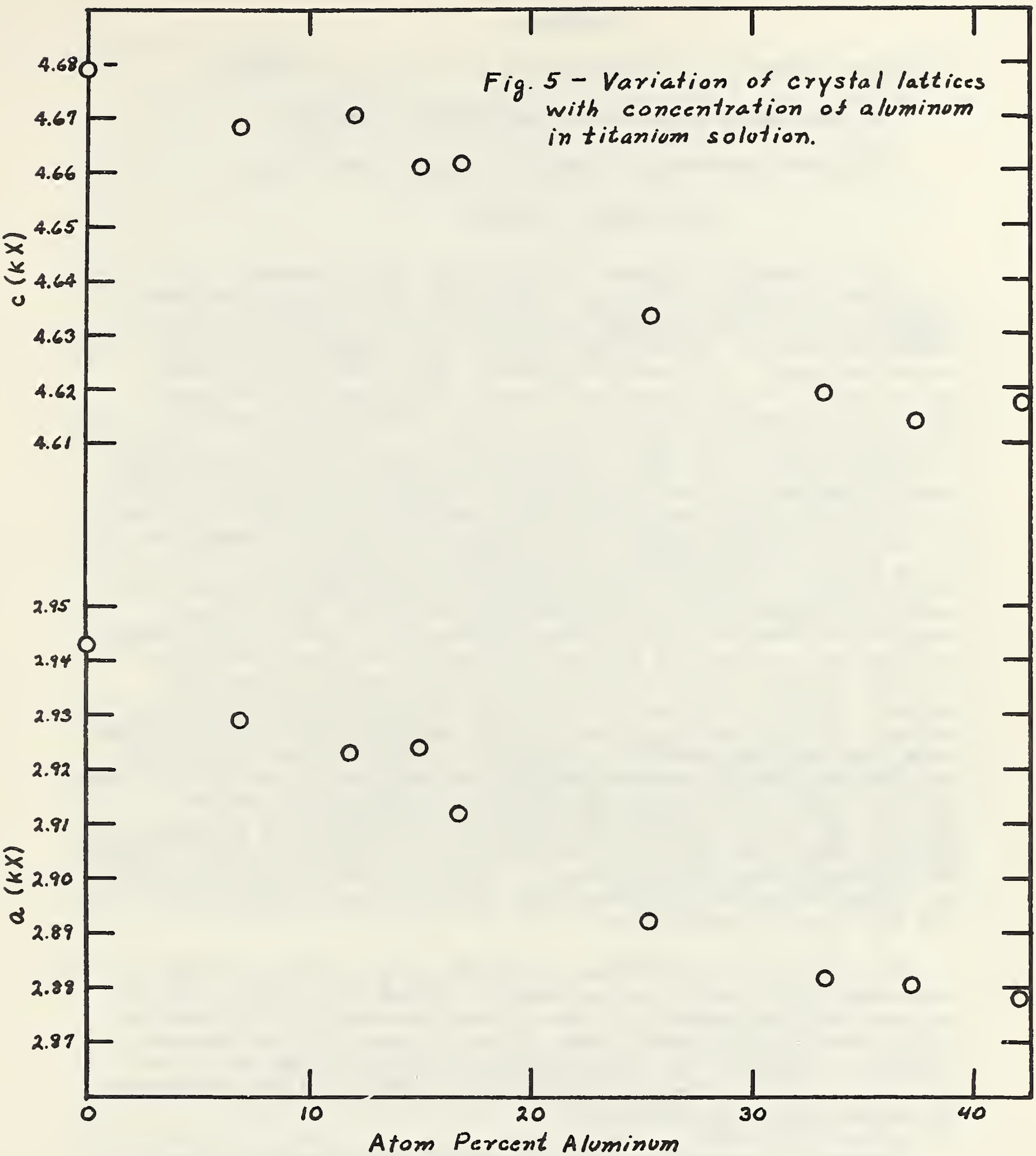
Fig. 5 - Variation of crystal lattices with concentration of aluminum in titanium solution.
c (kX)
4.68
4.67
4.66
4.65
4.64
4.63
4.62
4.61
a (kX)
2.95
2.94
2.93
2.92
2.91
2.90
2.89
2.88
2.87
0
10
20
30
40
Atom Percent Aluminum

CHAPTER 4

LITERATURE SURVEY ON LOW-TEMPERATURE HEAT CAPACITY AND ENTROPY AT 298.15°K OF W AND Pb AND SOME OF THEIR COMPOUNDS AND OF THE BROMIDES AND IODIDES OF Li, Be, Mg, and Al

by George T. Furukawa

The substances of interest to the program have increased. As a part of the program to determine the thermodynamic properties of these substances, a literature survey was made on the low-temperature heat capacity of tungsten and lead and some of their compounds with oxygen and the halogens. A literature survey was made also on the bromides and iodides of lithium, beryllium, magnesium and aluminum, and found that no heat-capacity data on these substances exist. The Bureau of Mines (BM) Bulletin 592 [22][1] and the Ohio State University [2] bibliography on low-temperature calorimetry were used to locate references to experimental measurements. The Annual Review of Physical Chemistry, Volumes 10 and 11 [38,27] and the bibliography compilation for 1960 by Zwolinski and Danti [43], that appeared in the Bulletin of Chemical Thermodynamics, No. 4, 1961 in advance of its publication in the 1961 issue of the Annual Review of Physical Chemistry, were also examined for experimental data. The Bulletin of Chemical Thermodynamics No. 4, 1961 [5] was consulted for sources of unpublished measurements. The original papers were examined and the data evaluated. Time was, however, insufficient to obtain smoothed values of heat capacities at equally spaced temperature intervals from which the various thermal functiona could be derived. For this report, values of heat capacity selected from a large-scale plot were compared with those given in the BM Bulletin 592 [22]. When the experimental data are reliable, the selected values of heat capacity were found to be in good agreement with those given in the BM Bulletin 592 [22]. Wherever the investigator evaluated the entropy at 298.15°K (S^o_{298}), the value was compared with that given in the BM Bulletin 592 [22] and in the National Bureau of Standards (NBS) Circular 500 [34]. The adopted values of S^o_{298} were taken from the above compilations or from the original publications.

The substances are discussed separately after listing the low-temperature heat-capacity measurements in chronological order, with the reference and the temperature range of each investigation. Information on the chemical and physical state of the substance is given wherever available. Tables of the adopted values of S^o_{298} are given at the end of the discussion. References given in the tables are those from which the adopted values were obtained.

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[1] Numbers in brackets refer to literature references at the end of this chapter.

Tungsten, W, 183.86

Measurements of the heat capacity of tungsten metal have been reported by a number of investigators: Nordmeyer and Bernoulli [32] (-185° to 20° C); Dewar [10] (20° to 80° K); Lange [25] (26° to 91° K); Zwikker and Schmidt [41,42] (92° to 2521° K); Bronson, Chisholm, and Dockerty [3] (-20° to 501° C); Silvidi and Daunt [37] (1.5° to 3.0° K); Horowitz and Daunt [15] (0.03° to 0.34° K); Rayne [33] (0.2° to 1° K); Waite, Craig, and Wallace [39] (4° to 15° K); DeSorbo [9] (13 ° to 93° K); Clusius and Franzosini [7] (12° to 274° K). The extensive measurements of Clusius and Franzosini [7] were based on a sample of 99.99 percent purity. S^{o}_{298}=7.83 eu reported by Clusius and Franzosini [7] was adopted. DeSorbo [9] reported S^{o}_{298}=8.2±0.2 eu. Kelley and King [22] give S^{o}_{298}=7.80± 0.10 eu and the NBS Circular 500 [34] 8.0 eu.

Tungsten Dioxide, WO_2, 215.86

Heat-capacity measurements on tungsten dioxide have been reported by King, Weller, and Christensen [24] (52° to 297° K). The sample was prepared from pure tungstic acid by reduction with hydrogen at 600° to 625° C. The product from eight separate preparations were mixed and heated for 11 hours in helium at 990° C. The analysis of the final product was reported to be 14.80 percent oxygen (theoretical = 14,82 percent). The x-ray diffraction pattern was reported to agree with that given for TiO_2 in the A.S.T.M. catalog. The value S^{o}_{298}=12.08±0.07 eu obtained by King *et al*. [24] was adopted.

Tungsten Trioxide, WO_3, 231.86

Heat-capacity measurements on tungsten trioxide have been reported by Russell [35] (-189° to 47° C); by Seltz, Dunkerley, and DeWitt [36] (63° to 299° K); and by King, Weller, and Christensen [24] (53° to 297° K). The WO_3 sample investigated by King *et al*. [24] was prepared from reagent-grade tungstic acid by heating at 770°C for 16 hours. The analysis of the product by hydrogen reduction was reported to be 20.72 percent oxygen (theoretical = 20.70 percent). The value S^{o}_{298}=18.15±0.12 eu obtained by King *et al*. [24] was adopted.

Lead, Pb, 207.21

Heat-capacity measurements on lead have been reported by Nernst [30] (23° to 273° K); Eucken and Schwers [12] (16° to 276° K); Griffiths and Griffiths [14] (23° to 380° K); Keesom and Onnes [20] (14° to 80°K); Keesom and Andrews [17] (2° to 21° K); Keesom and Ende [18,19] (2° to 20° K); Bronson and Wilson [4] (-80° to 120° C); Meads, Forsythe and Giauque [28] (14° to 300° K); Clement and Quinnell [6] (6° to 8° K); and Horowitz, Silvidi, Malaker, and Daunt [16] (1° to 75° K). Measurements of Meads *et al.* [28] and Horowitz *et al*. [16] which together cover the range 1° to 300° K, join fairly continuously. Meads *et al*. [28] calculated S^{o}_{298} to be 15.51 eu. Kelley and King [22] give 15.49±0.05 eu. NBS Circular 500 [34] lists S^{o}_{298}=15.51 eu, which was adopted.

Lead Monoxide (yellow, rhombic), PbO, 223.21

Nernst and Schwers [31] (21° to 93° K), Russell [35] (-191° to 44° C), and King [23] (54° to 296° K) measured the heat-capacity of the rhombic, high-temperature form of PbO. The sample investigated by King [23] was prepared by heating lead carbonate, precipitated by treating a solution of reagent grade lead nitrate with an excess of ammonium carbonate solution, for 10 hours at 725° C and quenching to room temperature. Analysis of the sample was reported to be 92.84 percent lead (theoretical = 92.83 percent). No reconversion to the red PbO was observed. The x-ray diffraction pattern for the sample was reported to be in agreement with that listed for yellow PbO in the ASTM catalog. King [23] reported S^o_{298} = 16.1±0.2 eu, which was adopted.

Lead Monoxide (red, tetragonal), PbO, 223.21

King [23] (53° to 296° K) measured the heat capacity of the tetragonal, low-temperature form of PbO. The sample of red PbO was prepared by heating electrolytic PbO_2 under vacuum at 430° to 480° C for about 8 weeks. The chemical analysis on the sample was reported to be 92.69 percent lead (theoretical = 92.83 percent). X-ray diffraction pattern was reported to indicate a presence of a small amount of yellow PbO. King [23] reported S^o_{298} = 15.6±0.2 eu, which was adopted.

Lead Orthoplumbate, Pb_3O_4, 685.63

Millar [29] (72° to 293° K) reported heat-capacity measurements on lead orthoplumbate. The sample was prepared by thermal decomposition of PbO_2 at 460° C. An average of five analyses for active oxygen on the product indicated 97 percent of the theoretical quantity. The analysis for the lead content was reported to be 90.62 percent (theoretical = 90.66 percent). Millar [29] reported S^o_{298} = 60.53 eu. Kelley and King [22] lists 50.5±1.6 eu. In an earlier bulletin No. 350 Kelley [21] pointed out an arithematic error in Millar's value for entropy. NBS Circular 500 [34] lists 50.5 eu. The value 50.5 eu was adopted.

Lead Sesquioxide, Pb_2O_3, 462.42

King [23] (53° to 297° K) measured the heat capacity of Pb_2O_3. The sample was prepared by heating in air $PbCO_3$, precipitated from a solution of reagent grade $Pb(NO_3)_2$ with an excess of $(NH_4)_2CO_3$ solution, for 40 hours at 290° C, 64 hours at 310° C, and 10 days at 320° C. Chemical analysis of the product was reported to be 89.64 percent lead (theoretical = 89.62 percent). The x-ray diffraction pattern was reported to agree with that listed in the ASTM catalog. King [23] reported S^o_{298} = 36.3±0.7 eu, which was adopted.

Lead Dioxide, PbO_2, 239.21

Russell [35] (-188° to 46° C) and Millar [29] (70° to 297° K) reported heat-capacity measurements on lead dioxide. The sample investigated by Millar [29] was prepared by electrolysis of an acidic solution of lead nitrate. The average of three analyses for active oxygen on the product indicated 99.5 percent of the theoretical quantity. Millar [29] reported S^o_{298} = 18.27 eu. Kelley and King [22] lists 18.3±0.5 eu, which was adopted. NBS Circular 500 [34] lists 18.3 eu.

Lead Fluoride, PbF_2, 241.21

No low-temperature heat-capacity data were found. NBS Circular 500 [34] lists an estimated S^o_{298} = 29 eu. Kelley and King [22] estimated S^o_{298} = 23.0±0.5 eu, which was adopted.

Lead Chloride, $PbC\ell_2$, 278.124

Eucken [11] (at three mean temperatures: +17.5°, -67.5°, and -166.5° C) and Nernst [30] (16° to 88° K) measured the heat capacity of $PbC\ell_2$. The purity of the samples investigated is not known. From these measurements Kelley and King [22] estimated S^o_{298} = 34.0±1.0eu. From cell measurements, Gerke [13] obtained ΔS^o_{298} = -8.58 eu for the reaction:

$$Pb(c) + AgC\ell(c) = PbC\ell_2(c) + 2Ag(c)$$

and ΔS^o_{298} = 6.70 eu for the reaction:

$$Pb(c) + 2HgC\ell(c) = PbC\ell_2(c) + 2Hg(l).$$

The entropies at 298.15° K of $PbC\ell_2(c)$ corresponding to the above reactions calculated by Kelley and King [22] are 32.5±0.5 and 32.2±1.0 eu, respectively. NBS Circular 500 [34] lists S^o_{298} = 32.6 eu. This value was adopted.

Lead Bromide, $PbBr_2$, 367.042

Heat measurements on $PbBr_2$ have been reported by Barschall [1] (-183° to -75° C) and by Latimer and Hoenshel [26] (18° to 297° K). Latimer and Hoenshel [26] prepared the $PbBr_2$ sample from c.p. $Pb(NO_3)_2$ and KBr by precipitation. The $PbBr_2$ precipitate was washed and finally dried at 120° C. Latimer and Hoenshel [26] reported S^o_{298} = 39.7±0.45 eu. Kelley and King [22] calculated S^o_{298} = 38.6±0.5 eu on the basis of the same data. NBS Circular 500 [34] lists S^o_{298} = 38.6 eu, which was adopted.

Lead Iodide, PbI_2, 461.03

Nernst and Schwers [31] (22° to 96° K) measured the heat capacity of PbI_2. Recently, Westrum [40] measured the heat capacity of this substance in the range 6° to 300° K. The latter results, however, have not been published as yet. Kelley and King [22] estimated S^o_{298} = 41.3±1.5 eu based on the measurements of Nernst and Schwers [31]. Gerke [13] obtained ΔS^o_{298} = -1.20 for the reaction:

$$Pb(c) + I_2(c) \rightarrow PbI_2(c),$$

from cell measurements, from which Kelley and King [22] calculated S^o_{298}= 42.2±0.5 eu for $PbI_2(c)$. NBS Circular 500 [34] lists S^o_{298} = 42.3 eu. The latter value was tentatively adopted until Westrum's low-temperature heat-capacity data become available.

Lithium Bromide, LiBr, 86.856

No low-temperature heat-capacity data have been found. Kelley and King [22] give an estimated value of S^o_{298} = 16.0±0.5 eu, which was tentatively adopted.

Lithium Iodide, LiI, 143.850

No low-temperature heat-capacity data have been found. Kelley and King [22] give an estimated value of S^o_{298} = 17.5±0.5 eu, which was tentatively adopted.

Beryllium Bromide, $BeBr_2$, 168.845

No low-temperature heat-capacity data have been found.

Beryllium Iodide, BeI_2, 262.833

No low-temperature heat-capacity data have been found.

Magnesium Bromide, $MgBr_2$, 184.152

No low-temperature heat-capacity data have been found. Kelley and King [22] give an estimated value of S^o_{298} = 28.0±1.0 eu, which was tentatively adopted.

Magnesium Iodide, MgI_2, 278.14

No low-temperature heat-capacity data have been found. Kelley and King [22] give an estimated value of S^o_{298} = 31.0±1.0 eu, which was tentatively adopted.

Aluminum Bromide, $AlBr_3$, 266.728

No low-temperature heat-capacity data have been found. NBS Circular 500 [34] lists an estimated value of S^o_{298} = 44 eu, which was tentatively adopted.

Aluminum Iodide, AlI_3, 407.71

No low-temperature heat-capacity data have been found. Corbett and Gregory [8] investigated the equilibrium of the reaction:

$$AlI_3(c) + 3HCl(g) \rightarrow AlCl_3(c) + 3HI(g)$$

and obtained ΔF^o_{298} = -8.7±0.2 kcal for the reaction. Using values of ΔF^o_f (at 298.15°K) given in NBS Circular 500 [34], Corbett and Gregory [8] calculated ΔF^o_f (at 298.15°K) for $AlI_3(c)$ to be -74.4 kcal. NBS Circular 500 [34] lists -75.0 kcal for this quantity. Corbett and Gregory [8] calculated S^o_{298}=46.0 eu. Kelley and King [22] assigned the uncertainty ±2.0 eu to this. NBS Circular 500 [34] lists an estimated value of S^o_{298}=48 eu. The value S^o_{298}=46.0±2.0 eu was adopted.

TABLE I

Entropy of Some Compounds of Tungsten and of Lead in the Solid State

Chemical Formula	Gram Formula Mass	S^o_{298} cal/deg mole	References
W	183.86	7.83	[7]
WO_2	215.86	12.08±0.07	[24]
WO_3	231.86	18.15±0.12	[24]
WF_6	297.86	no data	----
WCl_6	396.602	no data	----
Pb	207.21	15.51	[34]
PbO (yellow)	223.21	16.1±0.2	[23]
PbO (red)	223.21	15.6±0.2	[23]
Pb_3O_4	685.63	50.5±1.6	[22,34]
Pb_2O_3	462.42	36.3±0.7	[23]
PbO_2	239.21	18.3±0.5	[22,34]
PbF_2	241.21	23.0±0.5	[22]
$PbCl_2$	278.124	32.6	[22,34]
$PbBr_2$	367.042	38.6±0.5	[22,34]
PbI_2	461.03	42.3	[22,34]

TABLE II

Entropy of the Bromides and Iodides of Li, Be, Al, and Mg

Chemical Formula	Gram Formula Mass	S^o_{298} cal/deg mole	References
LiBr	86.856	16.0±0.5	[22]
LiI	143.850	17.5±0.5	[22]
$BeBr_2$	168.845	no data	----
BeI_2	262.833	no data	----
$MgBr_2$	184.152	28.0±1.0	[22]
MgI_2	278.14	31.0±1.0	[22]
$AlBr_3$	266.728	44	[34]
AlI_3	407.71	46.0±2.0	[22]

REFERENCES

[1] H. Barschall; Über spezifische Wärmen fester Stoffe bei tiefen Temperaturen; Z. Elektrochem. 17, 341-345 (1911).

[2] T. W. Bauer, C. W. Beckett, and H. L. Johnston; Calorimetry at Low Temperatures; TECH INT REPORT NO. F-TR-2262-IA, The Ohio State University, March 15, 1949.

[3] H. L. Bronson, H. M. Chisholm, and S. M. Dockerty; On the Specific Heats of Tungsten, Molybdenum, and Copper; Can. J. Research 8, 282-303 (1933).

[4] H. L. Bronson and A. J. C. Wilson; The Heat Capacities of Silver, Nickel, Zinc, Cadmium, and Lead from -80° to 120° C; Can. J. Research 14A, 181-193 (1936).

[5] Bulletin of Chemical Thermodynamics, No. 4, 1961, International Union of Pure and Applied Chemistry, March 20, 1961.

[6] J. R. Clement and E. H. Quinnell; The Atomic Heat of Lead in the Region of the Transition to Superconductivity; Phys. Rev. 85, 502-503 (1952).

[7] K. Clusuis and P. Franzosini; Ergebnisse der Tieftemperaturforschung. XXIII. Atom-- und Elektronenwärme des Molybdäns und Wolframs zwischen 10°K und 273°K; Z. Naturforsch. 14A, 99-105 (1959).

[8] J. D. Corbett and N. W. Gregory; The AlI_3-HCl-$AlCl_3$-HI System. The Free Energy of Formation of Aluminum Iodide; J. Am. Chem. Soc. 76, 1446-1447 (1954).

[9] W. DeSorbo; Low Temperature Heat Capacity of Bismuth and Tungsten; J. Phys. Chem. 62, 965-967 (1958).

[10] J. Dewar; Atomic Specific Heats between the Boiling Points of Liquid Nitrogen and Hydrogen. I. The Mean Atomic Specific Heats at 50° Absolute of the Elements a Periodic Function of the Atomic Weights; Proc. Roy. Soc. (London) 89A, 158-169 (1913).

[11] A. Eucken; Über die Bestimmung spezifischer Wärmen bei tiefen Temperaturen; Physik. Z. 10, 586-589 (1909).

[12] A. Eucken and F. Schwers; Eine experimentelle Prüfung des T^3-Gesetzes für den Verlauf der spezifischen Wärme fester Körper bei tiefen Temperaturen; Ber. deut. physik. Ges. 15, 578-588 (1913).

[13] R. H. Gerke; Temperature Coefficient of Electromotive Force of Galvanic Cells and the Entropy of Reactions; J. Am. Chem. Soc. 44, 1684-1704 (1922).

[14] E. H. Griffiths and E. Griffiths; The Capacity for Heat of Metals at Low Temperatures; Proc. Roy. Soc. (London) 90A, 557-560 (1914).

[15] M. Horowitz and J. G. Daunt; The Electronic and Lattice Specific Heats in W, Mo, and Re; Phys. Rev. 91, 1099-1106 (1953).

[16] M. Horowitz, A. A. Silvidi, S. F. Malaker, and J. G. Daunt; The Specific Heat of Lead in the Temperature Range 1°K to 75°K; Phys. Rev. 88, 1182-1186 (1952).

[17] W. H. Keesom and D. H. Andrews; The Specific Heats of Solid Substances at the Temperatures Attainable with the Help of Liquid Helium. I. Measurements of the Atomic Heat of Lead; Comm. Phys. Lab. Univ. Leiden No. 185a, 2-13 (1927).

[18] W. H. Keesom and J. N. van den Ende; The Specific Heat of Solid Substances at the Temperatures Obtainable with the Aid of Liquid Helium. II. Measurements of the Atomic Heats of Lead and Bismuth; Proc. Acad. Sci. Amsterdam 33, 243-245 (1930). Comm. Phys. Lab. Univ. Leiden No. 203d, 25-38 (1930).

[19] W. H. Keesom and J. N. van den Ende; The Specific Heat of Solid Substances at the Temperatures Obtainable with the Aid of Liquid Helium. III. Measurements of the Atomic Heats of Lead and Bismuth. A Correction; Proc. Acad. Sci. Amsterdam 34, 210-211 (1931). Comm. Phys. Lab. Univ. Leiden No. 213c, 27-31 (1931).

[20] W. H. Keesom and H. K. Onnes; The Specific Heat at Low Temperatures. I. Measurements on the Specific Heat of Lead between 14° and 80° K and of Copper between 15° and 22° K; Comm. Phys. Lab. Univ. Leiden No. 143,13, 2-26 (1914).

[21] K. K. Kelley; Contributions to the Data on Theoretical Metallurgy. I. The Entropies of Inorganic Substances, U. S. Bureau of Mines Bulletin 350 (1932).

[22] K. K. Kelley and E. G. King; Contributions to the Data on Theoretical Metallurgy. XIV. Entropies of the Elements and Inorganic Compounds, U. S. Bureau of Mines Bulletin 592, August, 1961.

[23] E. G. King; Low Temperature Heat Capacities and Entropies at 298.15° K. of Lead Sesquioxide and Red and Yellow Lead Monoxide; J. Am. Chem. Soc. 80, 2400-2401 (1958).

[24] E. G. King, W. W. Weller, and A. U. Christensen; Thermodynamics of Some Oxides of Molybdenum and Tungsten; U. S. Bureau of Mines Report of Investigations No. 5664, 1960.

[25] F. Lange; Untersuchungen über die spezifische Wärme bei tiefen Temperaturen; Z. physik. Chem. 110, 343 (1924).

[26] W. M. Latimer and H. D. Hoenshel; The Heat Capacity and Entropy of Lead Bromide and Bromine; J. Am. Chem. Soc. 48, 19-28 (1926).

[27] John P. McCullough; Thermochemistry and Thermodynamic Properties of Substances, Annual Review of Physical Chemistry, Volume 11, Annual Reviews, Inc., Palo Alto, 1961.

[28] P. F. Meads, W. R. Forsythe, and W. F. Giauque; The Heat Capacities and Entropies of Silver and Lead from 15° to 300° K; J. Am. Chem. Soc. 63, 1902-1905 (1941).

[29] R. W. Millar; The Heat Capacities at Low Temperatures of the Oxides of Tin and Lead; J. Am. Chem. Soc. 51, 207-214 (1929).

[30] W. Nernst; Der Energieinhalt fester Stoffe; Ann. Physik (4) 36, 395-439 (1911).

[31] W. Nernst and F. Schwers; Untersuchungen über die spezifische Wärme bei tiefen Temperaturen. VIII; Sitzber. könig. preuss. Akad. Wiss. 1914, 355-370 (1914).

[32] P. Nordmeyer and A. L. Bernoulli; Determination of the Specific Heat of Some Elements; Alloys, and Compounds between -185° and 20° C; Verhandl. deut. physik. Ges. 9, 175-183 (1907).

[33] J. Rayne; Specific Heat of Metals Below One Degree Absolute; Phys. Rev. 95, 1428-1434 (1954).

[34] F. D. Rossini, D. D. Wagman, W. H. Evans, S. Levine, and I. Jaffe; Selected Values of Chemical Thermodynamic Properties, National Bureau of Standards Circular 500 (1952).

[35] A. S. Russell; Messungen von spezifischen Wärmen bei tiefen Temperaturen; Physik. 13, 59-64 (1912).

[36] H. Seltz, F. J. Dunkerley, and B. J. DeWitt; Heat Capacities and Entropies of Molybdenum and Tungsten Trioxides; J. Am. Chem. Soc. 65, 600-602 (1943).

[37] A. A. Silvidi and J. G. Daunt; Electronic Specific Heats in Tungsten and Zinc; Phys. Rev. 77, 125-129 (1950).

[38] J. M. Sturtevant; Thermochemistry and Thermodynamic Properties of Substances, Ann. Rev. of Phys. Chem.; Volume 10, Annual Reviews, Inc., Palo Alto, 1960.

[39] T. R. Waite, R. S. Craig, and W. E. Wallace; Heat Capacity of Tungsten between 4 and 15° K; Phys. Rev. 104, 1240-1241 (1956).

[40] E. F. Westrum, Jr.; Bulletin of Chemical Thermodynamics, No. 4, 1961, p. 44, International Union of Pure and Applied Chemistry, March 20, 1961.

[41] C. Zwikker, Messungen der spezifischen Wärme von Wolfram zwischen 90 und 2600° abs.; Z. Physik 52, 668-77 (1928).

[42] C. Zwikker and G. Schmidt; Metingen over de Soortelijke Warmte van Wolfraam tusschen 90 en 2600° Absoluut; Physica 8, 329-346 (1928).

[43] B. Zwolinski and A. Danti, Bibliography of Recent Papers and Substance Property Index, Appendix 1, Bulletin of Chemical Thermodynamics, No. 4, 1961, International Union of Pure and Applied Chemistry, March 20, 1961.

CHAPTER 5

A RECENT SURVEY OF REPORTED HIGH-TEMPERATURE HEAT CONTENTS AND HEAT CAPACITIES

by Thomas B. Douglas and Willis R. Thurber

Beginning with the first report of this series (NBS Report 6297, January 1, 1959), heat-content and heat-capacity data on condensed phases of propulsion interest have been compiled. It was not, however, until the second report (NBS Report 6484, July 1, 1959) that the extensive task was seriously begun to select "best" values of these properties and to make adjustments of the values such that the resulting tables of thermodynamic functions would not have discontinuities reflecting the many obvious discordances of data covering different temperature ranges. All the tables of thermodynamic functions of condensed phases issued so far in our NBS program are to be found in the fourth and fifth reports (NBS Report 6928, 1 July 1960; NBS Report 7093, 1 January 1960).

Because new data are constantly being reported, and also especially because additional elements and their compounds have acquired considerable propulsion interest, we recently began an up-to-date survey of the available data on heat contents and heat capacities of a selected list of light-element substances "at high temperatures" (above the ice-point, 273°K). The results thus far obtained are tabulated below (Table 1). They are preliminary and incomplete in two respects: (1) We have made no attempt so far to assess many of the data and arrive at "best" values, and (2) the sources of information covered, while complete in principle, do not include such obvious alternative sources as abstract journals (except in the case of a few substances). The survey began with a well-known critical compilation (U. S. Bur. Mines Bulletin 584), and to that extent (1) covers all early data still considered of value, and (2) includes values for gases based on published experimental or estimated molecular constants.

With the following specific statement of substances and sources of information covered, the table should be useful as a starting point for more detailed surveys, and also by indicating in which cases high-temperature heat-content data are probably inadequate or totally lacking.

<u>Substances Covered, and Order of Listing</u> -- Table 1 is divided into twelve sections. Each section covers one of the following elements and its compounds (listed in the order of presentation): Aℓ, Be, B, Hf, Pb, Li, Mg, Hg, K, Ti, W, and Zr. (All compounds including two of these elements are listed twice -- i.e., in the sections for both elements.) For each of these elements are included only the free element, compounds with others of the above elements, and compounds with H, O, F, Cℓ, Br,

I, N, C, and/or Si. For each substance the reported investigations are listed in chronological order, on the basis that a later investigation is often (though frequently not) more accurate or more extensive than an earlier one.

Sources of Information Covered -- The dates in parentheses indicate the period of time for which literature coverage is claimed by the given reference source.

1. U. S. Bureau of Mines Bulletin 584, 1960 (same as reference [37]) (to September 1958).

2. "Annual Review of Physical Chemistry," Volume 10--chapter entitled "Thermochemistry and Thermodynamic Properties of Substances," by J. M. Sturtevant -- Annual Reviews, Inc., Palo Alto, Calif., 1959, pp. 1-30 (Dec. 1957 to Dec. 1958).

3. "Annual Review of Physical Chemistry," Volume 11 -- chapter entitled "Thermochemistry and Thermodynamic Properties of Substances," by J. P. McCullough -- Annual Reviews, Inc., Palo Alto, Calif., 1960, pp. 1-20 (Dec. 1958 to Dec. 1959).

4. "Bibliography on the High Temperature Chemistry and Physics of Materials in the Condensed State" (covering the literature of several countries), International Union of Pure and Applied Chemistry, Commission on High Temperatures and Refractories, Sub-Commission on Condensed States, Jan. 1960 through Mar. 1961 (5 issues), 172 pages.

5. Journal of Physical Chemistry, Jan. 1959 through June 1961.

6. Journal of Chemical Physics, Jan. 1959 through June 1961.

7. Journal of the American Chemical Society, July 5, 1960, through June 5, 1961.

8. Bulletin of Chemical Thermodynamics, "No. 4, 1961," March 20, 1961 (same as reference [38]).

Further Comments on Table 1 -- As is customary, the empirical formulas are given for condensed states, but the true molecular formulas are given for gases. The physical state is designated as crystalline(c), liquid (ℓ), gas (g), amorphous, or glass, with a distinction among different crystalline forms if the existence of more than one is recognized. The actual temperature range of measurements on a condensed phase is given where it was possible to ascertain it in the time available, with an attempt to indicate the cases where the temperature scale referred to is ambiguous. Even the sources of information listed above were not covered completely with respect to "low-temperature" measurements which extend only up to or slightly above room temperature, as this temperature region has been covered thoroughly for many of the elements listed above (but yet incompletely for many of the other elements) by another group in the NBS program. Finally, it may be mentioned that the absence from the table of the description "critical compilation" is in some cases due to lack of information rather than real evidence that critical selection was not used.

For the substances covered in the present survey, all individual investigations included in U. S. Bureau of Mines Bulletin 584 have been given separately in the table below, but the Bulletin must be consulted for the original references. For each particular substance and state where that Bulletin lists more than one reference, the column "Rating by Bulletin 584" lists "1" if the Bulletin italicized the reference ("given greatest weight") or "2" if not italicized ("not given greatest weight").

Heat Content, Melting Point, and Heat of Fusion of Beryllium Oxide -- As noted in Table 1, measurements of the heat content of BeO from 1200°K to the melting point have recently been reported by Kandyba, Kantor, Krasovitskaya, and Fomichev [14]. The samples, 99.9% BeO after sintering finally at 1800°C, were contained in molybdenum below 2400°K and in tungsten above this temperature. They used a vacuum furnace, measured temperatures with an optical pyrometer, and reported they found the melting point of BeO to be 2820° ±9° K, which agrees with earlier measurements within the stated precisions. Their smoothed values of the heat content of BeO(c) are represented by the equation (in cal/mole at T° K) (1200°-2820°K)

$$H_T - H_{298.16} = 9.471\ T + 1.045\ (10^{-3})\ T^2 - 3540.$$

The above results may be compared with values in NBS Report 6484 (July 1, 1959), which gave (in Table 2-8) thermodynamic functions for BeO (c) up to 2800°K based on the long and hence inaccurate extrapolation of the heat capacity from precise measurements made only up to 1200°K. The smoothed heat capacities of KKKF are 1.8% lower at 1200°K, 4.4% higher at 2000°K, and 13.5% higher at 2800°K and should of course be more reliable than the estimated values at the higher temperatures.

In the same report (NBS Report 6484, p.59), the heat of fusion of BeO was estimated as being about 17 kcal/mole by analogy with the entropies of fusion of MgO and FeO. Although KKKF's heat-content data obviously reflect varying amounts of melting at 2820°, 2822°, and 2840°K, if fusion were complete at the last temperature (which they apparently do not claim), their data would give a heat of fusion of 15 kcal/mole. Although based on a single experimental heat-content value in the liquid range, this value thus represents a lower limit to the true heat of fusion.

TABLE 1. REPORTED INVESTIGATIONS OF THE HIGH-TEMPERATURE

HEAT CONTENTS AND HEAT CAPACITIES OF SELECTED SUBSTANCES

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
			Aluminum Compounds			
Aℓ	c	1888	Naccari [37]	293-593	2	
	c	1903	Tilden [37]	288-708	1	
	c	1910	Magnus [37]	289-820	1	
	c	1914	Schübel [37]	291-875	1	
	c,ℓ	1918	Wust, Meuthen, Durrer [37]	273-1273	2	
	c	1924	Eastman, Williams, & Young [37]	293-873	1	
	c,ℓ	1926	Awbery and Griffiths [37]	293-1036	1	
	c,ℓ	1926	Umino [37]	273-1273	2	
	c	1931	Seekamp [37]	291-873	1	
	c	1935	Sato [37]	273-871	2	
	c	1937	Tscherboff and Tsherniah [37]	290-373	2	
	c,ℓ	1938	Awbery [37]	932	2	
	c	1939	Avramescu [37]	373-873	2	
	c,ℓ	1952	Wittig [37]	932	1	
	c,ℓ	1955	Oelsen,Oelsen, and Thiel [37]	932	1	
	c,ℓ	1955	Oelsen,Rieskamp, & Oelsen [37]	932	1	
	g	1957	Kolsky,Gilmer, & Gilles [37]	0-8000		critical compilation
$Aℓ_3Mg_4$	c	1910	Schimpff [37]	290-373		
AℓH	g	1950	Herzberg [37]	298-2000		molecular constant data
AℓO	g	1950	Herzberg [37]	298-2000		molecular constant data
$Aℓ_2O_3$	c	1912	Lyashenko [37]	290-1483	2	
	c	1926	Miehr, Immke, & Kratzert [37]	281-1676	2	
	c	1929	Roth and Bertram [37]	293-1187	2	
	c	1930	Kolossowsky and Skoulski [37]	291-624	2	
	c	1930	Newman and Brown [37]	300-1300	2	
	c	1932	Wilkes [37]	303-1973	2	
	c	1933	Esser,Averdieck, & Grass [37]	273-1473	2	
	c	1933	Gronow and Schwiete [37]	293-1973	1	
	c	1935	Laschschenko & Kompanskii [37]	289-1443	2	
	c	1936	Auzhbikovich [37]	295-1420	2	
	c	1945	Shomate and Naylor [37]	298-1788	1	
	c	1947	Ginnings and Corruccini [37]	273-1173	1	
	c	1950	Egan,Wakefield, & Elmore [37]	273-1573	1	
	c	1951	Blomeke and Ziegler [37]	303-1172	1	
	c	1953	Ginnings and Furukawa [37]	273-1200	1	
	c	1954	Ewing and Baker [37]	303-978	1	
	c	1954	Oriani and Murphy [37]	273-786	1	
	c	1955	Rodigana and Gomel'skii [37]	273-1673	1	
	c	1955	Shomate and Cohen [37]	298-1362	1	
	c	1956	Furukawa,Douglas,McCoskey,& Ginnings [37]	273-1200	1	
	c	1956	Lucks and Deem [37]	298-1508	2	
	c	1956	Walker, Grand, and Miller [37]	303-976	1	
	c	1957	Olette [24]	1173,1500		
	c	1958	Gomel'skiy [12]	373-1173		
	c	1958	Margrave and Grimley [19]	686-1261		
	c	1958	McKeown [21]	273-1373		
	c	1958	Medvedev [22]	?		
	c	1960	Kirillin,Sheindlin,Chekhovski[17]	500-2000 (°Cor°K?)		
	c	1960	Romanovsky and Tarasov [26]	65-300		
	c	1960	Shmidt and Sokolov [28]	326-987		
	c	1961	Hoch and Johnston [42] 1555-2278	1200-2250		
$Aℓ_2O_3 \cdot H_2O$	c	1946	Shomate and Cook [37]	298-520		
$Aℓ_2O_3 \cdot 3H_2O$	c	1946	Shomate and Cook [37]	298-424		
$BeAℓ_2O_4$	c	1880	Nilson and Pettersson [37]	273-373		
$LiAℓO_2$	c	1960	Christensen,Conway, & Kelley [5]	298-1796		

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
Aluminum Compounds (cont.)						
$MgAl_2O_4$	c	1955	Bonnickson [37]	298-1806		
Al_2TiO_5	c	1955	Bonnickson [37]	298-1803		
Al_2SiO_5 (sillimanite)	c	1924	Cohn [37]	293-1673	2	
Al_2SiO_5 (andalusite)	c	1925	Neumann [37]	273-1573		
Al_2SiO_5 (kyanite)	c	1925	Neumann [37]	273-1573	1	
	c	1930	Kolossowsky & Skoulski [37]	289-615	2	
$Al_6Si_2O_{13}$ (mullite)	c	1931	Kolossowsky [37]	290-576		
$KAlSiO_4$	c	1953	Kelley, Todd, Orr, King, and Bonnickson [37]	298		
$KAlSi_2O_6$	c	1953	Kelley,Todd,Orr,King and Bonnickson [37]	298		
$KAlSi_3O_8$	c,gls	1909	White [37]	273-1373		
$AlMg_3Si_3O_{10}F_2$	c,l	1959	Kelley,Barany,King,&Christensen [37]	298-1804		
AlF	g	1950	Herzberg [37]	298-2000	1	molec.-const.data
	g	1959	Altman [1]	0-6000		molec.-const.data
AlF_3	c	1935	Lyashenko [37]	290-1305	2	
	c	1957	O'Brien and Kelley [37]	298-1401	1	
$AlF_3 \cdot 3.5H_2O$	c	1903	Baud [37]	288-326		
$AlCl$	g	1950	Herzberg [37]	298-2000	1	molec.-const.data
	g	1959	Altman [1]	0-6000		molec.-const.data
$AlCl_3$	c,l	1931	Fischer [37]	273-504		
	c,l	unpubl.	McDonald and Stull [38]	298-500		
$AlCl_3 \cdot 6H_2O$	c	1903	Baud [37]	288-327		
$AlBr$	g	1950	Herzberg [37]	298-2000		molec.-const.data
	g	1959	Altman [1]	0-6000		molec.-const.data
$AlBr_3$	c,l	1931	Fischer [37]	273-456		
AlI	g	1950	Herzberg [37]	298-2000		molec.-const.data
AlI_3	c,l	1931	Fischer [37]	273-480		
AlN	c	1936	Sato [37]	273-871		
	c	unpubl.	Mezakii,Tilleux,&Margrave [38]	?(>298)		
	c	unpubl.	Kelley [40]	<298-1800		
$Al(NO_3)_3 \cdot 6H_2O$	c	1944	Shomate and Kelley [37]	298		
			Beryllium Compounds			
Be		1880	Nilson and Pettersson [37]	273-573	2	
		1929	Lewis [37]	282-463	2	
	c	1929	Magnus and Holzmann [37]	295-1173	2	
	c	1934	Jaeger and Rosenbohm [37]	273-1338	2	
	c	1951	Ginnings,Douglas,&Ball [37]	273-1170	1	
	c,l	1956	Stull and Sinke [37]	298-2700	1	
	g	1957	Kolsky,Gilmer, & Gilles [37]		1	compilation
	c,l	1960	Kanter,Krasovitskaya,Kisel [15]	600-2200		
BeH	g	1950	Herzberg [37]			molec.-const.data
BeO	c	1880	Nilson and Pettersson [37]	273-373	2	
	c	1926	Magnus and Danz [37]	293-1175	1	

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
Beryllium Compounds (cont.)						
BeO (cont.)	c,ℓ	1960	Kandyba, Kantor, Krasovitskaya, and Fomichev [14]	1200-2820		Discussed in text of this chapter
	c	unpubl.	Victor and Douglas [38]	273-1173		
$BeAl_2O_4$	c	1880	Nilson and Pettersson [37]	273-373		
Be_2SiO_4	c	1939	Kelley [37]	298		
BeF	g	1950	Herzberg [37]	298-2000		molecular constant data
BeCℓ	g	1950	Herzberg [37]	298-2000		molec.-const.data
$BeCl_2$	c to ℓ	1960	Furby and Wilkinson [10]	672		melting point
Be_3N_2	c	1938	Sato [37]	273-773		
			Boron Compounds			
B	c	1893	Moissan and Gauthier [37]	273-507	2	
	c	1926	Magnus and Danz [37]	289-1174	2	
	c, amorph.	1956	NBS [37]		1	
	g	1956	NBS [37]		1	
	c,ℓ	1956	Stull and Sinke [37]		1	
	g	1957	Kolsky, Gilmer, and Gillis [37]		1	
	c, amorph.	1960	Wise, Margrave, and Altman [34]	500-1200		
	c	1961	McDonald and Stull [20]	298-1700		
	?	unpubl.	McDonald and Stull [38]	298-1700		
B_2	g	1956	NBS [37]			
MgB_2, MgB_4	c	1957	Swift and White [37]	298		
HfB_2	c	unpubl.	Mezaki, Tilleaux, and Margrave [38]	? (>298)		
BH	g	1950	NBS [37]	298-5000		molec.-const.data
B_2H_6	g	1956	NBS [37]	298-3000		
$B_{10}H_{14}$	g	1956	NBS [37]	298-1000		
$LiBH_4$	c	1953	Hallett and Johnston [37]	298		
KBH_4	c	1958	Douglas and Harman [37]	298-700		
BO	g	1956	NBS [37]	298-3000		
B_2O_3	ℓ, gls	1929	Samsoen [37]	491	2	
	glass	1931	Thomas and Parks [37]	306-622	2	
	c, ℓ, gls	1941	Southard [37]	298-1777	1	
HBO_2	g	1960	White, Mann, Walsh, and Sommer [33]			molec.-const.data
$LiBO_2$	c,ℓ	unpubl.	McDonald and Stull [38]	298-1700		
KBO_2	c	1841	Regnault [37]	290-373		
$K_2B_4O_7$	c	1841	Regnault [37]	290-373		
BF	g	1956	NBS [37]	298-3000	1	
	g	1959	Altman [1]			molec.-const.data
BF_3	g	1956	NBS [37]	298-2500		
BCℓ	g	1956	NBS [37]	298-3000	1	
	g	1959	Altman [1]			molec.-const.data
BCl_3	g	1956	NBS [37]	298-2500		
B_2Cl_4	c?	1958	Linevsky and Wartik [39]	?		
BBr	g	1956	NBS [37]	298-3000	1	
	g	1959	Altman [1]			molec.-conts.data

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
Boron Compounds (cont.)						
BBr_3	g	1956	NBS [37]			
BI_3	g	1958	Wentink and Tiensuu [37]			molec.-const.data
BN	c	1926	Magnus and Danz [37]	294-1174		
	c	unpubl.	McDonald and Stull [38]	298-1550		
	c(cubic)	unpubl.	Mezaki,Tilleux, & Margrave [38]	?(>298)		
B_4C	c	1949	King [37]	298-1726		
BH_3CO	g	1960	Sundaran and Cleveland [30]	100-1000		molec.-const.data
			Hafnium Compounds			
Hf		1950	Skinner,Beckett, & Johnston[37]		2	melting point
	c,ℓ	1951	Litton [37]		2	melting point
	c,ℓ	1952	Adenstedt [37]		2	melting point
	c,ℓ	1956	Deardorff and Hayes [37]		1	melting point
	c,ℓ	1956	Stull and Sinke [37]	298-3000	1	crit.compilation (estd.values)
HfO_2	c	1953	Orr [37]	298-1804		
HfF_4	c	1959	Kaylor,Walden, & Smith [16]	273-1103		
	c,g	1959	Kelley and King [37]	298-1500	1	estimated values
$HfCl_4$	c,g	1953	Orr [37]	298-486	1	
	c,g	1959	Kelley and King [37]		1	estimated values
$HfBr_4$	c,g	1959	Kelley and King [37]	298-700		estimated values
HfI_4	c,g	1959	Kelley and King [37]	298-800		estimated values
HfN	c	1959	Kelley and King [37]	298-2000		estimated values
HfC	c	1959	Kelley and King [37]	298-2000		estimated values
HfB_2	c	unpubl.	Mezaki,Tilleux,Margrave [38]	?(>298)		
			Lead Compounds			
Pb	c,ℓ	1849	Person [37]	293-724	2	
	c	1855	Bede [37]	287-445	2	
	c	1881	Lorenz [37]	293-403	2	
	c	1886	Spring [37]	286-566	2	
	c	1887	Naccari [37]	287-560	1	
	c	1892	LeVerrier [37]	273-573	2	
	c,ℓ	1904	Gläser [37]	290-670	2	
	c	1905	Stücker [37]	293-593	2	
	c	1910	Magnus [37]	289-529	1	
	c	1913	Griffiths and Griffiths [37]	273-371	1	
	c	1914	Schübel [37]	291-576	2	
	c,ℓ	1918	Wüst,Meuthen,& Durrer [37]	273-1273	1	
	c,ℓ	1919	Iitaka [37]	293-914	1	
	c,ℓ	1926	Awbery and Griffiths [37]	291-759	2	
	c,ℓ	1926	Umin [37]	273-1073	2	
	ℓ	1927	Dixon and Rodebush [37]	627-692	2	
	c,ℓ	1927	Klinkhardt [37]	323-773	2	
	c,ℓ	1928	Magnus and Oppenheimer [37]		2	heat of fusion
	c	1936	Bronson and Wilson [37]	273-393	1	
	c,ℓ	1948	Bartenev [37]	273-673	2	
	c,ℓ	1954	Douglas and Dever [37]	273-1173	1	
	ℓ	1955	Oelsen [37]	621-719	2	
	c,ℓ	1955	Oelsen, Oelsen, and Thiel [37]		1	heat of fusion
	c,ℓ	1955	Oelsen,Rieskamp, & Oelsen [37]		2	heat of fusion
	c,ℓ	1956	Stull and Sinke [37]	298-3000	1	crit.compilation
	c,ℓ,g		Hultgren and co-workers [37]	298-2100	1	crit.compilation
Pb_2	g	1950	Herzberg [37]	298-2000		molec.-const.data
PbH	g	1950	Herzberg [37]			molec.-const.data
PbO		1913	Magnus [37]	289-542	1	

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
Lead Compounds (cont.)						
PbO (cont.)	red	1942	Spencer and Spicer [37]	298-823	1	
	yellow	1942	Spencer and Spicer [37]	298-923	1	
	g	1950	Herzberg [37]	298-2000	1	molec.-const.data
		1954	Richardson and Webb [37]			heat of fusion
	red	1958	King [37]	51-298		
	yellow	1958	King [37]	51-298		
PbO_2		1923	Palmaer [37]	289-542	1	
	c	1950	Kelley [37]	298	1	crit. compilation
Pb_2O_3	c	1958	King [37]	51-298		
Pb_3O_4	c	1950	Kelley [37]	298		crit. compilation
$PbWO_4$	c	1957	Zharkova and Rezukhina [35]	401-749		
PbF_2	c	1909	Schottky [37]	273-307		
PbF	g	1950	Herzberg [37]	298-2000		molec.-const.data
PbCℓ	g	1950	Herzberg [37]	298-2000		molec.-const.data
$PbCℓ_2$	c,ℓ	1885	Ehrhardt [37]	273-813	1	
	c,ℓ	1909	Goodwin and Kalmus [37]	298-841	1	
	c	1910	Magnus [37]	288-623	1	
	c,ℓ	1936	Krestovnikov and Karetnikov [37]	288-1073	2	
PbBr	g	1950	Herzberg [37]			molec.-const.data
$PbBr_2$	c,ℓ	1885	Ehrhardt [37]	273-796	1	
	c,ℓ	1909	Goodwin and Kalmus [37]	298-860	1	
PbI	g	1950	Herzberg [37]	298-2000		molec.-const.data
PbI_2	c,ℓ	1885	Ehrhardt [37]	273-776	1	
	c	1910	Magnus [37]	290-523	1	
$Pb(NO_3)_2$	c	1865	Kopp [37]	289-320		
$PbCO_3$	c	1935	Kelley and Anderson [37]	298-800		crit.compilation (estd.values)
$PbSiO_3$	c,amorph.	1950	Kelley [37]	298		crit.compilation
Pb_2SiO_4	c	1959	King [37]	298		
			Lithium Compounds			
Li	c,ℓ	1905	Laemmel [37]	273-453	2	
	c,ℓ	1906	Kleiner and Thum [37]	298-455	2	
	c,ℓ	1907	Bernini [37]	273-430	2	
	ℓ	1950	Kubaschewski [37]	453-550	2	
	c to ℓ	1952	Kilner [37]	453	2	heat of fusion
	ℓ	1952	Redmond and Lones [37]	503-1374	2	
	c,ℓ	1955	Douglas,Epstein,Dever,&Howland[37]	273-1173	1	
	c,ℓ,g	1955	Evans,Jacobson,Munson,&Wagman[37]	298-3500	1	crit. compilation
	c,ℓ	1956	Schneider and Hilmer [37]	403-553	2	
	c,ℓ,g	1956	Stull and Sinke [37]	298-3000	1	crit.compilation
	g	1957	Kolsky,Gilmer, & Gillis [37]	298-8000	1	crit.compilation
Li_2	g	1955	Evans,Jacobson,Munson,&Wagman[37]	298-3500	1	crit. compilation
	g	1956	Stull and Sinke [37]	298-3000	1	crit. compilation
$LiAℓO_2$	c	1960	Christensen,Conway, & Kelley [5]	298-1796		
$LiBH_4$	c	1953	Hallett and Johnston [37]	up to 298		
$LiBO_2$	c,ℓ	unpubl.	McDonald and Stull [38]	298-1700		
LiK	g	1950	Herzberg [37]	298-2000		molec.-const.data
LiCℓ-KCℓ	ℓ	unpubl.	Douglas and Harman [38]	628-1073		eutectic mixture
$LiTiO_3$	c?	1960	Christensen,Conway, & Kelley [5]	?		

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
Lithium Compounds (cont.)						
Li_2TiO_3	c(α),c(β),ℓ	unpubl.	Bonnickson [37]	298-1850		
LiH	c	1950	Kelley [37]	298		crit. compilation
	g	1950	Herzberg [37]	298-2000		molec.-const.data
Li_2O	c	1955	Shomate and Cohen [37]	298-1045		
LiOH	c	1950	Bauer,Johnston, and Kerr [37]	up to 298	1	
	c,ℓ	1954	Powers and Blalock [37]	273-1213	2	
	c,ℓ	1955	Shomate and Cohen [37]	298-879	1	
LiF	c,ℓ	1954	Douglas and Dever [37]	273-1169	1	
	c to ℓ	1956	Petit and Cremieu [37]			heat of fusion
	c?	1958	Sense and Stone [37]	?		
	g	1959	Altman [1]	0-6000		molec.-const.data
$LiHF_2$	c	1961	Westrum and Burney [32]	6-305		
LiCℓ	c	1856	Regnault [37]	286-370	2	
	c	1926	Hüttig and Wehling [37]	276-363	1	
	g	1957	Klemperer and Rice [37]		1	molec.-const.data
	g	1959	Altman [1]	0-6000		molec.-const.data
	c,ℓ	1959	Rodigina,Gomel'skii,&Luginina[25]	367-1075		
	c to ℓ	1960	Dworkin and Bredig [7]	883		heat of fusion
	c	1960	Shirley [27]	15-325		
	c,ℓ	unpubl.	Douglas & Harman [38]	273-1173		
$LiCℓ{\cdot}H_2O$	c	1929	Slonim & Hüttig [37]	279-360		
LiBr	c	1926	Hüttig and Wehling [37]	276-364	1	
	c,ℓ,g	1957	Klemperer and Rice [37]	298-2000	1	
	c,ℓ	1958	Blanc [3]	819		data for transitions
	g	1959	Altman [1]	0-6000		molec.-const.data
	c to ℓ	1960	Dworkin and Bredig [7]			heat of fusion
$LiBr{\cdot}H_2O$	c	1929	Slonim & Hüttig [37]	278-368		
LiI	c	1926	Hüttig and Wehling [37]	276-373	1	
	c,ℓ,g	1957	Klemperer and Rice [37]	298-2000	1	
	c to ℓ	1960	Dworkin and Bredig [7]			heat of fusion
LiI hydrates	c	1929	Slonim & Hüttig [37]	277-359		
Li_3N	c	1939	Sato [37]	273-773		
$LiNO_3$	c,ℓ	1909	Goodwin & Kalmus [37]	298-576		
Li_2CO_3	c	1936	Brown & Lattimer [37]	298		
Magnesium Compounds						
Mg	c	1881	Lorenz [37]	293-403	2	
	c	1905	Stücker [37]	293-923	2	
	c	1910	Magnus [37]	289-812	2	
	c	1914	Schübel [37]	291-773	1	
	c	1924	Eastman,Williams, & Young [37]	293-873	1	
	c,ℓ	1926	Awberry & Griffiths [37]	289-1023	1	
	c,ℓ	1928	Zalesinskii and Zulinskii [37]	295-1048	2	
	c	1930	Losana [37]	293-573	2	
	c	1931	Seekamp [37]	291-773	1	
	c	1935	Poppema and Jaeger [37]	273-823	2	
	c	1936	Jaeger and Poppema [37]	273-823	1	
	ℓ	1950	Kubaschewski [37]	923-1133	2	
	c,ℓ	1955	Stull and McDonald [37]	700-1100	1	
	c,ℓ,g	1956	Stull and Sinke [37]	298-3000	1	
	c	1957	Wallace,Craig,Saba, & Sterrett[37]	298-543	1	
	c	1959	Mannchen & Bronkessel [18]	12-300		
	c,ℓ		Hultgren [37]	298-1500	1	crit. compilation

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
Magnesium Compounds (cont.)						
Mg_4Al_3	c	1910	Schimpff [37]	290-373		
$MgAl_2O_4$	c	1955	Bonnickson [37]	298-1806		
$KMg_3AlSi_3O_{10}F_2$	c,ℓ	1959	Kelley,Barany,King,&Christensen [37]	298-1804		
$MgBr_2$	c	1957	Swift & White [37]	298		
MgB_4	c	1957	Swift & White [37]	298		
$6MgO \cdot MgCl_2 \cdot 8B_2O_3$	c(α),c(β)	1883	Mallard [37]	287-612		
	c(α),c(β)	1892	Kroeker [37]	273-573		
$MgCl_2 \cdot KCl$	c,ℓ	1935	Lyashenko [37]	290-797	1	
		1936	Auzhbikovich [37]	273-1073	2	
$MgTiO_3$	c	1946	Naylor & Cook [37]	298-1720		
Mg_2TiO_4	c	1952	Orr & Coughlin [37]	298-1818		
$MgTi_2O_5$	c	1952	Orr & Coughlin [37]	298-1812		
MgH	g	1950	Herzberg [37]	298-2000	1	molec.-const.data
	g	1958	Veits,Gurvich, & Rtishcheva[31]			calculated values
MgO	c	1913	Magnus [37]	288-1040	1	
	c	1914	Steger [37]	289-678	2	
	c	1919	Wartenberg & Witzel [37]	415-2780	2	
	c	1932	Wilkes [37]	303-2073	1	
	c	1935	Lyashenko [37]	290-1466	2	
	c	1936	Auzhbikovich [37]	298-973	2	
	c	1950	Arthur [37]	296-1104	2	
	g	1958	Veits,Gurvich,&Rtishcheva [31]			calculated values
	c	1959	Barron,Berg,&Morrison [2]	?		
	c(macro)	unpubl.	Victor & Douglas [38]	273-1173		
$Mg(OH)_2$	c	1865	Kopp [37]	292-323	2	
	c	1935	Laschshenko & Kompanskii [37]	283-667	1	
MgF_2	c	1934	Krestovnikov & Karentnikov [37]	288-1273	2	
	c,ℓ	1945	Naylor [37]	298-1760	1	
	g	1950	Herzberg [37]			molec.-const.data
$MgCl_2$	c,ℓ	1935	Lyashenko [37]	292-1025	2	
	c,ℓ	1936	Auzhbikovich [37]	273-1073	2	
	c,ℓ	1943	Moore [37]	298-1428	1	
	g	1950	Herzberg [37]	298-1700		molec.-const.data
$MgCl_2$ hydrates	c	1945	Kelley [37]			estimated equations
MgOHCℓ	c	1945	Kelley [37]	298-850		estimated equations
MgBr	g	1950	Herzberg [37]	298-2000		molec.-const.data
MgI	g	1950	Herzberg [37]	298-2000		molec.-const.data
Mg_3N_2	c(α)	1938	Sato [37]	273-690	2	
	c(α,β,γ)	1949	Mitchell [37]	298-1273	1	
$Mg(NO_3)_2$	c	1944	Shomate [37]	298-623		
$MgCO_3$	c	unpubl.	Shomate [37]	298-743		
Mg_2Si	c	1910	Schimpff [37]	290-373		
$MgSiO_3$		1919	White [37]	273-1173	1	amphibole-type
		1919	White [37]	273-773	1	pyroxene-type
	glass	1919	White [37]	273-973	1	
	c	1932	Wagner [37]	273-1570		clinoenstatite
Mg_2SiO_4		1953	Orr [37]	298-1808		forsterite

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
			Mercury Compounds			
Hg	ℓ	1818	Dulong and Petit [37]	273-573	2	
	ℓ	1888	Naccari [37]	289-499	2	
	ℓ	1889	Milthaler [37]	273-473	2	
	ℓ	1902	Gaede [37]	290-366	2	
	ℓ	1912	Lussana [37]	291-435	2	
	ℓ	1927	Dixon and Rodebush [37]	314-430	2	
	ℓ,g	1951	Douglas,Ball,andGinnings[37]	298-773	1	
	ℓ,g	1956	Stull and Sinke [37]	298-3000	1	crit. compilation
	g	1957	Kolsky,Gilmer, & Gilles [37]	298-8000	1	crit. compilation
Hg_2	g	1950	Herzberg [37]	298-2000		molec.-const.data
HgH	g	1950	Herzberg [37]	298-2000		molec.-const.data
HgO	(red)	1953	Bauer and Johnston [37]	298		
HgF	g	1950	Herzberg [37]	298-2000		molec.-const.data
$HgC\ell$	g	1950	Herzberg [37]	298-2000	1	molec.-const.data
	c	1950	Kelley [37]	298	1	crit. compilation
$HgC\ell_2$	c	1841	Regnault [37]	285-372		
	g	1956	Klemperer and Lindeman [37]	298-1000		molec.-const.data
HgBr	g	1950	Herzberg [37]	298-2000		molec.-const.data
$HgBr_2$	g	1956	Klemperer and Lindeman [37]	298-1000		molec.-const.data
HgI	c	1841	Regnault [37]	289-372		
	g	1950	Herzberg [37]	298-2000		molec.-const.data
HgI_2	c(α),c(β),ℓ	1907	Guinchant [37]	273-600	1	
	g	1936	Landolt-Börnstein [37]		1	molec.-const.data
	g	1956	Klemperer and Lindeman [37]		1	molec.-const.data
			Potassium Compounds			
K	c,ℓ	1906	Bernini [37]	273-430	2	
	c,ℓ	1913	Rengade [37]	273-373	2	
	c,ℓ	1927	Dixon and Rodebush [37]	363-454	1	
	c,ℓ	1939	Carpenter and Stewart [37]	273-610	1	
	c,ℓ	1946	NBS [37]	298-500	1	
	c,ℓ	1952	Douglas,Ball,Ginnings,andDavis[37]	298-1070	1	
	c,ℓ,g	1955	Evans,Jacobson,Munson [37]	273-2500	1	a critical survey paper
	c,ℓ,g	1956	Stull and Sinke [37]	298-3000	1	critical compilation
	g	1953	Griffel [37]	298-3000	1	
KLi	g	1950	Herzberg [37]	298-2000		molec.-const.data
	g	1957	Kolsky,Gilmer, and Gillis [37]	298-8000	1	crit. compilation
KH	g	1950	Herzberg [37]	298-2000		molec.-const.data
KBH_4	c	1958	Douglas and Harman [37]	298-700		
KO_2	c	1953	Todd [37]	298		
KBO_2	c	1841	Regnault [37]	290-372		
$K_2B_4O_7$	c	1842	Regnault [37]	290-372		
KF	c,ℓ	1935	Lyashenko [37]	290-1187	1	
	c	1949	Westrum and Pitzer [37]	298-530	1	
	g	1950	Herzberg [37]			molec.-const.data
	c to ℓ	1956	Petit and Cremieu [37]			heat of fusion
KHF_2	c(α),c(β),ℓ	1949	Westrum and Pitzer [37]	298-523		
$KC\ell$	c,ℓ	1906	Plato [37]	293-1208	2	
	c	1913	Magnus [37]	289-823	1	
	c,ℓ	1935	Lyashenko [37]	290-1127	1	
	c	1940	Popov, Skuratov, Nikonova [37]	293-923	2	
	c	1951	Mustajoki [37]	334-721	1	

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
Potassium Compounds (cont.)						
$KC\ell$ (cont.)	c	1956	Strelkov [29]	?		
	g	1957	Rice and Klemperer	298-2000		
	c?	1958	Chernyaev,Palkin, andBaranova [4]	?		
	c to ℓ	1960	Dworkin and Bredig [7]			heat of fusion
	c,ℓ	unpubl.	Douglas and Harman [38]	273-1173		
$KC\ell \cdot LiC\ell$	ℓ	unpubl.	Douglas and Harman [38]	628-1073		eutectic mixture
$KMgC\ell_3$	c,ℓ	1935	Lyashenko [37]	290-797	1	
	c,ℓ	1936	Auzhbikovich [37]	273-1073	2	
$KC\ell O_3$	c	1934	Latimer,Schutz, and Hicks [37]	298		
$KC\ell O_4$	c	1930	Latimer and Ahlberg [37]	298		
KBr	c	1913	Magnus [37]	289-543	1	
	c	1951	Mustajoki [37]	325-702	2	
	c	1953	Cooper [37]	298-993	1	
	c	1954	Voskresenskaya & Banashek [37]	697-751	2	
	g	1957	Rice and Klemperer [37]	298-2000		
	c to ℓ	1958	Blane [3]	1005		data for transitions
	c to ℓ	1960	Dworkin and Bredig [7]			heat of fusion
$KBrO_3$	c	1934	Ahlberg and Latimer [37]	298		
KI	g	1950	Herzberg [37]	298-2000		molec.-const.data
	c	1953	Cooper [37]	298-973		
	c to ℓ	1960	Dworkin and Bredig [7]			heat of fusion
KIO_3	c	1934	Ahlberg and Latimer [37]	298		
KNO_3	ℓ	1847	Person [37]	623-708	2	
	c(α),c(β),ℓ	1909	Goodwin and Kalmus [37]	298-684	1	
K_2CO_3	c	1841	Regnault [37]	295-373		
$KA\ell SiO_4$	c	1953	Kelley,Todd,Orr,King,&Bonnickson [37]	298		
$KA\ell Si_2O_6$	c	1953	Kelley,Todd,Orr, & Bonnickson [37]	298		
$KA\ell Si_3O_8$	c,gls	1919	White [37]	273-1373		
$KMg_3A\ell Si_3O_{10}F_2$	c,ℓ	1959	Kelley,Barany,King,&Christensen [37]	298-1804		
			Titanium Compounds			
Ti	c to ℓ	1886	Oriani and Jones [37]		1	melting point
	c(α)	1887	Nilson and Pettersson [37]	273-713	2	
	c(α),c(β)	1936	Jaeger,Rosenbohm, & Fonteyne [37]	293-1476	1	
	g	1951	Gillis and Wheatly [37]	298-5000	1	
		1954	Kolsky and Gillis [37]	298-8000	1	
	c to ℓ	1954	Schoefield [37]		2	heat of transition
	c to ℓ	1956	Deardorff and Hayes [37]		1	melting point
	c (α),c(β)	1956	Stull and Sinke [37]	298-3000	1	crit. compilation
	g	1957	Kolsky,Gilmer, & Gillis [37]	298-8000	1	crit.compilation
	c	1959	Golutvin [11]	388-1402		
	c(α),c(β)	1959	Kelley and Mah [37]	298-2000	1	
TiB_2	c	1957	Walker,Ewing, & Miller [37]	303-977		
TiO	c(α),c(β)	1946	Naylor [37]	298-1771		
TiO_2	c	1887	Nilson and Pettersson [37]	273-713	2	
	anatase	1946	Naylor [37]	298-1305		
	rutile	1946	Naylor [37]	298-1746		
	c	1950	Arthur [37]	295-1072	2	
	c	1956	Lietz [37]	290-1283	2	
Ti_2O_3	c(α),c(β)	1946	Naylor [37]	298-1750		

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
Titanium Compounds (cont.)						
Ti_3O_5	c(α),c(β)	1946	Naylor [37]	298-1340		
Al_2TiO_5	c	1955	Bonnickson [37]	298-1803		
$LiTiO_3$	c?	1960	Christensen, Conway, & Kelley [5]	?		
Li_2TiO_3	c(α),c(β),ℓ	unpubl.	Bonnickson [37]	298-1850		
$MgTiO_3$	c	1946	Naylor and Cook [37]	298-1720		
Mg_2TiO_4	c	1952	Orr and Coughlin [37]	298-1818		
$MgTi_2O_5$	c	1952	Orr and Coughlin [37]	298-1812		
TiF_4	c	1961	Euler and Westrum [8]	6-304		estimated values
TiCℓ	g	1950	Herzberg [37]	298-2000		molec.-const.data
$TiCℓ_2$	c	1959	Kelley and Mah [37]	298-1200		
$TiCℓ_3$	c	unpubl.	Christensen [37]	298-1002		
$TiCℓ_4$	g	1938	Herman [37]	273-573	1	molec.-const.data
	ℓ	1955	Hawkins and Carpenter [37]	298-500	1	
	ℓ,g	1959	Kelley and Mah [37]		1	
$TiBr_2$	c	1959	Kelley and Mah [37]	298-1200		estimated values
$TiBr_3$	c	1959	Kelley and Mah [37]	298-1200		estimated values
$TiBr_4$	c,ℓ,g	1954	Skinner, Johnston, & Beckett [37]	298-3000	1	
	c,ℓ,g	1959	Kelley and Mah [37]		1	molec.-const.data
	g	1960	Miller and Carlson [23]	298-600		molec.-const.data
TiI_2	c	1959	Kelley and Mah [37]	298-1200		estimated values
TiI_3	c	1959	Kelley and Mah [37]	298-1200		estimated values
TiI_4	c,ℓ,g	1959	Kelley and Mah [37]	298-2000		estimated values
TiN	c	1938	Sato [37]	273-773	2	
	c	1946	Naylor [37]	298-1738	1	
TiC	c	1946	Naylor [37]	298-1735		
TiSi	c	1959	Golutvin [11]	378-1352		
$TiSi_2$	c	1959	Golutvin [11]	407-1181		
Ti_5Si_3	c	1959	Golutvin [11]	381-1170		
			Tungsten Compounds			
W	c	1901	Defacqz and Guichard [37]	288-696	2	
	c	1912	Corbino [37]	1073-2173	2	
	c	1912	Pirani [37]	613-1623	2	
	c	1918	Gaehr [37]	1416-2465	2	
	c	1918	Worthing [37]	1200-2400	2	
	c	1918	Wüst, Meuthen, and Durrer [37]	273-1773	2	
	c	1922	Smith and Bigler [37]	2368-2485	2	
	c	1925	Bockstahler [37]	2371-2486	2	
	c	1926	Magnus and Danz [37]	288-1173	2	
	c	1927	Jones and Langmuir [37]	273-3655	2	
	c	1928	Zwikker [37]	1415-2521	2	
	c	1929	Bronson and Chisholm [37]	293-553	2	
	c	1929	Magnus and Holzmann [37]	294-1174	1	
	c	1928,-30,-32	Jaeger and Rosenbohm [37]	273-1873	1	
	c	1933	Bronson, Chisholm, and Dockerty [37]	273-773	1	
	c	1956	Stull and Sinke [37]	298-3000	1	crit. compilation
	c?	1958	DeSorbo [6]	?		
	c	1961	Hoch and Johnston [41]	1000-3000		

TABLE 1 (continued)

Formula	Physical State	Year Reported	Author(s) and Reference No.	Temp. Range(°K)	Rating by [37]	Comments
Tungsten Compounds (cont.)						
WO_2	c	1960	King,Willer, & Christensen [36]	53-1800		
WO_3	c	1943	Seltz, Dunkerley, & DeWitt [37]	298	1	
	c(α),c(β),ℓ	1960	King, Willer, & Christensen [36]	53-1836		
$WPbO_4$	c	1957	Zharkova and Rezukhina [35]	401-749		
WF_6	g	1952	Burke,Smith, & Nielsen [37]	298-1000	1	molec.-const.data
	g	1953	Gaunt [37]	298-500	1	molec.-const.data
WSi_2	c	unpubl.	Mazaki,Tilleny, & Margrave [38]	?(>298)		
			Zirconium Compounds			
Zr	c	1934	Jaeger and Veenstra [37]	294-1074	1	
	c	1950	Coughlin and King [37]	298-1371		
	c to ℓ	1952	Adenstedt [37]		2	melting point
	c	1952	Redmond and Lones [37]	273-1309	1	
	c to ℓ	1954	Oriani and Jones [37]		1	melting point
	c to ℓ	1956	Deardorff and Hayes [37]		1	melting point
	g	1956	Kolsky and Gillis [37]	298-800	1	
	c,ℓ	1956	Stull and Sinke [37]	298-3000	2	crit. compilation
	g	1957	Kolsky,Gilmer, & Gillis [37]	298-8000	1	crit. compilation
	c	1957	Scott [37]	363-1223	1	
	c	1958	Douglas and Victor [37]	273-1173	1	
	c(α),c(β)	unpubl.	Skinner and Johnston [38]	1000-2100		
ZrH	c	1958	Douglas and Victor [37]	273-1173		
ZrH_2	c	1961	Flotow and Osborne [9]	5-350		
ZrO_2	c(α),c(β)	1920	Bradshaw and Emery [37]	298-1673	1	
	c(α)	1934	Jaeger and Veenstra [37]	294-1073	2	
	c(α)	1950	Arthur [37]	300-1265	1	
	c(α),c(β)	1950	Coughlin and King [37]		2	
ZrF_4	c,ℓ	unpubl.	McDonald, Stull, & Sinke [20]	284-1226		
$ZrCl_4$	c	1950	Coughlin and King [37]			estimated values
	g	unpubl.	Kelley [37]			
ZrN	c	1950	Coughlin and King [37]	298-1672		
Zr_3N_2	c	1938	Sato [37]	273-773		
Zr_5Si_3	c	unpubl.	Mezaki,Tilleuy, & Margrave [38]	?(>298)		
$ZrSiO_4$	c	1950	Coughlin and King [37]	298-1823		
	c	unpubl.	Victor and Douglas [38]	273-1173		

REFERENCES

[1] Altman, R. L., Thermodynamic Functions of Some Gaseous Diatomic Halides of Aℓ, B and Li, J. Chem. Phys. 31, 1035 (1959).

[2] Barron, T. H. K., Berg, W. T. and Morrison, J. A., Proc. Roy. Soc. A250, 70 (1959).

[3] Blanc, M., Chaleurs de Fusion de Quelques Halogénures (Bromures Alcalins), Compt. rend. 246, 570 (1958).

[4] Chernyaev, I. I., Palkin, V. A. and Baranova, R. A., Zhur. Neorg. Khim. 3, 1512 (1958).

[5] Christensen, A. U., Conway, K. C. and Kelley, K. K., U. S. Bureau of Mines Rept. of Investigations No. 5565 (1960).

[6] DeSorbo, W., J. Phys. Chem. 62, 965 (1958).

[7] Dworkin, A. S. and Bredig, M. A., The Heats of Fusion of the Alkali Metal Halides, J. Phys. Chem. 64, 269 (1960).

[8] Euler, R. D. and Westrum, E. F., Heat Capacity and Thermodynamic Properties of Titanium Tetrafluoride from 6 to 304°K, J. Phys. Chem. 65, 132 (1961).

[9] Flotow, H. E. and Osborne, D. W., Heat Capacities and Thermodynamic Functions of ZrH_2 and ZrD_2 from 5-350°K and the Hydrogen Vibration Frequency in ZrH_2, J. Chem. Phys. 34, 1418 (1961).

[10] Furby, E. and Wilkinson, K. L., The Melting and Boiling Points of $BeC\ell_2$ and an Investigation of the $NaC\ell$-$BeC\ell_2$ System, J. Inorg. Nucl. Chem. 14, 123 (1960).

[11] Golutvin, Yu. M., Heat Contents and Heat Capacities in the Titanium-Silicon System, Zhur. Fiz. Khim. 33, 1798 (1959).

[12] Gomel'skiy, K. Z., The Enthalpy of Corundum in the Temperature Range from 100 to 900°C, Zhur. Fiz. Khim. 32, 1859 (1958).

[13] Hoch, M. and Johnston, H. L. See Bulletin of Chemical Thermodynamics No. 4 (1961).

[14] Kandyba, Kantor, Krasovitskaya, and Fomichev, Determination of Enthalpy and Cp of BeO in the 1200-2820°K Temperature Range, Dokl. Akad. Nauk. 131, 566 (1960).

[15] Kantor, P. B., Krasovitskaya, R. M. and Kisel, A. N., Enthalpy and Specific Heat of Be at 600-2200°K, Fiz. Metall. i Metallov 10, 835 (1960)

[16] Kaylor, C. E., Walden, G. E. and Smith, D. F., High Temperature Heat Content and Entropies of Hafnium Tetrafluoride and Rubidium Fluoride, J. Am. Chem. Soc. 81, 4172 (1959).

[17] Kirillin, V. A., Sheindlin, A. E. and Chekhovskoi, V. J., Enthalpy of Corundum from 500-2000°, Doklady Akad. Nauk. 135, 125 (1960).

[18] Mannchen, Von W. and Bornkessel, K., Die Atomwärme Cp von Reinem und Wasserstoff-haltigem Mg Zwischen 12-300°K, J. Naturforsch. 14A, 925 (1959).

[19] Margrave, J. L. and Grimley, R. T., The High Temperature Heat Contents of Sodium Ferrite and α-Aluminum Oxide, J. Phys. Chem. 62, 1436 (1958).

[20] McDonald, R. A., Stull, D. R. and Sinke, G. C. (Dow Chemical Co.), Preprint on ZrF_4 paper to T. B. Douglas, July, 1961.

[21] McKeown, J. J., Ph.D. Thesis, Iowa State College, Dissertation Abstr. 19, 57 (1958).

[22] Medvedev, V. A., Zhur. Fiz. Khim., 32, 1690 (1958).

[23] Miller, F. A. and Carlson, G. L., Infrared and Raman Spectra of $TiBr_4$, Spectrochim. Acta, 16, 6 (1960).

[24] Olette, Michel, Nernst-Magnus Calorimeter for Measuring Heat Contents up to 1600°, Compt. rend. 244, 891 (1957).

[25] Rodigina, E. N., Gomel'skii, K. Z. and Luginina, U. F., Enthalpy and Specific Heat of LiCℓ at High Temperature, Rus. J. of Inorganic Chem. 4, 442 (1959).

[26] Romanovsky, U. A. and Tarasov, V. V., Solid State Physics, Akad. Nauk. USSR, 2, (No. 6), 1289, 1294 (1960).

[27] Shirley, D. A., The Heat Capacity of LiCℓ from 15-325°K, J. Am. Chem. Soc. 82, 3841 (1960).

[28] Shmidt, N. E. and Sokolov, V. A., Adiabatic Calorimeter for the Determination of the Specific Heats between 30° and 750° of Substances with Low Thermal Conductivity: Cp of Corundum, Zhur. Neorg. Khim. 5, 1641 (1960).

[29] Strelkov, P. G., Izmeritel'naya Tekh., No. 1, p. 22 (1955); Refarat Zhur., Khim., Abstr. No. 62011.

[30] Sundaran, S. and Cleveland, F. F., Potential Energy Constants, Rotational Distortion Constants, and Thermal Properties of BH_3CO and BDCO, J. Chem. Phys. 32, 166 (1960).

[31] Veits, I. V., Gurvich, L. V. and Rtishcheva, N. P., Thermodynamic Properties of Mg, Ca, Sr, Ba, Their Oxides and Monohydrides in the Gaseous State, Zhur. Fiz. Khim. 32, 2532 (1958).

[32] Westrum, E. F. and Burney, G. A., Thermodynamics of the Monohydrogen Difluorides. II. Heat Capacities of Lithium and Sodium Monohydrogen Difluorides from 6 to 305°K, J. Phys. Chem. 65, 344 (1961).

[33] White, D., Mann, D. E., Walsh, P. N. and Sommer, A., Infrared Emission Spectrum of Gaseous HBO_2, J. Chem. Phys. 32, 488 (1960).

[34] Wise, S. S., Margrave, J. L. and Altman, R. L., The Heat Content of Boron at High Temperatures, J. Phys. Chem. 64, 915 (1960).

[35] Zharkova, L. A. and Rezukhina, T. N., The Heat Capacities of Lead and Cadmium Tungstates at High Temperatures, Zhur. Fiz. Khim. 31, 2278 (1957).

[36] King, E. G., Willer, W. W. and Christensen, A. V., Thermodynamics of Some Oxides of Molybdenum and Tungsten, Bur. of Mines Report of Investigations No. 5664 (1960).

[37] Kelley, K. K., "Contributions to the Data on Theoretical Metallurgy: XIII. High-Temperature Heat-Content, Heat-Capacity, and Entropy Data for the Elements and Inorganic Compounds", Bur. Mines Bull. 584, U. S. Government Printing Office, Washington, D. C., 1960.

[38] Bulletin of Chemical Thermodynamics, "No. 4, 1961", International Union of Pure and Applied Chemistry, Commission on Thermodynamics, Subcommissions on Experimental Thermochemistry and on Experimental Thermodynamics, Mar. 20, 1961, 151 pages.

[39] Linevsky, M. J., and Wartik, T., J. Phys. Chem. 62, 1146 (1958).

[40] Kelley, K. K. (private communication, 1960).

[41] Hoch, M., and Johnston, H. L., A High Temperature Drop Calorimeter. The Heat Capacities of Tantalum and Tungsten between 1000° and 3000°K, J. Phys. Chem. 65, 855 (1961).

[42] Hoch, M., and Johnston, H. L., The Heat Capacity of Aluminum Oxide from 1000 to 2000° and of Thorium Dioxide from 1000 to 2500°, J. Phys. Chem. 65, 1184 (1961).

CHAPTER 6

THERMODYNAMIC PROPERTIES OF BORATES

by William H. Evans

The available data leading to values for the heats of formation at 25° C of the crystalline borates have been reviewed, and "best" values are summarized below.

Li_2O - B_2O_3 system

ΔHf $B_2O_3(c)$ = -305.34±0.3 kcal/mole (NBS Report 7093)

ΔHf $Li_2O(c)$ = -142.4±0.8 kcal/mole (NBS Circular 500)

Based on heats of solution in 2N HNO_3, reported by L. Shartsis and W. Capps (J. Am. Ceram. Soc. 37, 27 (1954)) and G. S. Smith (Ph.D. Thesis, Penn. State Univ. (1959)). The agreement is good (0.1%) in ΔHf.

$Li_2O \cdot B_2O_3$ [$2LiBO_2$] (extrapolated)

ΔHf = -40.4±1.0 kcal/mole	from oxides
= -488.2±1.3 kcal/mole	from elements

$Li_2O \cdot 2B_2O_3$ [$Li_2B_4O_7$]

ΔHf = -54.9±0.7 kcal/mole	from oxides
= -808.0±1.4 kcal/mole	from elements

$Li_2O \cdot 3B_2O_3$

ΔHf = -58.6±1.0 kcal/mole	from oxides
= -1117.0±1.6 kcal/mole	from elements

$Li_2O \cdot 4B_2O_3$

ΔHf = -56.9±1.3 kcal/mole	from oxides
= -1420.7±1.9 kcal/mole	from elements

Shartsis and Capps, and Smith both give data for glasses.

Na_2O-B_2O_3 system

ΔHf $B_2O_3(c)$ = -305.34 ±0.3 kcal/mole (NBS Report 7093)
ΔHf $Na_2O(c)$ = -99.4 ±0.5 kcal/mole (NBS Circular 500)

Based on heats of solution in 2N HNO_3, reported by L. Shartsis and W. Capps (J. Am. Ceram. Soc. 37, 27 (1954)), G. S. Smith (Ph. D. Thesis, Penn. State Univ. (1959)), and by G. Grenier and D. White (J. Phys. Chem. 61, 1681 (1957)).

$Na_2O \cdot B_2O_3$ [$2NaBO_2$]

The data of Grenier and White, measured directly on the compound, lead to $\Delta Hf = -472.0 \pm 1.3$ kcal/mole (from elements). The extrapolated data of Shartsis and Capps (which agree very well with the data of Smith for $Na_2O \cdot 2B_2O_3$ and $Na_2O \cdot 3B_2O_3$) lead to -462.7 ± 1.4 kcal/mole. The value from Grenier andWhite seems to be too negative; it leads to a value, from the oxides, of -67.3 kcal/mole, which gives -16.8 kcal/gram-atom oxygen. The corresponding Li and K values are -10.1 and -18.4; the extrapolated value for Na is -14.5. For consistency, we select the extrapolated value.

$Na_2O \cdot B_2O_3$ [$2NaBO_2$] (extrapolated)

$\Delta Hf = -58.0 \pm 1.0$ kcal/mole	from oxides
$= -462.7 \pm 1.4$ kcal/mole	from elements

$Na_2O \cdot 2B_2O_3$ [$Na_2B_4O_7$]

$\Delta Hf = -76.1 \pm 0.7$ kcal/mole	from oxides
$= -786.2 \pm 1.1$ kcal/mole	from elements

$Na_2O \cdot 3B_2O_3$

$\Delta Hf = -85.3 \pm 1.0$ kcal/mole	from oxides
$= -1100.7 \pm 1.5$ kcal/mole	from elements

$Na_2O \cdot 4B_2O_3$

$\Delta Hf = -91.5 \pm 1.3$ kcal/mole	from oxides
$= -1412.3 \pm 1.8$ kcal/mole	from elements

Shartsis and Capps, and Smith both give data for glasses.

Entropies have been reported for

$Na_2O \cdot B_2O_3$ $S^\circ_{298} = 35.14$ cal/deg mole
(Grenier and Westrum, J. Am. Chem. Soc. 78, 6226 (1956))

$Na_2O \cdot 2B_2O_3$ $S^\circ_{298} = 45.30$ cal/deg mole
(Westrum and Grenier, J. Am. Chem. Soc. 79, 1799 (1957))

K_2O - B_2O_3 system

ΔHf $B_2O_3(c) = -305.34 \pm 0.3$ (NBS Report 7093)

ΔHf $K_2O(c) = -86.4 \pm 0.5$ kcal/mole (NBS Circular 500)

Based on heats of solution in 2N HNO_3, reported by L. Shartsis and W. Capps (J. Am. Ceram. Soc. 37, 27 (1954)).

$K_2O \cdot B_2O_3$ [$2KBO_2$] (extrapolated)

$\Delta Hf = -73.5 \pm 1.0$ kcal/mole $K_2O \cdot B_2O_3$	from oxides
$= -465.2 \pm 1.2$ kcal/mole	from elements

$K_2O \cdot 2B_2O_3$ [$K_2B_4O_7$]

$\Delta Hf = -99.3 \pm 0.7$ kcal/mole	from oxides
$= -796.3 \pm 1.1$ kcal/mole	from elements

$K_2O \cdot 3B_2O_3$

$\Delta Hf = -110.1 \pm 1.0$ kcal/mole — from oxides
$= -1112.5 \pm 1.5$ kcal/mole — from elements

$K_2O \cdot 4B_2O_3$

$\Delta Hf = -118.3 \pm 1.3$ kcal/mole — from oxides
$= -1426.1 \pm 1.8$ kcal/mole — from elements

Shartsis and Capps also give data for glasses.

CaO-B_2O_3 system

ΔHf $CaO(c) = -151.9 \pm 0.3$ kcal/mole (NBS Circular 500)

ΔHf $B_2O_3(c) = -305.34 \pm 0.3$ kcal/mole (NBS Report 7093)

Heats of solution in 1N HCℓ are reported by D. R. Torgeson and C. H. Shomate (J. Am. Chem. Soc. 69, 2103 (1947)).

$CaO \cdot B_2O_3$ $[Ca(BO_2)_2]$

$\Delta Hf = -29.42 \pm 0.05$ kcal/mole — from oxides
$= -486.7 \pm 0.5$ kcal/mole — from elements

$CaO \cdot 2B_2O_3$ $[CaB_4O_7]$

$\Delta Hf = -42.93 \pm 0.05$ kcal/mole — from oxides
$= -805.5 \pm 0.7$ kcal/mole — from elements

$2CaO \cdot B_2O_3$

$\Delta Hf = -45.76 \pm 0.05$ kcal/mole — from oxides
$= -654.9 \pm 0.7$ kcal/mole — from elements

High temperature heat contents - King, Torgeson, and Cook (J. Am. Chem. Soc. 70, 2160 (1948)).

$CaO \cdot 2B_2O_3$ (gls) Data of King, Torgeson, and Cook.

$\Delta Hf = -30.29 \pm 0.05$ kcal/mole — from oxides
$= -792.9 \pm 0.7$ kcal/mole — from elements

N. S. Kurnakov, A. V. Nikolaev, and A. G. Chelishcheva, Compt. rend. acad. sci. U.R.S.S. 16, 92 (1937) report the heat of solution of dehydrated inyoite, $Ca_2B_6O_{11}$ $(2CaO \cdot 3B_2O_3)$ in 4N H_2SO_4.

ΔHf $2CaO \cdot 3B_2O_3 = -58.2 \pm 1.0$ kcal/mole — from oxides
$= -1278. \pm 4.$ kcal/mole — from elements

A second sample, fired at high temperature, gave

$\Delta Hf = -118.2 \pm 1.0$ kcal/mole — from oxides
$= -1338. \pm 4.$ kcal/mole — from elements

Interpolation in the data of Torgeson and Shomate gives

$\Delta Hf = -73.0 \pm 1.2$ kcal/mole — from oxides
$= -1292.8 \pm 1.9$ kcal/mole — from elements

Kelley, Todd, and Shomate (J. Am. Chem. Soc. 70, 1350 (1948)) give entropies from low-temperature heat capacity data:

$CaO \cdot B_2O_3$	25.1 ±0.5 cal/deg mole
$CaO \cdot 2B_2O_3$	32.2 ±0.5 cal/deg mole
$2CaO \cdot B_2O_3$	34.7 ±0.5 cal/deg mole
$3CaO \cdot B_2O_3$	43.9 ±0.5 cal/deg mole
$2CaO \cdot 3B_2O_3$	48.9 ±1.0 cal/deg mole (estimated)

$PbO - B_2O_3$ system

ΔHf PbO(c) = -45.1 ±0.3 kcal/mole (NBS Circular 500)

ΔHf B_2O_3(c) = -305.34 ±0.3 kcal/mole (NBS Report 7093)

L. Shartsis and E. Newman (J. Research NBS 40, 471 (1948)) (also J. Am. Ceram. Soc. 31, 213 (1948)) measured heats of solution of glasses in 2N HNO_3.

According to the phase studies of C. Mazzetti and F. De Carli (Gazz. chim. ital. 56, 19 (1926)) the compounds formed are $PbO \cdot B_2O_3$, $PbO \cdot 2B_2O_3$, $PbO \cdot 3B_2O_3$, and $2PbO \cdot 5B_2O_3$.

$PbO \cdot B_2O_3$ (gls) [$Pb(BO_2)_2$]

ΔHf = -9.2 ±0.5 kcal/mole — from oxides
= -359.6 ±0.7 kcal/mole — from elements

Assuming ΔHm = 7.0 kcal/mole, these become for $PbO \cdot B_2O_3$(c)

ΔHf = -16.2 ±1.3 kcal/mole — from oxides
= -366.6 ±1.4 kcal/mole — from elements

$PbO \cdot 2B_2O_3$ (gls) [PbB_4O_7]

ΔHf = -11.9 ±0.7 kcal/mole — from oxides
= -667.7 ±1.0 kcal/mole — from elements

$PbO \cdot 2B_2O_3$ (c), estimating the heat of fusion

ΔHf = -23.3 ±1.3 kcal/mole — from oxides
= -689.1 ±1.5 kcal/mole — from elements

$PbO \cdot 3B_2O_3$ (gls)

ΔHf = -24.5 ±1.0 kcal/mole — from oxides
= -961.1 ±1.4 kcal/mole — from elements

$PbO \cdot 3B_2O_3$(c), estimating the heat of fusion,

ΔHf = -40.5 ±1.5 kcal/mole — from oxides
= -977. ±2. kcal/mole — from elements

$2PbO \cdot 5B_2O_3$ (gls)

ΔHf = -45.2 ±1.8 kcal/mole — from oxides
= -1662.1 ±2.3 kcal/mole — from elements

$2PbO \cdot 5B_2O_3(c)$, estimating the heat of fusion,

ΔHf = -72. ±3. kcal/mole	from oxides
= -1689. ±3.5 kcal/mole	from elements

The values for the glasses should be rather good; those for the crystalline oxides include an estimated - very roughly - heat of fusion, which may be several kcal/mole in error.

Lepinskikh and Esin (Zhur. Neorg. Khim. 6, 1223 (1961)) have studied the systems $PbO-B_2O_3$ and $MnO-B_2O_3$ at 1000° with cells of the type $Pb(liq) | PbO, B_2O_3 | Pt | O_2(g)$. Their results for the $PbO-B_2O_3$ system are in fair agreement with the results of Shartsis and Newman.

CHAPTER 7

HEATS OF FORMATION OF BINARY MIXED-OXIDE SYSTEMS OTHER THAN BORATES

by R. F. Walker, E. S. Newman, and T. B. Douglas

1. Introduction

A more thorough search of the literature has been undertaken to survey data on the heats of mixing of binary systems of oxides or to find thermodynamic data from which the heats may be computed. Studies of compound formation in binary systems of the oxides of Li, Be, Mg, Al, Ti and Zr were surveyed and available phase diagrams were presented in the last report (NBS No. 7093). Many compounds are identified on the diagrams for which no thermodynamic data is available. Furthermore, it is probable that the existence of many new compounds will be established during future phase equilibrium studies. In general it can be said that data on heats of formation of the compounds are scarce and even then not of high accuracy. In order to provide additional background in the evaluation of the heats of mixing, data on binary systems containing BaO, CaO and Na_2O have also been noted. Furthermore, the current interest of Si to the program has also led to the inclusion of data on binary systems with SiO_2.

A prime reason for the lack of data has probably been lack of motivation. However, there are two major obstacles to ready experimental measurement: First, the preparation of pure, stoichiometric samples in sufficient quantity to make measurements worthwhile may often be the most difficult part of an investigation. Secondly, the heat of mixing of few oxides can be measured directly; hence, another reaction which the reactant and compound oxides will undergo must be found. The difference between the heats of reaction of the compound and of the reactants is then the required heat of formation of the compound from the oxides. If the difference is small, high precision in the individual measurements is necessary to obtain meaningful data. A brief discussion of calorimetric methods of measuring the heats is given later.

In principle, the phase diagrams can be used to determine heats of mixing. However, the data and phase boundaries given on most high-temperature diagrams are not usually known with sufficient accuracy to yield reliable heats.

2. Heats of Formation of Binary Oxides

Available data on the heats of formation of the mixed oxide systems (Al, Be, Ca, Mg, Na, Si, Ti and Zr) are summarized in Table I. In the literature search, Metallurgical Thermochemistry by Kubaschewski and Evans [1] was taken as the point of departure. Data given in the compilations of that volume were checked with original literature. The references to this and other literature are summarized in Table I. The following discussion amplifies some of the background to the selection of the values given in Table I.

TABLE I

HEATS OF FORMATION OF SOME MIXED OXIDES

Compound	$-\Delta H_{298}$, Heat of Formation (kcals/mole) From Oxides **		From Elements *
$Al_2O_3 \cdot BaO$	24.0 ± 1.5	[14]	557.8
$Al_2O_3 \cdot 3BaO$	45.0 ± 2.0	[14]	845.6
$Al_2O_3 \cdot BeO$	4.0	(See text)	547.5
$Al_2O_3 \cdot CaO$	3.7 ± 0.4	[15]	556.0
$Al_2O_3 \cdot 3CaO$	1.6 ± 0.4	[15]	857.7
$1/2[Al_2O_3 \cdot Li_2O]$	12.9 ± 1.5	[12]	284.3
$Al_2O_3 \cdot MgO$	Close to zero	[2, 16]	~ 544
$1/2[Al_2O_3 \cdot Na_2O]$	20.9 ± 1.2	[12]	270.8
$Al_2O_3 \cdot SiO_2$:			
Andalusite	39.3 ± 7.0	[11]	645.1
Kyanite	39.7 ± 7.0	[11]	645.5
Sillimanite	45.9 ± 7.0	[11]	651.7
$Al_2O_3 \cdot ZrO_2$	Close to zero	(See text)	~ 659
$2BeO \cdot SiO_2$	12.0 ± 5.0	[1]	503.6
$CaO \cdot SiO_2$	21.5 ± 0.3	[11]	378.8
$2CaO \cdot SiO_2$	30.2 ± 1.5	[1]	539.4
$3CaO \cdot SiO_2$	27.0 ± 1.5	[1]	688.1
$CaO \cdot TiO_2$	19.4		396.8
$Li_2O \cdot SiO_2$	24.6 ± > 10	[11]	372.4
$2MgO \cdot SiO_2$	15.1 ± 1.0	[11]	507.9
$MgO \cdot SiO_2$	8.7 ± 0.7	[11]	357.8
$2MgO \cdot TiO_2$	4.2		517.1
$MgO \cdot TiO_2$	6.4		375.6
$MgO \cdot 2TiO_2$	4.5		599.2
$Na_2O \cdot 2SiO_2$	60.5 ± 3.5	[13]	570.7
$Na_2O \cdot SiO_2$	55.5 ± 3.5	[11]	360.3
$3Na_2O \cdot 2SiO_2$	136.5 ± 7.0	[13]	845.5
$2Na_2O \cdot SiO_2$	74.9 ± 7.0	[1]	479.1

* Heats of formation of the many oxide systems were taken from NBS Report 6928 (July 1, 1960) and NBS Circular 500.

** Numbers in brackets refer to literature references.

$Al_2O_3 \cdot MgO$

Altman and Searcy [2] have recently reported measurements of the vapor pressure of MgO vaporizing from Al_2O_3 Knudsen cells. During the experiments the Al_2O_3 and MgO reacted to form the spinel $MgO \cdot Al_2O_3$. The weight loss from the cell during the runs yielding nearly stoichiometric spinel suggested that its heat of formation is close to zero.

A recent value of the heat of formation obtained by Grjotheim, Herstad and Toguri [16] from a study of the reaction:

$$4\ MgO(c) + 2\ Al(l) = MgAl_2O_4(c) + 3\ Mg(g)$$

is in good agreement with Altman and Searcy's result. Grjotheim _et al's_ value of +1.1 kcals/mole is subject to accumulated experiment errors in the heats of formation of reactants and products, and the removal of these errors could easily result in a small negative value for the heat of formation of $MgO \cdot Al_2O_3$.

Al_2O_3-ZrO_2 System

The rates of vaporization of Al_2O_3 and Al_2O_3-ZrO_2 mixtures have been crudely investigated at NBS in recent months. Much additional work is necessary before definitive conclusions can be drawn. An x-ray examination of mixtures fused _in vacuo_ with an arc image furnace yielded no evidence of new compound formation beyond a small quantity of stabilized, cubic ZrO_2. Corundum and the monoclinic form of ZrO_2 formed the bulk of the fused mixture.

The previously published phase diagrams on ternary systems containing Al_2O_3 and ZrO_2 were summarized in the last report (NBS No. 7093). The diagrams show no evidence of compound formation between the oxides. The liquid curve of the binary system was reported by von Wartenberg and Reusch [3] and shows a single minimum, suggesting lack of congruent-melting compounds. The reliability of the curve may be questionable, but the consensus of available evidence is that there is no stable compound formation in the Al_2O_3-ZrO_2 system.

The question may be posed as to how much the total heat of combustion of given amounts of Al and Zr depends on whether the metals are burned separately or together. Numerous intermetallic compounds of the two metals are known, and if the metals are present in such a form, the heat of formation of the intermetallic compound would make a direct additive contribution. For the sake of simplicity, it will be assumed that the Al and Zr are present as a mere mixture of the two elemental phases. The heat of formation of the product compared with the sum of the heats for the separate oxides is then the remaining consideration.

The above evidence of no stable compound between Al_2O_3 and ZrO_2 does not preclude the possibility that the two oxides may be formed together under such rapid conditions that metastable compounds or solid solutions may form and be "frozen" into permanence. Two theoretical factors enter here: (a) the crystal radii of Al^{+++} and Zr^{++++} differ substantially (Pauling [4] gives 0.50 and 0.80 Å respectively), a fact which would lead to considerable strain energy and a corresponding lower heat of combustion, and (b) the difference in valence would lead to a considerable concentration of lattice vacancies, which energetically are equivalent to lattice strains. At a given temperature the equilibrium concentrations of such vacancies and "foreign" ions varies more or less exponentially with the added energy, so that the gross enhancement of energy would decrease rapidly with increase in strain energy per foreign ion or vacancy; and, at least qualitatively, one would expect a similar rough parallel for given non-equilibrium conditions. There are methods, at least in principle, for calculating such lattice strains. However, the kinetics of the problem are probably of equal importance, and suggest that empirical tests may, after all, be the simplest and most reliable way to settle the question.

Al_2O_3 and ZrO_2 both form several phases which have appreciably different energies, and there is at least some evidence to show that simultaneous crystallization of the oxides can result in a different proportion of these forms than when they crystallize separately. Furthermore it is possible that different crystal sizes may result from simultaneous quenching of the oxides. Liquid eutectic compositions often crystallize in finely-divided form, and their surface energies could conceivably be different.

No information is at hand as to whether studies of the surface energies of Al_2O_3, ZrO_2, or comparable substances have been made. Considerable experimental and theoretical work is available for the alkali halides, however, and a rough analogy may be useful. It is worth observing that the experimentally determined surface tensions (and hence, surface energies) of liquid salts are in comparative agreement with the theoretical values.

Numerous investigators have calculated the surface energies of crystalline alkali halides, with and without various refinements. Benson, Balk and White [5]; and Benson, Dempsey, and Balk [6] have given more refined calculations for all the alkali halides, including the effects of van der Waals attraction, polarization, and shifts in position of the surface ions. For NaCl, e.g., they calculate surface energies of 124 and 307 ergs/cm^2 for the 100 and 110 planes, respectively; and they find that these values agree with the experimental ones if it be assumed that the experiments were conducted on fine crystals with 75% of the faces as 110 and 25% as 100 — obviously not an equilibrium state.

We may try to apply these results to Al_2O_3 and ZrO_2 in a very rough way, and examine the result. Let us assume for simplicity that these two oxides are formed as uniform cubes each $\underline{x}$ microns on an edge. The application of a simple Born treatment is known to give a surprisingly good lattice energy for Al_2O_3, and it may be assumed that the effective valence product for the two oxides is several times as great as for the (univalent) alkali halides. The molal volumes of Al_2O_3 and ZrO_2 average about 25 cm^3/mole. If we assume a surface energy of 2000 ergs/cm^2, we then get a surface of $1.5(10^6)/x$ cm^2 per mole and a surface energy of $0.08/x$ kcal./mole. The heats of formation of Al_2O_3 and ZrO_2 average 331 kcal/mole, and if we assume a particle size $\underline{x}$ of 0.1 micron (equivalent to several hundred atoms per edge), this calculation gives a surface-energy contribution of 0.8 kcal/mole, or only about 0.2% of the total heat of combustion. Unless the particles are considerably smaller than 0.1 micron, it thus seems unlikely that the surface energy makes a contribution to the heat of combustion of much practical importance.

It is presently believed that the system AlF_3-ZrF_4 forms no solid compounds. If this is true, similar conclusions may be drawn about the combustion of Al-Zr mixtures in fluorine.

In conclusion, the available evidence indicates that in the combustion of Al-Zr mixtures (to form oxides or fluorides) the heat produced is not likely to be much different from the additively calculated equilibrium values for the separate systems, being more likely to be less than greater.

Al_2O_3-BeO System

Young [7] studied by transpiration experiments what seem to be the following three reactions, obtaining for ΔH°_{1673} the following respective values. (Tolerances stated refer to precision only.)

	Reaction	ΔH°_{1673} (kcal)
(1)	$BeO(c) + H_2O(g) = Be(OH)_2(g)$	42.5 ± 0.4
(2)	$(3/2)\ BeO\cdot Al_2O_3(c) + H_2O(g) = (1/2)\ BeO\cdot 3Al_2O_3(c) + Be(OH)_2(g)$	49.4 ± 0.6
(3)	$BeO\cdot 3Al_2O_3(c) + H_2O(g) = 3Al_2O_3(c) + Be(OH)_2(g)$	43.2 ± 0.8

Linear combination of these results gives

	Reaction	ΔH°_{1673} (kcal)
(4)	$BeO(c) + Al_2O_3(c) = BeO\cdot Al_2O_3(c)$	-4.8 ± 0.6
(5)	$BeO(c) + 3Al_2O_3(c) = BeO\cdot 3Al_2O_3(c)$	-0.7 ± 0.9

The data yield also, for ΔF°_{1673}, -3.2 ± 1.1 kcal. for reaction (4) and -3.7 ± 1.7 kcal. for reaction (5). There are insufficient data on the heat capacities of these mixed oxides for correction of these heats of reaction to 298°K. According to early data of Nilson and Pettersson [8] on the heat capacity of $BeO\cdot Al_2O_3(c)$, for reaction (4) $\Delta C_p = -1.2$ between 273° and 373°K; if half this value were assumed for the interval from 298° to 1673°K one would obtain $\Delta H^\circ_{298} = -4.0$ kcal. for reaction (4).

As Young implies, his assumption that reactions (2) and (3) represent his experiments, and under equilibrium conditions, is subject to some uncertainty, particularly since each equilibrium involved two solid phases. However, considering his qualitative x-ray evidence and the fact that this part of the BeO-Al_2O_3 phase diagram has been well investigated [9, 10], it seems likely that these were the principal reactions occurring in Young's experiments. Unless future solution calorimetry or other relatively straightforward techniques reveal substantially different heats of formation of these mixed oxides, it must be concluded on experimental grounds that the heat of combustion of mixtures of beryllium and aluminum metals in oxygen is not increased more than about one percent through formation of these "mixed" oxides.

Al_2O_3-SiO_2 System

The three crystalline forms of aluminum monosilicate are naturally-occurring minerals, which are believed to be formed only under high pressure. In addition, there is some evidence to suggest that impurities may act as "mineralizers," speeding up, if not being essential to, the formation of phases. In the laboratory the minerals can be synthesized in the 700-900°C temperature range and under pressures of 10,000-20,000 atmos. The formation of andalusite and sillimanite in particular appears to be controlled by chemical factors. According to evidence at hand, andalusite has not been formed in the absence of sodium, although one might suspect that lithium would be an alternative; sillimanite has not been formed in the absence of fluorine, and forms a complete series of solid solutions with topaz, $Al_2SiO_4(F,OH)_2$. Kyanite is the only phase relatively insensitive to the composition of the reaction mixture.

The only aluminum silicate formed at atmospheric pressure is mullite, $3Al_2O_3$: $2SiO_2$, for which no heat of formation has yet been located. Another silicate, $Al_2O_3 \cdot 3SiO_2$, forms at 900°C under 40,000 atm. pressure.

Al_2O_3-Li_2O and Li_2O-SiO_2 Systems

Recent data on these systems have been published by Fedorov and Shamrai [17]. This paper has been seen in abstract form only, and the abstract contains some ambiguity of notation. It appears that a heat of formation of 26 kcals/mole was determined for either $Li_2O \cdot SiO_2$, $2Li_2O \cdot SiO_2$ or $3Li_2O \cdot SiO_2$. For lithium monoaluminate (presumably $Al_2O_3 \cdot Li_2O$), a heat of 27 kcals/mole is given. This value compares favorably with the value given in Table I, but may not refer to 298°K. Examination of the actual paper is necessary to resolve these uncertainties, and the data have not, therefore, been included in Table I.

3. Possible Measuring Techniques for Determining Additional Heats of Formation

The literature has been surveyed to determine what calorimetric techniques have been used in recent years to determine heats of formation and to evaluate prospects for applying the techniques to the mixed oxides discussed in this chapter.

Probably, the most common calorimetric reaction studied is that of combustion. In many cases, the heat of the reaction of metals with oxygen, or other substances, can be determined directly, and this process has been studied in the calorimeter over many years. A great deal of the data on the heats of formation of the oxides of metals has been determined in this manner, many references and much expert knowledge is available, and no further attention will be given to heats of combustion in the present discussion.

A second very common calorimetric reaction is that of solution in water or in aqueous or other solutions, and it is to this reaction that attention is mainly directed. Some refractory oxides, similar to those of concern to this program, are soluble directly in acids or acid mixtures, or their heats of solution in acid can be calculated fairly directly from the heats of solution of the metals themselves and their heats of combustion. In this manner the heats of formation of calcium [18], barium [14], and strontium aluminates have been determined by measurement of their heats of solution in hydrochloric acid solutions at room temperature, although Al_2O_3 has not been dissolved directly.

In mixtures of nitric or hydrochloric acid with hydrofluoric acid, the heats of solution of hydrated and unhydrated calcium silicates [19, 20], as well as more complex materials [21, 22] have been determined at room temperature. Although the silicates are in many cases thus soluble, silica itself is more difficult to dissolve. To deal with SiO_2, as well as minerals such as albite, $NaAlSi_3O_8$, nepheline, $NaAlSiO_4$, and jadeite, $NaAl(SiO_3)_2$ [23] and others [24, 25], calorimeters using HF solutions have been built to operate at temperatures in the neighborhood of 75° C. At least one operating at room temperature, the rocking-bomb calorimeter [26], has been built, and this, it seems probable, could be used with aqueous solutions at still higher temperatures.

The oxides with which this project is most immediately concerned are Li_2O, BeO, B_2O_3, MgO, Al_2O_3, TiO_2, ZrO_2, and SiO_2. Of these, BeO and Al_2O_3 are listed [27] as the least soluble in acid. It appears that with the others, choices of acids or acid mixtures and temperature of operation would permit calorimetric determinations. Certainly some of the borates should be amenable to calorimetric determination of their heats of solution.

A great deal of work has been done with heat-of-solution calorimeters at elevated temperatures, using molten metal as a solvent, for example, molten tin [28, 29, 30, 31 and 32], and molten silver [33]. Temperatures as high as 1100°C have been reached [33], although temperatures of 300 to 500°C are more commonly indicated. Molten metals are unsuited as solvents for the oxide compounds with which this project is concerned, but a few similar measurements have been made using molten salts [34, 35]. It has been found that "in many instances fused salt mixtures are close to ideal solutions" [36]. It would seem that further work with molten salts might well make possible measurements of heats of reaction of substances impossible to dissolve calorimetrically in aqueous solutions. Beryllium oxide, for example, is said to be soluble in fused KOH [27].

Ginnings [37] has suggested the possibility of raising the temperature of a reaction mixture by electrical heating until a desired reaction occurs, carrying out the reaction in an isolated capsule in a calorimeter, and correcting for the electrical energy. Such measurements have indeed been made using a bomb calorimeter and heating the reaction mixture in its crucible [38]. The precision of the calorimetry and the definition of the final products would probably be much poorer both for this type of measurement as well as for measurements made with molten salts than for modern combustion or heat-of-solution calorimetry. Precisions of 0.2 to 1.5 per cent have been given for molten-tin calorimetry.

REFERENCES

[1] O. Kubaschewski and E. L. Evans. Metallurgical Thermochemistry. Pergamon Press, New York, 1958.

[2] R. L. Altman and A. W. Searcy. Abstracts of Symposium on Chemical and Thermodynamic Properties at High Temperatures. XVIIIth International Congress of Pure and Applied Chemistry, Montreal. August 6-12, 1961, p. 54.

[3] H. von Wartenberg and H. J. Reusch. Z. anorg. allgem. Chem. 207, 18 (1932)

[4] L. Pauling. The Nature of the Chemical Bond, Cornell University Press, Ithaca, N. Y. 1945 p. 346.

[5] G. C. Benson, P. Balk, and P. White. J. Chem. Phys., 31, 109 (1959).

[6] G. C. Benson, E. Dempsey, and P. Balk. J. Chem. Phys., 34, 157 (1961).

[7] W. A. Young. J. Phys. Chem. 64, 1003 (1960).

[8] L. F. Nilson and O. Pettersson. Ber. chem. Gesell. 13, 1459 (1880) as quoted by K. K. Kelley, U. S. Bur. Mines Bulletin No. 584. 1960, p. 26.

[9] W. R. Foster and H. F. Royal. J. Am. Ceram. Soc., 32, 33 (1949)

[10] S. M. Lang, C. L. Fillmore, and L. H. Maxwell. J. Res. Natl. Bur. Stand. 48, 301 (1952).

[11] F. D. Richardson, J. H. E. Jeffes and G. Withers. J. Iron and Steel Inst., 166, 213 (1950).

[12] J. P. Coughlin. J. Am. Chem. Soc., 79, 2397 (1957).

[13] C. Kröger and W. Janetzko. Z. anorg. allg. Chem., 284, 83 (1956).

[14] R. B. Peppler and E. S. Newman, J. Res. Natl. Bur. Stand., 47, 439 (1951).

[15] J. P. Coughlin. J. Amer. Chem. Soc., 78, 5479 (1956)

[16] K. Grjotheim, O. Herstad and J. M. Toguri. Can. J. Chem. 39, 443 (1961).

[17] T. F. Fedorov and F. I. Shamrai. Primenie Vakuuma u Met., Akad. Nauk SSSR., Inst. Met. im. A. A. Baikova p. 137 (1960). Chem. Abstr. 55, 12214d (1961).

[18] T. Thorvaldson, W. G. Brown, and C. R. Peaker, J. Am. Chem. Soc., 52, 3927 (1930).

[19] S. Brunauer, D. L. Kantro, and C. H. Weise. The heat of decomposition of tricalcium silicate into beta-dicalcium silicate and calcium oxide, J. Phys. Chem., 60, 771 (1956).

[20] S. Brunauer, J. C. Hayes, and W.E. Hass. J. Phys. Chem., 58, 279 (1954).

[21] E. S. Newman and R. Hoffman. J. Research NBS 56, 313-318 (1956).

[22] E. S. Newman. J. Research NBS 62, 207-211 (1959).

[23] F. C. Kracek, K. J. Neuvonen, and G. Burley. J. Wash. Acad. Sci., 41, 373-83 (1951).

[24] D. R. Torgeson and Th. G. Sahama. J. Am. Chem. Soc., 70, 2156-60 (1948).

[25] E. G. King. J. Am. Chem. Soc., 73, 656-8 (1951)

[26] S.R.Gunn. Rev. Sci. Inst. 29, 277-80 (1958).

[27] Handbook of Chemistry and Physics, Chemical Rubber Co., Cleveland, Ohio. 41st Edition, 1960.

[28] O. J. Kleppa. J. Phys. Chem., 59, 175 (1955).

[29] O. J. Kleppa. J. Phys. Chem., 60, 846 (1956).

[30] Raymond L. Orr, A. Goldberg, and R. Hultgren. Rev. Sci. Inst., 28, 767-73 (1957).

[31] R. L. Orr, A. Goldberg, and R. Hultgren. J. Phys. Chem., 62, 325-7 (1958).

[32] R. A. Oriani and W. K. Murphey. J. Phys. Chem., 62, 327-31 (1958).

[33] R. A. Oriani and W. K. Murphey. J. Phys. Chem., 62, 199-202 (1958).

[34] O. J. Kleppa. J. Phys. Chem., 64, 1937-40 (1960).

[35] Matti Nurmia, Ann. Acad. Sci. Fennicae. Series A, I, No. 243, 27 pp. (in English).

[36] R. P. Seward. J. Phys. Chem., 63, 760-61 (1959).

[37] D. C. Ginnings, Private Communication.

[38] C. Kröger and W. Janetzko. Zeit. für anorg. u. allgem. Chemie, 284, 83-100 (1956).

For other references to measurements of heats of reaction see also:

F. E. Wittig and W. Schilling. Isothermal heat convection calorimeter for high temperature. Z. Elektrochemie, 65, 70-80 (1961).

W. R. Grimes, N. V. Smith, G. M. Watson, Solubility of noble gases in molten fluorides. J. Phys. Chem., 62, 862-6 (1958).

O. Kubaschewski, W. A. Dench, and V. Genta, High temperature calorimeter for slow reactions. Phys. Chem. Metallic Solutions Intermetallic Compounds. Symposium, Teddington, Middlesex, England. 1, 110-16 (1960). Nat'l Phys. Lab. Symposium No. 9. Vol. 1, Paper 1G, 8 pp. (1959).

A. Magnus and F. Oppenheimer. The heat of fusion of silver nitrate. Z. anorg. allgem. Chem., 168, 305-9 (1928).

K. K. Kelley, R. Barany, E. G. King, and A. V. Christensen. Heat of formation of synthetic fluorphlogopite mica. U. S. Bureau of Mines. Report of Investigations No. 5436, 1959.

L. A. Resnitskii and K. G. Khomyakov, Calorimetric determination of the heat of reduction of ferrites by hydrogen. I. Calorimeter, Reduction of ferric oxide. Vestnik Moskov. Univ., Ser. Mat., Mekh. Astron., Fiz. i Khim. 14, No. 2, 217-24 (1959). Abstract only seen. CA 54:9481i.

N. Karnelis, Thermodynamic Properties of Zinc phosphide. 1. Determination of the heat of formation of ZnP during its synthesis from zinc and red phosphorus. Vilniaus Univ. Mokslo Darbai, Chemija 28, 110-17 (1959), Abstract only seen.

S. N. Gadzhiev and K. A. Sharifov. Determination of the heat of formation (antimonide) by melting in a bomb calorimeter. Doklady Akad. Nauk. SSSR, 136, 1339-41 (1961). Title only seen.

Madeleine Blanc. Heat of fusion of some alkali and alkaline earth halides. Compt. rend. 249, 2012-13 (1959). Abstract only seen. CA 54:16158f.

M. Bizourd and F. Pauty, Measurement of the molar heats of some molten salts and metals. Compt. rend. 252, 514-15 (1961).

CHAPTER 8

THE HEATS OF FORMATION OF INORGANIC FLUORINE COMPOUNDS -- A SURVEY

by George T. Armstrong and Leslie A. Krieger

Abstract

This paper examines the current state of measurements leading to heats of formation of the inorganic fluorine compounds, and carbon compounds of one carbon atom per molecule. It is based upon a survey of the literature from 1949 to mid-1961. A bibliography of 625 references is given. Reported values of ΔHf^{o}_{298}, cited from the literature, are listed for individual compounds in eight tables. Related thermodynamic measurements are also listed. No attempt is made to indicate the best values to be assigned when conflicting data exist. As a group the binary fluorine compounds have been the most thoroughly studied. The availability of the thermodynamic information decreases rapidly as the complexity of the compounds increases. Recent developments in certain phases of the calorimetry of fluorine compounds are discussed.

Acknowledgment

This survey was prepared at the National Bureau of Standards, as part of the basic program of the Heat Measurements Section, and the work was supported by Bureau RTS funds. Because of the wide interest in the material of this survey, it is incorporated in the present ARPA report.

1. Introduction.

This paper presents in brief review and summary form the results of a survey of the recent literature on the thermochemical properties of inorganic fluorine compounds. The purpose of the paper is to indicate the present status of the heats of formation of this group of compounds without attempting an exhaustive critical evaluation of the data.

The fluorine compounds form a group of special interest from a scientific point of view because of the extreme position of fluorine in the periodic table. For many years it received less study than this extreme position warrants, probably for two reasons: the low abundance of fluorine relative to neighboring elements in the periodic table, and the extreme reactivity of the element, which has hindered work with it. In recent years this situation has changed and a large volume of research has been carried out, leading to a rapid growth of the literature of the fluorine compounds and the publication of several general review works [1,2,3,4,5,6,7,8].

2. Scope and Completeness of Survey.

A large amount of effort has been expended by others in searching and evaluating the literature relating to the heats of formation of fluorine compounds. In carrying out the literature search in the present survey, advantage was taken of the results of prior work whenever possible. The National Bureau of Standards Circular 500 [9] was used as a starting point. This critical evaluation was considered to be complete through the 1949 Chemical Abstracts and further search of the literature covered in [9] was thought to be unnecessary. For the period following 1949, the Chemical Abstracts was the primary source searched.

For aqueous species we have not attempted to duplicate in our references the survey on stability constants of metal ion complexes and solubility products of inorganic substances, by Bjerrum, Schwarzenbach, and Sillen [16]. Many thermodynamic studies related to heats of formation of aqueous complex ions are listed there. When reference to a source of work on an aqueous species is made by Bjerrum, et al. [16], in general we refer to [16] rather than to the original source. Material not found in Bjerrum for these species is listed in the usual manner.

A complete search of the literature pertaining to such a large group of compounds, and covering all modes of information of potential value to the calculation of heats of formation, is a complex, painstaking task. A considerable amount of ingenuity is required to ferret out sources of information. In some instances, a source may contain the only applicable information available on a particular compound, but because the article is principally about a subject other than thermochemistry, the information may not be revealed in the abstract. A search of Chemical Abstracts, therefore, can hardly be expected to be complete in itself.

For this reason use was also made of other reviews in order to complete the search. The principal published reviews searched are listed as references [10,11,12,13,14,15,16,17]. Of these, several may be commented on. In two lengthy reviews Brewer, Bromley, Gilles and Lofgren [12] and Brewer [13] gave the heats of formation, fusion, and vaporization and other thermodynamic properties of most of the binary fluorides for which data were available. They also estimated values for many compounds for which measurements had not been made. They discussed briefly the sources of the selected values. Their references were essentially completed in 1946, though reference was made to some additional work published through 1948. For many values of heats of formation they depended heavily upon Bichowsky and Rossini [10].

Herzberg [11] and Gaydon [14] are standard references for the dissociation energies of diatomic molecules. Additional information on dissociation energies might have been found in Cottrell [18] which, however, was not specifically searched. Kubaschewski and Evans [15] list many heats of formation, principally of materials of interest to metallurgists. Bjerrum [16] has compiled stability constants for complex ions in aqueous solutions, summarizing a good deal of literature which should be applicable to the calculation of enthalpies and free energies of formation of aqueous ions. Fluoride ion, forming many strongly bonded complex ions, is well represented. The second edition of Lewis and Randall's Thermodynamics, revised by Pitzer and Brewer, [17] contains extensive tables of thermodynamic properties including heats of formation. Of these the values for the gaseous alkali halides, based on a recent survey by Brewer and Brackett [19], are new.

Glassner, in an informal publication [20], tabulates the heats of formation of a great many binary fluorides, including estimates for many compounds for which experimental values are lacking. Aside from the estimates he depends upon Brewer, et al. [12], Kubaschewsky and Evans [15] or NBS Circular 500 [9], and lists data from other sources only for the fluorides of polonium and the actinide elements.

The Annual Reviews of Physical Chemistry have provided a review chapter on thermodynamics and thermochemistry each year since 1950. These chapters have become more complete and more uniform in coverage so that they formed a useful source for checking the completeness of our search. In addition, chapters on heterogeneous equilibrium and phase diagrams, high temperature chemistry, and bond energies supplied useful information. Volumes 1 - 11 were examined. The Bulletin of Chemical Thermodynamics (1958-1961) has provided a guide to very recent work. The "Table of Contents" of several journals and the serial publication Current Chemical Papers have been examined for new work each month for about three years.

Advantage was also taken of the current active interest in twenty or thirty elements, particularly of the low atomic weights, as potential ingredients of rocket fuels or oxidizers. This interest has led to surveys of thermochemical properties, with emphases on compounds which could occur as ingredients, products or intermediate species. Such surveys by Sinke [21], Gordon [22], Mickle [23], Hildenbrand [24] and Gordon [25] have appeared as listed reports. Others [26,27,28,29,30,31,32] have come in the form of informal communications to the authors. Still others [33,34,35,36,37] represent unpublished communications by the authors. These surveys differ widely in the extent to which they resort to the original literature or to prior surveys, and also in the extent to which they attempt to justify the values they list. The values presented include estimates of the properties of some species considered to be possible, but for which no experimental data exist. Fluorine is a prominent element in most of these surveys, and so these have been scanned for information suitable for this paper.

The search of Chemical Abstracts included a page-by-page scanning of unindexed issues, sections 1,2,3,6,9 and 24 (Apparatus, General and Physical Chemistry, Electronic Phenomena, Inorganic Chemistry, Metallurgy, and Propellants, respectively). This portion of the search began with the 1957 volume, and is complete through 18 issues of 1961. The issues from 1950 to 1956 have been searched in the formula index for all references to fluorine compounds, excluding carbon compounds C_2 or higher. In addition, a limited number of subject index headings have been searched, including the names of fluorine compounds cross-referenced from the formula index, as well as certain headings involving heat processes.

Although the search of Chemical Abstracts has been intensive and detailed, it is probable that certain sources have been missed, because of the primary dependence upon the mention of the compound and the heat measurement in the abstracts studied. It is also probable that resort to other surveys did not completely fill the gap, because the other surveys in general did not cover all the fluorine compounds in any systematic manner.

The present examination and evaluation of the sources of data on fluorine compounds are expected to continue. Therefore, information about data not referred to in this article will be welcomed by the authors.

The information selected from the various references was limited to energy changes occurring at constant temperature. In particular, this criterion excludes the listing of specific heat measurements. It permits the inclusion of energies of phase changes, free energy changes (or the related equilibrium constants), as well as enthalpy changes occurring in chemical processes of all types and determined by any means.

For the preparation of this survey gaseous ions as chemical species were not covered. It is believed, however, that all other clearly recognized classes of chemical species have been included.

3. Arrangement of the Tables.

The information relating to heats of formation is summarized in Tables 1 to 8. There the chemical species are separated into fluorine (Table 1), binary fluorides (Table 2), ternary fluorine compounds (containing three elements including fluorine) (Table 3), quaternary and higher fluorine compounds (containing four or more elements) (Table 4), aqueous fluoride ion (Table 5), binary aqueous species (Table 6), ternary aqueous species (Table 7), and quaternary and higher aqueous species (Table 8). Hydrates, ammoniates, and hydrofluorides are treated consistently with other compounds in these tables, in which each element that occurs is counted without regard to chemical relationships or tightness of binding. Within Tables 2 and 5, the compounds are arranged alphabetically with respect to the symbol of the non-fluorine element.

In the remaining tables, the compounds are arranged in the order of the formula index in Chemical Abstracts, with a single modification: compounds containing water or other coordinated molecules and compounds containing C and H are not treated as exceptions to the general rules for arrangement. The rule for arrangement of elements within a compound is that they are in alphabetical order according to their symbols. The rule for arrangement of compounds within a table is that the compounds are in alphabetical order except that for the first element in a compound, for example Al, all formulas with Al come before those with Al_2 and so on. This rule is maintained for each successive element in the formula.

When this procedure leads to a formula not easily recognizable in terms of the molecular configuration, a more conventional formula is listed in parenthesis.

A compound whose existence has not been demonstrated, but for which a heat of formation is presented is followed by the abbreviation, hyp.

Table 2 lists all binary fluorides which were encountered in the search, whether or not thermodynamic data were found. The binary compounds listed were found by scanning the formula indices of Chemical Abstracts, 1950-1957; such monographs as Simons [1] and Ryss [2]; and the recent summaries by George [4] and Peacock [5]. The practice of including compounds for which no thermochemical data have been reported is not continued in the other tables.

The data for each compound are listed according to the phase of the compound in the order gas, liquid, crystal.

The purpose of these tables is to provide a very brief summary of new data related to the heat of formation of each compound, and its relation to prior data. For this purpose, in the column labelled "ΔHf°_{298}" are listed the experimental values for the heat of formation found in the search. In addition, the heat of formation listed in NBS Circular 500 or a more recent authoritative review is listed. References are given for each value listed. It should be emphasized that appearance of a number in the column does not mean that it has been critically evaluated, or that precedence over other values or partial data listed elsewhere in these tables is intended. In addition, no effort has been spent toward making the values consistent.

In the column headed "Remarks" are described the processes by which heats of formation have been derived. In this column are listed data which are not reported as heats of formation, but which are applicable to the evaluation of a heat of formation when the data are combined with suitable other data. Also listed are values for heats of formation given by some other reviews, and estimated values.

The usual chemical process which can be used to derive a value suitable for listing in these tables involves more than one fluorine compound. To avoid duplication, cross references are given as needed. When two phases of the same substance are involved, as in a vaporization process, any enthalpy change reported is arbitrarily listed by the substance formula in the phase that results from an increase in energy; i.e., the vapor phase in this instance. This procedure is adopted in order to avoid ambiguity in those cases in which more than one molecular formula may be found in the vaporizing gases. Vapor pressure measurements are listed for the condensed phase in equilibrium with the vapor. These vapor pressure studies may provide additional information on the heat of vaporization or sublimation.

4. Evaluation of the Data.

Due to the lack of time, it has not been possible in this survey to give an evaluation of the available data, or any calculation of heats of formation on a consistent and critical basis, from the reported heat measurements of particular processes, and from the reported free energy and entropy data for equilibrium processes. The values given must, therefore, be taken as citations from the original literature.

It must be left to future critical analysis to indicate the greater or lesser degree of reliability of different experimental reports; to place the calculations upon a consistent basis, particularly with regard to the values to be used for auxiliary thermodynamic quantities required in the calculation; and to apply the most appropriate schemes for correlation or analysis of the data.

Similarly, as stated earlier, it has not been possible to discriminate definitely between the listed values which were taken from various other reviews. Each value listed in the second column of the tables, as coming from a review, is, therefore, merely a recent value from a competent review, and is not to be considered as necessarily superior to other values found in other reviews listed under "Remarks". The reason for listing such a value selected from a review is to provide a fair picture of the situation with regard to compounds for which data adequate for evaluation of a heat of formation may have existed prior to the period covered by the present survey. No values are listed in this column which are based to any important degree upon estimation.

5. Status of Data on the Heats of Formation of Fluorine Compounds.

In the absence of a critical evaluation of the data, a judgment of the reliability of the existing thermochemical measurements on the fluorine compounds as a group will not be attempted here. Of some interest is an estimation of the extent to which thermochemical data are lacking as compared to the extent to which measurements have been made. A careful estimate of this status for all classes of inorganic compounds would require a more thorough counting of the polyatomic fluorine compounds than has been possible for this review. At best such a count would be incomplete at any given time because the number of known compounds is continually being augmented. It is possible, however, on the basis of the information in these tables to make some limited and tentative estimates of the situation.

Let us consider for example the binary compounds. Two hundred seventy-eight (278) compounds are listed in Table 2, an average of about three fluorides for each element. Of these we find listed in the table a value for the heat of formation based on experimental work for 93 compounds; and data, in some instances sufficient for the calculation of a heat of formation, for 32 additional compounds, a total of 125. This leaves 153 binary compounds, somewhat more than half of all the binary fluorine compounds, with insufficient data to permit a statement of the heat of formation based upon experiment.

Estimates have been made for many of these. The adequacy of such estimates is a moot point. The possible uncertainties are suggested by a few examples from the table. For AcF_3(c) estimates of the heat of formation range from -395 to -477 kcal/mole. For AlF_3(c) a value of -311 kcal/mole was given in NBS Circular 500 [9] for which an estimate of the heat of solution was used to complete a cycle of thermochemical data. A more recently measured value reported on the basis of non-aqueous reactions was -356.2 kcal/mole. A recently measured value for PF_5(g) is -381.4 kcal/mole, whereas Gordon [26] estimated -420 kcal/mole, and Kapustinskii [38] estimated -315 kcal/mole. Undoubtedly some estimates are better than these; nevertheless, the illustrations given above are by no means only for exotic or exceptional compounds.

The estimates of the completeness of existing data can be extended to the case of more complex compounds only in a qualitative way. In Table 3, 147 ternary compounds are listed, for which some thermochemical data have been presented. Of these there are sufficient data for 41 compounds for us to present a value of ΔHf. For the remainder some relevant data or estimates of the heats of formation are available.

The various monographs on fluorine chemistry and the Chemical Abstracts indices were not scanned for the purpose of obtaining a count of ternary compounds, so we do not have even an approximate count of the total number of known ternary fluorine compounds. However, examination of a single source (George [4]) gives an approximate number of the ternary compounds involving elements of groups Vb and VIb. This source lists 45 ternary compounds involving nine elements from these two groups, compared to 17 binary compounds involving the same elements. The ratio of ternary to binary compounds is somewhat over 2.5 to 1. Assuming the same ratio to hold for the ternary and binary fluorine compounds of all the elements, we find that the total number of ternary fluorine compounds would be somewhat in excess of 700. The validity of this assumption is not easy to justify, and the number could be made very far in error by the discovery of a group of compounds such as chain linked molecules analogous to the carbon compounds. Thus estimates of the number of compounds in the area for which measurements remain to be made can only be suggestive of the magnitude of the tasks involved if measurements were contemplated on all compounds. The contrast between 41 compounds for which measurements have been made, leading to an experimental value for the heat of formation, and approximately 700 for which measurements might be contemplated is striking, and indicates the need for a very careful consideration of the desirability of closing the gap, and of ways in which it might be done.

6. Some Problems and New Developments in the Calorimetry of Fluorine Compounds.

The calorimetry of fluorine compounds has been hindered by the fact that in comparison with oxygen the use of elemental fluorine in reaction is attended with difficulties due to its great reactivity and its toxicity. Procedures for reactions of oxygen have been refined to such a degree, that reaction vessels, and materials compatible with oxygen are not lacking for almost any reaction process desired, either in a flame or a bomb calorimeter. Recent developments suggest that calorimetry of fluorine will also be possible in a comparably wide range of experiments. Already promising procedures have been worked out for a very satisfying variety of measurements directly on elemental fluorine. Gross [39,40, 568] and co-workers have developed procedures for the use of fluorine at 1 to 2 atm pressure in glass vessels in which the fluorine can be kept separate from the other reactant until reaction is desired. Hubbard and co-workers [41,42,43, 44, 241, 567] have demonstrated the feasibility of fluorine-bomb calorimetry, using nickel or monel bombs. They have applied their method to measurements of metals and metalloids forming volatile fluorides, such as those of titanium and boron. Armstrong and Domalski [45] have been able to extend fluorine bomb calorimetry to metals such as aluminum, which form relatively non-volatile fluorides. Other laboratories are also attempting work in this direction [46].

Combustion of organic and hydrogeneous compounds in a fluorine bomb calorimeter apparently has not been attempted for precise measurements. The use of hydrogenous materials offers difficulties in the great non-ideality, the probable condensation of part of the hydrogen fluoride that would be formed, as well as the extreme corrosiveness of the gas at elevated temperatures. The presence of water in the bomb to dissolve the HF reduces the amount of corrosion to an extent that may make it tolerable, as was shown by Armstrong, Marantz and Coyle [47] in an experiment not involving elemental fluorine. The use of water in the presence of fluorine to dissolve the hydrogen fluoride as it is formed would be precluded by the reaction of water with fluorine. Nevertheless these difficulties may be susceptible to a careful approach. There seems to be no a priori reason why, for instance, hydrogen fluoride formed by combustion in a bomb could not be absorbed in sodium fluoride, much as it is absorbed in NaF traps in flame calorimetry experiments [48]. "Teflon" has been shown [45] to burn readily in fluorine and is now available in thermosealable thin films, from which it should be possible to fabricate sample containers for liquids or spontaneously igniting substances. Such an experiment could open up the whole field of the thermochemistry of the fluorocarbons and the partially fluorinated hydrocarbons, as well as other substances not now accessible to such reactions. Of more immediate importance to the thermochemistry of fluorocarbons has been the development of methods for the satisfactory combustion of such materials in oxygen by Good, Scott and Waddington [49,50].

Of equal importance to the development of bomb calorimetric methods with fluorine has been the development of a flame calorimeter suitable for burning gaseous samples in an atmosphere of fluorine [48]. This procedure, successfully used in the combustion of methane and ammonia, should be adaptable to the combustion of other gaseous materials in which either a fluoride is formed, or a fluorine oxidizer burns another material such as hydrogen or ammonia.

The difficulties in the use of elemental fluorine are at least, in part, compensated by another aspect of fluorine thermochemistry: the very great utility of hydrofluoric acid as a solvent. It is probable that the dissolving characteristics of hydrofluoric acid solutions have not been used to their fullest extent for the determination of heats of formation of fluorine compounds. There have been many applications to the determination of the heats of formation of mineral products, mostly oxides and silicates. More satisfactory and more frequent application to the determination of the heats of formation of fluorine compounds should follow a better understanding of the species equilibria and rate processes involved in solutions of complex fluoride ions.

In some areas, it is apparent that uncertainties in the heats of various processes exert a significant effect upon the thermochemical calculations, and that there is room for improvement of some of the more basic quantities of fluorine thermochemistry. A few instances will be briefly cited.

(1) The heat of formation for HF(g) is listed in NBS Circular 500 as $\Delta Hf = -64.2$ kcal/mole. This value is less negative than the value obtained by Von Wartenberg and Schutza [51] in their careful experiments. A more negative value is also indicated by the experiments of Armstrong and Jessup [48]. If a value as negative as -64.6 kcal/mole were the proper value, the determinations of the heat of formation of CF_4 by Jessup, McCoskey and Nelson [52] and by Scott, Good and Waddington [49], would be brought into essential agreement at -220 kcal/mole and the value determined by Neugebauer and Margrave [173] would be only 1 kcal different at -219 kcal/mole rather than these determinations being separated by 2 or 3 kilocalories.

(2) The non-ideality of hydrogen fluoride in the low pressure region is so poorly known that use of one set of P-V-T data or another can lead to differences up to nearly 1 kcal/mole for the heat of formation at various pressures (see [48] for a discussion).

(3) A great deal of work has been done on the dissociation energy of fluorine (Table 1). Despite the large amount of work, the value which lies near 38.7 kcal/mole, as indicated by most of the recent work, still has not been as precisely established as would be desirable. This value enters into all calculations of average bond energies of fluorine compounds.

7. Symbols and Abbreviations Used in Tables 1-8.

amorph.	amorphous
assoc.	association
dissoc.	dissociation
D_o, D	dissociation energy
equil.	equilibrium
est.	estimate
e.v.	electron volts
hyp.	hypothetical compound
K	equilibrium constant
K i	ionization constant
K sp	solubility product constant
log K	logarithm to the base 10 of the equilibrium constant
meas.	measured
thermodyn. prop.	thermodynamic properties
v.p.	vapor pressure
(aq)	aqueous
(c)	crystal
(g)	gas
(ℓ)	liquid
(var.)	various concentration of real solutions are also given
(400 H_2O)	in 400 moles of water
ΔF reac.	free energy of reaction
ΔFf	free energy of formation
ΔH	enthalpy change
ΔHf	heat of formation

ΔHf^{o}_{298}	standard heat of formation at 298°K.
ΔH fus.	heat of fusion
ΔH hydr.	heat of hydrolysis
ΔH pptn.	heat of precipitation
ΔH reac.	heat of reaction
ΔH soln.	heat of solution (in H_2O unless otherwise specified)
ΔH sub.	heat of sublimation
ΔH vap.	heat of vaporization

TABLE 1. FLUORINE

Substance	D_o or ΔH° (kcal/mole)	Remarks
F(g)		N.B.S. Circ. 500 [9] gives 18.3 for ΔHf^o_{298}. See F_2(g) for extensive later information.
F_2(g)	Experimental measurements leading to D_o or ΔH° for dissociation have been reported as follows: 66[54], 50 ±6[55], < 45[56], 37.7 at 759 to 1115°K or 38.9 at 1000°K[57], > 45[58], 40-45[59], 37.7[60], 39.9 ±0.8[61], 37.0 ±2[62], 31.5 ±0.9[63], 37.6 ±1.6[64], 37.6 ±0.8[65], 31[66,67], 38 ±0.4[68, 69], 32 ±3[70], 37.5[71], 41.3 ±0.5[73], 37.1[92], 31.6 ±4.3[606], ≤ 39.0[606].	Discussions and calculations of the dissociation energy have been reported by [9, 11, 14, 18, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 89, 90, 91, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 508]. [105] meas. v.p. and ΔH vap. [540] meas. ionization and dissociation by electron impact. [580] est. D_o values from -34 to +180.
F_2(ℓ)		[105] meas. ΔH fus.
F_2(c)		[105] meas. ΔH trans. (c,I) → (c,II).

Data in tables 1 - 8 are citations from the literature and have not been critically reviewed for this paper.
All numerical values are in kcal $mole^{-1}$ unless otherwise specified.
See [9] for additional references prior to 1949.
Superscript a on ΔHf values for Br and I compounds indicates that such values are based on Br_2(g) or I_2(g) as standard states.

TABLE 2. BINARY FLUORIDES

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
$AcF_3(c)$		[20] est. ΔHf^o_{298} = -395. [12] est. -420 ± 10. [106] reports ≅ -477 from consideration of the high temp. reaction: $3Li(g) + AcF_3(c) = Ac(c) + 3LiF(\ell)$.
$AgF(c)$	-48.5 [9]	[107] lists ΔH soln. [108] calc. lattice energy. Other reviews give for ΔHf^o_{298}: -48.5 ± 1.0 [15], -48.7 [12,20].
$AgF_2(c)$	-88.5 [9]	Other reviews give for ΔHf^o_{298}: -83.0 ± 2.5 [15], -83 ± 4 [12].
$Ag_2F(c)$	-50.4 [9]	[12] lists -50.3 for ΔHf^o_{298}.
$AlF(g)$	-61.3 ± 2.0 [35] -49 [510] -59.2 [115] -61.4 [116] -50.9 [607]	The equilibrium: $2Al + AlF_3 = 3AlF$, was studied by [111, 113, 115, 510, 607]. Spectroscopic measurements of D_o were reported by [74, 112]. [114] lists many ΔF reac. of AlF(g). D_o is also reported or discussed by [11, 12, 14, 18, 37, 109, 110, 111, 115, 116]. [547] calc. binding energy. Other reviews give for ΔHf^o_{298}: -50 ± 5 [109], -51.4 [9], -55 [12], -60 [25], -60.1 ± 1 [26] -60.5 [21], -60.97 ± 1 [24], -61 ± 5 [17], -61.0 ± 2 [15], -61.3 [27, 37].
AlF[illegible] hyp.		[109] est. ΔHf^o_{298} = -103. [12] lists -102. [34] lists -102 ± 10. See also [514].
AlF[illegible](g) hyp.		[34] lists ΔHf^o_{298} = -114 ± 5. [25, 27] est. -157. [24] est. -172 ± 15. [26] est. -172 ± 20.
AlF[illegible] hyp.		[109] est. ΔHf^o_{298} = -184. [33] lists -184 ± 10.
$AlF_3(g)$	-284.8 ± 6 [34] -285.3 ± 2 [122]	[111, 120, 122, 123, 510] calc. ΔH sub. [121] calc. ΔH vap. [9] lists and [32] reviews ΔH sub. Other reviews give for ΔHf^o_{298}: -270 [33], -283.0 ± 2 [24, 26], -283.8 [21], -284.8 ± 6 [25, 37], -285.4 ± 5 [27]. See $Al_2F_6(g)$ and $AlF_4Li(g)$.
$AlF_3(\ell)$		[121] meas. v.p. [124] meas. ΔH fus.
$AlF_3(c)$	-356.2 ± 2 [35] -355.7 [115] -356.15 [116] -356.3 [116, 117, 118] -357.0 ± 2.0 [119]	[115, 117, 119] meas. ΔH for the reaction: $Al + 3/2\ PbF_2 = AlF_3 + 3/2\ Pb$. See also [116, 118]. See [45] for ΔHf. [124] meas. ΔH trans. $\alpha - AlF_3 \rightarrow \beta - AlF_3$. [514] gives e.m.f. of $Al - AlF_3$ electrode. [111, 120, 121, 122, 123] meas. v.p. [38, 516, 517, 518] est. ΔHf^o_{298}. Other reviews give for ΔHf^o_{298}: -311 (est.) [9], -323 ± 5 (est.) [12, 20], -331.5 [2], -355.7 [21, 24, 26, 33], -355.8 ± 2 [15], -356.3 [25], -356.3 ± 1 [17], -356.3 ± 2 [37], -356.3 ± 5 [34]. [517] also reviewed ΔHf^o_{298}. See also AlF(g), $AlF_6Na_3(\ell)$.
$Al_2F_6(g)$		For the reaction: $Al_2F_6(g) = 2AlF_3(g)$, [125] meas. ΔH^o_{1000} = 48.0. See alao [32].
$AmF_2(c)$		
$AmF_3(g)$		[128] calc. ΔH sub. See also v.p. meas. for $AmF_3(c)$. See also [106].
$AmF_3(c)$		[126, 127, 128] meas. v.p. [20] est. ΔHf^o_{298} = -382.
$AsF_3(g)$	-218.3 [9]	[9] lists ΔH vap. [17] lists -218.3 for ΔHf^o_{298}.
$AsF_3(\ell)$	-226.8 [9]	[129] meas. ΔH fus. [9] lists ΔH fua. [20] lists ΔHf^o_{298} = -198.3.
$AsF_3(c)$		
$AsF_5(g)$		[2] lists ΔH sub. [9] lists Δ H vap. [20] est. ΔHf^o_{298} = -265.
$AsF_5(\ell)$		[9] lists ΔH fua.
$AsF_5(c)$		
AuF(c) hyp.		[130] calc. lattioe energy and est. ΔHf = 39 and 45. [12] est. ΔHf^o_{298} = -18 ± 4. [20] est. -18.
$AuF_2(c)$		[12] est. ΔHf^o_{298} = -57 ± 20. [20] est. -57.
$AuF_3(c)$	-83.3 ± 2 [15] -83.3 [131]	[131] meas. ΔH hydr. of $AuF_3(c)$. [12] est. ΔHf^o_{298} = -100 ± 40. [20] est. -100.

Compound	ΔHf^{o}_{298} (kcal/mole)	Remarks
BF(g)	-43.867 [31]	[11, 14, 110] report D_o, [132] gives bond energy (B-F). [547] calc. binding energy. Other reviews give for ΔHf^{o}_{298}: -17.4 [9, 22], -40.27 [29], -42.87 ± 5 [26], -42.87 [27, 30], -42.9 ± 5 [24], -42.9 [17], -43.2 [21], -47.9 [25].
BF_2(g)		[25] est. ΔHf^{o}_{298} = -133.2. [27] lists -133.843*. [31] est. -134.84. [26] est. -156 ± 15. [24] est. -157 ± 15.
BF_3(g)	-270.0 ± 2.5 [31] -270.8; -271.6 [40] -270.2 [133]	[40, 133] meas. ΔH for direct combination of elements. See [42, 43] for preliminary values for ΔHf^{o}_{298} prior to [133]. [134] meas. ΔH soln. of BF_3(g) in HF. [520] reviews v.p. [9] lists ΔH vap., ΔH sub. Other reviews give for ΔHf^{o}_{298}: -265.4 [9, 22], -266.9 [21, 29], -270 [17], -270.0 ± 2 [24, 25, 26, 27, 30], -273.5 [12, 20]. See also $(BFO)_3$(c), $BClF_2$(g) and BCl_2F(g).
BF_3(l)		[519, [illegible] meas. v.p. [135] meas. ΔH fus. [9] lists ΔH fus.
BF_3(c)		
B_2F_4(g)		[136] meas. ΔH for the reaction: $B_2F_4 + Cl_2 = 0.92\ BF_3 + 0.46\ BF_2Cl + 0.32\ BFCl_2 + 0.30\ BCl_3$ and calc. ΔHf^{o}_{298} = -342.0. [137] calc. ΔH vap.
B_2F_4(l)		[137] meas. v.p.
B_2F_4(c)		[137] meas. v.p.
B_2F_6(l)		
BaF(g)	-9 [9]	[11, 14] list D_o. [547] calc. binding energy.
BaF_2(g)		[9] lists ΔH vap. [610] calc. binding energy.
BaF_2(l)		[140] meas. ΔH fus. [9] lists ΔH fus.
BaF_2(c)	-286.9 [9]	[139] meas. ΔH reac. of: $BaF_2 + CaCl_2$, $BaF_2 + SrCl_2$, $BaF_2 + SrCl_2 \cdot SrF_2$. [264] calc. ΔF for the reaction: $BaCl_2 + 2HF = BaF_2 + 2HCl$. [138, 544] correlate ΔHf^{o}_{298}. Other reviews give for ΔHf^{o}_{298}: -286 [20], -286 ± 1 [12], -286.0 ± 3 [15], -286.9 [17].
BeF(g)	+3.80 [34]	[141] meas. D_o. [11, 14, 22, 33, 34, 37] list D_o. [547] calc. binding energy. Other reviews est. for ΔHf^{o}_{298}: +3.80 [37], + 3.80 ± 30 [24], +4 [17], +4.8 [21, 27], -16.5 ± 10 [26], -28.2 [25].
BeF_2(g)	-182.8 [35] -182.8 [27]	[144, 145, 146, 147, 149] calc. ΔH vap. [144, 145, 146] calc. ΔH sub. [353] obs. BeF_2 ion intensity. [610] calc. binding energy. Other reviews give for ΔHf^{o}_{298}: -168.6 ± 10 (est.) [24], -170.86 (est.) [21], -178 [33], -181.8 ± 5 [26], -182.8 [27], -182.9 ± 6 [37], -192.1 [15, 17, 25].
BeF_2(l)		[144, 145, 146, 147, 149] meas. v.p.
BeF_2(c)	-241.2 ± 2 [35] -241.08 [142] [46] see Remarks.	[142] determined ΔH soln. of BeO and BeF_2 in HF(aq). [46] has burned Be(c) in F_2 and reports ΔHf^{o}_{298} = -258.3, -256.8, -255.9 for the reaction Be(c) + F_2(g) = BeF_2(c). [143] reports three forms of BeF_2(c): $\alpha - BeF_2(c) \xrightarrow{217^o} \beta - \beta eF_2 \xrightarrow{337^o} \gamma - BeF_2$. [144, 145, 146] meas. v.p. [545] correlates ΔHf^{o}_{298}. Other reviews give for ΔHf^{o}_{298}: -220(est.) [20], -227 ± 5(est.) [12, 21], -227 ± 10 [15, 33], -241.1 [25, 34], -241.2 ± 2 [37], -241.7 ± 5 [26].
BeF_3(c)		
BiF(g)	+7 [9]	[11, 12, 14] list D_o. [17] lists ΔHf^{o}_{298} = +7.
BiF(c)		[20] est. ΔHf^{o}_{298} = -65.
BiF_2(c)		[20] est. ΔHf^{o}_{298} = -140.
BiF_3(c)	-212 ± 10 [15]	[12, 20] est. ΔHf^{o}_{298} = -216. See BiF_5(l).
BiF_4(c)		[20] est. ΔHf^{o}_{298} = -285.

* Apparently an error.

Compound	ΔHf°_{298} (kcal/mole)	Remarks
$BiF_5(g)$		[150] calc. ΔH vap.
$BiF_5(l)$		For the reaction: $BiF_5(l) = BiF_3(c) + F_2(g)$, [150] reports ΔF reac. is negative at 200° (decomposition pressure exceeded range of available apparatus). [150] meas. v.p.
$BrF(g)$	-18.36[a] [102]	[11, 14, 102, 152, 153, 154, 155, 156, 157, 158] report D_o. [505] calc. ΔHf°_{298} = -17.7[a] ± 0.5. See $BrF_3(g)$, $BrF_5(g)$.
$BrF_3(g)$	-64.8[a] ± 0.2 [505]	[505] meas. ΔH for the reaction of $Br_2(g) + F_2(g)$ forming BrF_3 and BrF_5. For the reaction: $Br_2(g) + BrF_3(g) = 3BrF(g)$, [151] meas. $\Delta F = + 1.2, \Delta H = 11.9$. See also [524]. [154] est. average bond energy (Br-F) in BrF_3. [159] calc. ΔH vap. [25] lists ΔHf°_{298} = -75. See $BrF_5(g)$, $Br_2F_6(g)$.
$BrF_3(l)$	-75 [151]	[159] meas. v.p., ΔH fus. See [155] for general review.
$BrF_3(c)$		
$BrF_5(g)$	-124.0[a] [102] -106.2[a] ± 0.3 [505]	For the reaction: $1/2\,Br_2(g) + 5/2F_2(g) = BrF_5(g)$, [505] meas. $\Delta H = -106.2 \pm 0.3$. For the reaction: $2BrF_3(g) = BrF(g) + BrF_5(g)$, [163] est. $\Delta F = -10.8$. [154] est. average bond energy (Br-F) in BrF_5. [160] gives thermodyn. prop. [162] calc. ΔH vap. [9] lists ΔH vap. See v.p. studies for $BrF_5(l)$. [221] studied dissociation. [17] lists ΔHf°_{298} = -120. See [155] for a general review.
$BrF_5(l)$		[161, 162, 164] meas. v.p. [164] meas. ΔH fus. [9] lists ΔH fus.
$BrF_5(c)$		
$BrF_7(g)$		
$Br_2F_6(g)$		[525] est. K for the reaction: $1/2\,Br_2F_6 = 2BrF_3$.
$CF(g)$		[526, 527] meas. D_o. [14] lists D_o. [357] meas. ion appearance potential from CF_3Br and CF_3I. [17, 22] calc. ΔHf°_{298} = +74. [28] lists +74.409. [21, 24, 25] calc. +74.5. [26] calc. +82.8 ± 10.
$CF_2(g)$		[165, 357] meas. appearance potential of CF_2^+. [167, 169] meas. energies of bond dissoc. leading to CF_2. [22, 531] est. ΔHf°_{298} = -17. [169] est. ≤ -18. [26] est. -18 ± 5. [21, 24] est. -23. [25] est. -30. [165] est. -30 ± 20. [28] est.-46 ± 5. [28] gives as sources [528, 529, 530].
$CF_3(g)$		[166] meas. ionization potential. [104, 166, 167, 169, 177, 358, 359] evaluate energies of bond dissoc. leading to CF_3. [166, 357, 532] meas. ion appearance potential. [624] est. ΔHf°_{298} = -113.5 ± 2. [166] est. -117. [168] est. -119. [169] est.-119.5. [21, 24, 26] est. -120. [22, 25, 167] est. -120.5. [28] est. -130 ± 10.
$CF_4(g)$	-162.5 [9] -231 [170] -225 [171] -212.7 [172] -218.3 [49, 50] -217.2 [173, 176, 537] -218 ± 2 [174] -219.2 ± 2.3 [175]	[49] (see also [50]) meas. ΔH for the combustion of $C_2F_4(s)$ in O_2 with CF_4 as a product. [52] meas. ΔH for the reaction: $CH_4(g) + 4F_2(g) = 4HF(g) + CF_4(g)$. [170, 171, 174] meas. ΔH for the reaction: $CF_4(g) + K(c) = 4KF(c) + C$. [175] meas. ΔH for the reaction: $CF_4(g) + Na(c) = 4NaF(c) + C$. [172, 173] (see also [176, 537]) meas. ΔH for the reactions: $C_2F_4(g) + 2H_2(g) = 2C + 4HF(aq)$, and $C_2F_4(g) = CF_4(g) + C$. [166, 167, 169, 177] report bond energy (F_3C-F). [9] lists ΔH vap. [610] calc. ΔH vap. [314] compared observed reactions with those calculated from thermodyn. data. [625] correlates ΔHf. Other reviews give for ΔHf°_{298}: -162.5 [20], -164 [12], -218 [17, 21, 22, 24, 25, 26, 28], -218 ± 2 [361], -220 ± 3.5 [15].
$CF_4(l)$		[610] meas. v.p. [135] meas. ΔH fus. [9] lists ΔH fus.
$CF_4(c)$		[135] meas. ΔH trans. [9] lists ΔH trans.
$CaF(g)$	-9.3 [9]	[11, 14] list D_o. [547] calc. binding energy. [25] lists ΔHf°_{298} = -9.3.
$CaF_2(g)$		[9] lists ΔH vap. [548, 610] calc. binding energy. [25] lists ΔHf°_{298} = -199.

[a] Value based upon $Br_2(g)$ as the standard state.

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
$CaF_2(\ell)$		[140] meas. ΔH fus. [9] lists ΔH fus.
$CaF_2(c)$	-290.3 [9]	[139] meas. ΔH reac. of: $CaF_2 + BaCl_2$, $CaF_2 + SrCl_2$. [9] lists ΔH trans. [138, 544] correlate ΔHf. Other reviews give for ΔHf^o_{298}: -290.2 [12, 17], -290.3 [15, 20]. See $SiF_4(g)$.
$CdF_2(g)$		[9] lists ΔH vap. [610] calc. binding energy.
$CdF_2(\ell)$		[9] lists ΔH fus.
$CdF_2(c)$	-164.9 [9]	See [43] for ΔHf. [178] reports ΔF of cell reactions of: $CdF_2 - PbF_2$; $CdF_2 - Hg_2F_2$; $CdF_2 - CuF_2$. [178, 179] meas. v.p. Other reviews give for ΔHf^o_{298}: -164.9 [20], -166.5 [15], -167 [12].
$CeF_3(\ell)$		[180] reports ΔHf^o_{1732} = -389. [180] meas. ΔH fus.
$CeF_3(c)$		[181] meas. ΔH pptn. [180] est. ΔHf^o_{298} = -410 ± 7. [15] est. -410 ± 10. [20] est. -416. [12] est. -416 ± 7. See $CeF_3HO_{\frac{1}{2}}(c)$.
$CeF_4(c)$		[12, 20] est. ΔHf^o_{298} = -442.
$ClF(g)$	-13.42 [102] -11.7 [62]	[62] reacted F_2 with Cl_2. [11, 14, 75, 77, 102, 153, 154, 158, 182, 183] report or discuss D_o. [9] lists ΔH vap. [102, 155] review thermodyn. prop. Other reviews give for ΔHf^o_{298}: -12.62 [25], -13.3 [9, 22, 24], -13.42 [17], -13.501 [28], -15 [12].
$ClF(\ell)$		
$ClF_2(g)$		[25] est. ΔHf^o_{298} = -25.
$ClF_3(g)$	-38.79 [102] -28.4 [170]	[170] meas. ΔH for the reaction: $ClF_3 + NaCl = 3NaF + 2Cl_2$. [154] est. average bond energy (Cl-F) in ClF_3. [184] calc. ΔH vap. [9] lists ΔH vap. See v.p. studies for $ClF_3(\ell)$. [185, 528, 534] calc. thermodyn. functions. [155, 186] review thermodyn. prop. Other reviews give for ΔHf^o_{298}: -37 [9, 25], -38.79 [17, 27], -42 ± 2 [12].
$ClF_3(\ell)$		[184, 535] meas. v.p. [184] meas. ΔH fus.
$ClF_3(c)$		[184] meas. ΔH trans.
$(ClF_3)_2(g)$		From equil. studies [187] gives for the reaction: $2ClF_3(g) = (ClF_3)_2(g)$, ΔH = -3.3.
$CmF_2(c)$		See [106].
$CmF_3(c)$		See [106].
$CoF_2(c)$	-159 [9]	Other reviews give for ΔHf^o_{298}: -158 ± 1 [12, 20], -159 ± 5 [15]. See $CoF_3(c)$.
$CoF_3(c)$	-187 [9]	For the reaction: $2CoF_2(c) + F_2(g) = 2CoF_3(c)$, [188] meas. ΔH_{250^oC} = -56.1; and for: $2CoF_3(c) + H_2(g) = 2CoF_2(c) + 2HF(g)$, ΔH_{335^oC} = -74 ± 4. Other reviews give for ΔHf^o_{298}: -187 ± 6 [15], -190 ± 10 [12, 20].
$CrF_2(c)$	-181.0 [9]	Other reviews give for ΔHf^o_{298}: -182 [12, 15, 20].
$CrF_3(c)$	-265.2 [9]	Other reviews give for ΔHf^o_{298}: -266 ± 5 [12, 15, 17], -266 [20].
$CrF_4(c)$	-286.5 [12]	Other reviews give for ΔHf^o_{298}: -286.5 ± 6 [15, 20].
$CrF_5(c)$		[20] est. ΔHf^o_{298} = -350.
$CrF_6(\ell)$		
$CsF(g)$		[64, 536] meas. D_o. [11, 14] list D_o. [19] reviews dissociation and vaporization. [190, 191] calc. ΔH sub. [549] calc. binding energy. [17] lists ΔHf^o_{298} = -82. [25] lists -85.
$CsF(\ell)$		[193] meas. ΔH fus. [9, 17] list ΔH fus.

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
CsF(c)	-126.9 [9]	[194] tabulates ΔH for reactions: CsF + MCl (M=Li, K, etc.). [192, 195] meas. ΔH soln. [192] meas. ΔH soln. in Cs. [195] meas. ΔH hydration. [190, 191] meas. v.p. [544, 613] calc. lattice energy. Other reviews give for ΔHf^o_{298}: -126.9 ± 4 [15], -131.7 ± 0.2 [12, 20].
CsF_3(c)		
$(CsF)_2$(g)		For the reaction: $(CsF)_2$(g) = 2CsF(g), [189, 512] calc. $\Delta H_{1121°K}$ = 41.4. [546] calc. energy of dimeriz. [190] reports dissoc. energy and ΔH sub. See CsF(g), CsF_2Rb(g).
$(CsF)_3$(g)		[196] reports binding energy. [189] reports species abundances.
CuF(g)	+44 [9]	[11, 14] list D_o. [17] lists ΔHf^o_{298} = +44.
CuF(c)		[130] calc. lattice energy and est. ΔHf = -14, -18, and -36. [15, 20] est. ΔHf^o_{298} = -60. [12] est. -60 ± 3.
CuF_2(c)	-126.9 [9]	[178] reports ΔFf. Other reviews give for ΔHf^o_{298}: -128 ± 4 [12, 15, 20].
DF(g)		
$(DF)_6$(g)		
DyF_3(c)		[12] est. ΔHf^o_{298} = -398 ± 7.
ErF_3(c)		[12] est. ΔHf^o_{298} = -392 ± 7.
EuF_2(c)		[12] est. ΔHf^o_{298} = -300 ± 7.
EuF_3(c)		[12] est. ΔHf^o_{298} = -391 ± 7.
FeF_2(c)	-168 ± 2 [12]	[15] lists ΔHf^o_{298} = -168 ± 5.
FeF_3(c)	-235 ± 13 [12]	Other reviews give for ΔHf^o_{298}: -235 [15, 20].
FrF(g)		[614] calc. ΔH sub.
GaF(g)		[14] lists D_o. [110, 197, 198] report D_o. [547] calc. binding energy.
GaF(c)		[12, 20] est. ΔHf^o_{298} = -56 ± 10.
GaF_2(c)		[12] est. ΔHf^o_{298} = -165 ± 10. [20] est. -160.
GaF_3(c)		[12, 20] est. ΔHf^o_{298} = -255 ± 10.
GdF_3(c)		[181] reports ΔFf^o_{298} = -388.7. [12] est. ΔHf^o_{298} = -404 ± 7.
GeF(g)		[515] meas. D_o. [11, 14] list D_o. [25] lists ΔHf^o_{298} = -16.6.
GeF_2(c)		[12, 20] est. ΔHf^o_{298} = -170 ± 15.
GeF_4(g)		[9] lists ΔH sub. [199, 200] calc. thermodyn. prop. [201] compares halides of Ge and Si. [314] compares observed reactions with those calcd. from thermo. data. [20] est. ΔHf^o_{298} = -281. [12] est. -290.
GeF_4(c)		
HF(g)	-64.2 [9] -64.4 ± 0.25 [48]	[48] meas. ΔH for the reaction: NH_3(g) + $3/2F_2$(g) = 3HF(g) + $1/2N_2$(g). [541] meas. ΔH soln. in molten NaF-ZrF_4. [539] meas. Ki of HF. [11, 14] list D_o. [84, 86, 202, 203, 204, 205] report D_o. [540] reports ionization and diasoc. by electron impact. [206, 207] give ΔH for the reaction: $(HF)_{n-1}$(g) + HF(g) = $(HF)_n$(g). [105, 207, 209, 215] est. assoc. factors. [105, 211] meas. ΔH vap. [209, 210] calc. ΔH vap. [9] lists ΔH vap. [208] reports general thermodyn. prop. Other reviews give for ΔHf^o_{298}: -64.2 [15, 17, 20, 21, 22, 24, 25, 26, 97], -64.4 ± 0.3 [28], -64.43 [12]. See also NaF(c), F_2HNa(c), SiF_4(g).

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
$HF(\ell)$	-71.8 [212]	[212] meas. ΔH soln. of salts in HF. [209, 211] meas. v.p. [210, 213] meas. v.p. over solns. of alkali fluorides in $HF(\ell)$. [178] meas. v.p. of HF over solns. of HgF, CdF_2, PbF_2. [220] meas. v.p. of HF over solns. of IF_5. [105, 164] meas. ΔH fus. [210] calc. ΔH fus. [9] lists ΔH fus. [214] gives thermodyn. prop. See BF_3.
HF(c)		
$(HF)_2(g)$		For the reaction: $2HF(g) = (HF)_2(g)$, [507] reports $-5<\Delta H<-7$. See also [206, 207].
$(HF)_3(g)$		See [206, 207].
$(HF)_4(g)$		For the reaction: $4HF(g) = (HF)_4(g)$, [215] reports ΔH = -19. See also [206, 207].
$(HF)_6(g)$	-426.0 [9]	For the reaction: $6HF(g) = (HF)_6(g)$, [215] reports ΔH = -40. See also [206, 207].
$HfF_2(c)$		[20] est. ΔHf^o_{298} = -230.
$HfF_3(c)$		[20] est. ΔHf^o_{298} = -350.
$HfF_4(c)$		See [43] for ΔHf. [12, 20] est. ΔHf^o_{298} = -435 ± 40.
HgF(g)	14 [9]	[11, 14] list D_o. [216] est. ΔHf^o_{298} = -15. Other reviews give for ΔHf^o_{298}: 14 [17, 25].
HgF(c)		See $Hg_2F_2(c)$.
$HgF_2(g)$		[9] lists ΔH sub.
$HgF_2(c)$		[216] est. ΔHf^o_{298} = -69.5. [12, 15, 20] est. -95 ± 10.
$Hg_2F_2(c)$ $(HgF)_2$		For the reaction: $TiF_4(g) + Hg(\ell) = \frac{1}{2}Hg_2F_2(c) + TiF_3(c)$, [217] meas. ΔH = -24.4, ΔF = -11.84, ΔS = -42.1 e.u. [178] reports ΔFf^o_0 = -104.5. [178] meas. v.p. over Hg_2F_2 - HF. [216] est. ΔHf^o_{298} = -77. For $\frac{1}{2}Hg_2F_2(c)$, [12, 15, 20] est. ΔHf^o_{298} = -46.0 ± 7.0.
$HoF_3(c)$		[12] est. ΔHf^o_{298} = -395 ± 7.
IF(g)	-30.089[a] [102]	[102, 154, 156, 157, 158] report or discuss D_o. Other reviews give for ΔHf^o_{298}: -9.59 [25], -22.5 [17].
$IF_3(g)$		
$IF_5(g)$	-202.6[a] ± 1.6 [102] -194.6 [218]	[218] meas. ΔH hydr. [154] est. average bond energy (I-F) in IF_5. [219] calc. ΔH vap. [9] lists ΔH vap. [155] lists general thermodyn. prop. Other reviews give for ΔHf^o_{298}: -195.1 [17], -196 [25]. See $IF_7(g)$.
$IF_5(\ell)$	-212.4[a] ± 1.5 [102] -204.7 [218]	[219] meas. v.p. [220] meas. v.p. of IF_5 - HF. [220] meas. ΔH fus. [9] lists ΔH fus.
$IF_5(c)$		
$IF_7(g)$	-231.7[a] ± 1.8 [102]	For the reaction: $IF_7(g) = IF_5(g) + F_2(g)$, [221] reports ΔH° = 28.5, ΔS° = 43.5 e.u. [154] est. average bond energy (I-F) in IF_7. [9] lists ΔH sub. [155] gives general thermodyn. prop. [25] lists ΔHf^o_{298} = -225.1.
$IF_7(c)$		
InF(g)		[197] meas. D_o. [14, 110] list D_o. [547] calc. binding energy.
InF(c)		[12, 20] est. ΔHf^o_{298} = -70 ± 5.
$InF_2(c)$		[12] est. ΔHf^o_{298} = -165 ± 5. [20] est. -160.
$InF_3(c)$		[12, 20] est. ΔHf^o_{298} = -250 ± 5.

[a] Value based upon $I_2(g)$ as the standard state.

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
$IrF(c)$		
$IrF_2(c)$		[20] est. ΔHf^o_{298} = -88.
$IrF_3(c)$		[20] est. ΔHf^o_{298} = -140.
$IrF_4(c)$		[12] est. ΔHf^o_{298} = -175. [20] est. -210.
$IrF_5(c)$		[20] est. ΔHf^o_{298} = -200.
$IrF_6(g)$		[222] calc. ΔH vap., ΔH sub. [9] lists ΔH vap.
$IrF_6(\ell)$	-130 [9]	[222] meas. v.p. and calc. ΔH fus. [12] lists ΔHf^o_{298} = -130.
$IrF_6(c)$		[222] meas. v.p. and calc. ΔH trans. [20] lists ΔHf^o_{298} = -130.
KF(g)		[11, 14] list D_o. [19] reviews sub. and dissoc. data. See also [64]. [203] determined bond energy (K-F). [549] calc. binding energy. [190, 191] calc. ΔH sub. [9] lists ΔH vap. [17] lists ΔHf^o_{298} = -77.2. [25] est. -81. See $K_2F_2(g)$.
$KF(\ell)$		[140] meas. ΔH fus. [9, 19] list ΔH fus. [541] est. ΔH fus. of mixtures.
KF(c)	-134.46 [9]	[194] correlates ΔH for reactions: KF + MCl(M=Li, Cs, etc.). [195] reviews ΔH soln. [192] meas. ΔH soln. in K. [190, 191] meas. v.p. [544, 613] calc. lattice energy. Other reviews give for ΔHf^o_{298}: -134.46 [20], -134.5 [12, 15, 17].
$KF_2(c)$		
$KF_3(c)$		
$(KF)_2(g)$		For the reaction: $(KF)_2(g) = 2KF(g)$, [189] reports ΔH_{1121^oK} = 52.3. For the same reaction [190] reports ΔH = 47.6, [191] reports ΔE_{960^oK} = 45. See also [512, 543]. [546] calc. energy of dimeriz. [190, 191] calc. ΔH sub. [19] reviewa sub. and dissoc. data. See F_2KRb, F_2KNa.
$(KF)_3(g)$		[189, 543] report ion intensity ratios of KF polymers.
$LaF_3(c)$		[12, 20] est. ΔHf^o_{298} = -421 ± 7. See alao [181].
LiF(g)	-79.3 ± 3 [34] -80.7 ± 1 [224]	[11, 14, 33] liat D_o. [203] gives bond energy (Li-F). [190, 191, 224, 225, 226, 227, 615] calc. ΔH sub. See also [512, 543] and v.p. meas. on LiF(c). [19, 32] review sublimation data. [9] lists ΔH vap. Other reviews give for ΔHf^o_{298}: -77.2 [33], -77.60 [21], -78.8 ± 5 [26], -79.3 ± 3 [24, 25, 28, 37], -80.2 [17]. See also $Li_2F_2(g)$, $Li_3F_3(g)$, $Li_4F_4(g)$.
$LiF(\ell)$		[230] reviews v.p. [140, 235, 236] meas. ΔH fus. [9, 19] list ΔH fus. [542] est. ΔH fus. of mixed fluorides.
LiF(c)	-146.3 ± 2 [34] -146.2 ± 0.3 [622] -145.1 [21]	[622] (see also [119]) meas. ΔH neutralization of HF(aq) and LiOH(aq) and ΔH soln. of LiF(c). [194] correlates ΔH for reactions: LiF + MCl (M=K, Cs, etc.). [232, 233] est. or meas. ΔH aoln. [234] meas. ΔH soln. of MgF_2 and Li_2O in LiF. [544, 545, 613] calc. lattice energy. [190, 191, 225, 226, 227, 228, 229, 231, 615] meas. v.p. [38, 233] correlate ΔHf^o_{298}. Other reviews give for ΔHf^o_{298}: -145.10 [27], -145.1 ± 1 [24], -145.6 ± 2 [12, 20], -145.7 ± 2 [17], -146.3 [9, 25, 33], -146.3 ±2[15, 26, 37].
$(LiF)_2(g)$	-222.6 ± 5 [34] -222.7 ± 3 [224]	For the reaction: $(LiF)_2(g) = 2LiF(g)$, [189] reports ΔH_{1121^oK} = 64.4. For the same reaction, [190] gives ΔE_{1127^oK} = 58.9 ± 2.1; [191] gives ΔE_{1060^oK} = 57.3 ± 2.7; [227] gives ΔH_{1073^oK} = 64.1; [546] calc. ΔE. See [512]. [191, 226, 231, 512, 543] meas. v.p. [190, 191, 226, 227, 615] calc. ΔH sub. [19, 32, 230] review vap. and sub. data. Other reviews give for ΔHf^o_{298}: -213.5 ± 7 [24, 27], -219.2 [33], -222.6 ± 5 [25, 37], -227.2 ± 10 [26]. See $(LiF)_3(g)$, $F_2LiNa(g)$, $F_2LiRb(g)$.

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
$(LiF)_3(g)$	-345.3 ± 8 [34]	For the reaction: $(LiF)_3(g) = (LiF)_2(g) + LiF(g)$, [226] reports ΔH = 50.7 ± 2.6. For the same reaction, [190] gives 38.3 ± 2.3; [227, 512] give 50 < ΔH_{1073} < 65. [227, 512] report for the reaction: $(LiF)_3(g) = 3LiF(g)$, 115 < ΔH_{1073} < 130. [196] calc. binding energy. [189, 213, 512, 543] obs. species abundance. [190, 226, 615] meas. v.p. and calc. ΔH sub. [230] reviews v.p. data. [19] reviews sub. and dissoc. data. Other reviews give for ΔHf^o_{298}: -339.6 ± 10 [26], -345.3 ± 8 [25, 37], -355.5 [33], -357.6 [27].
$(LiF)_4(g)$		[543] obs. species abundance. [33, 34] discuss the stability.
$LuF_3(c)$		[12] est. ΔHf^o_{298} = -392 ± 7.
$MgF(g)$	-20.44 [34]	[11, 14, 33, 34] list D_o. [547] calc. binding energy. Other reviews give for ΔHf^o_{298}: -20 [9, 17, 23], -20.4 ± 20 [21, 24], -20.44 [33], -21 ± 16 [27], -41 ± 10 [26], -43.2 [25].
$MgF_2(g)$	-178.8 ± 6 [37] -181.2 ± 2 [224, 237]	[224, 237] calc. ΔH sub. [9] lists ΔH vap. [32] reviews vap. data. [610] calc. binding energy. Other reviews give for ΔHf^o_{298}: -169.7 ± 5 [26], -175.3 ± 5 [24], -177.0 ± 4 [27], -178.37 [21], -178.8 ± 6 [36], -182.8 ± 6 [25, 34], -182.9 [17].
$MgF_2(\ell)$		[238] calc. ΔH fus. [9] lists ΔH fus. See $F_3MgNa(\ell)$.
$MgF_2(c)$	-264 ± 4 [37] -268 ± 1.8 [115]	For the reaction: $PbF_2 + Mg = Pb + MgF_2$, [115] meas. ΔH. [234] meas. energy of soln. of MgF_2 in LiF. [224, 237, 238] meas. v.p. [138, 545] correlate ΔHf^o_{298}. Other reviews give for ΔHf^o_{298}: -262.6 ± 3.2 [27], -263 ± 1 [12], -263.5 [9, 20, 33], -263.5 ± 2 [21, 24], -263.5 ± 5 [26], -264.0 ± 4 [36], -266.0 ± 2 [15], -268.0 [17, 25, 34].
$MnF(g)$		[11, 14] list D_o.
$MnF_2(c)$	-189 [9]	[239] meas. ΔH soln. Other reviews give for ΔHf^o_{298}: -190 ± 6 [15], -190 ± 5 [12, 17, 20].
$MnF_3(c)$		[12, 20] est. ΔHf^o_{298} = -238 ± 5. [15] gives -238 ± 7.
$MnF_4(c)$		[12, 20] est. ΔHf^o_{298} = -230 ± 7.
$MoF_2(c)$		
$MoF_3(c)$		
$MoF_4(c)$		[20] est. ΔHf^o_{298} = -256.
$MoF_5(g)$		[240] calc. ΔH vap.
$MoF_5(\ell)$		[240] meas. v.p.
$MoF_5(c)$		[20] est. ΔHf^o_{298} = -335.
$MoF_6(g)$	-382 [17] -372.35 ± 0.22 [241]	[241] meas. ΔH of direct combination of the elements. See [43]. [222] calc. ΔH vap. and ΔH sub. [242] est. ΔH vap. [9] lists ΔH vap. and ΔH sub.
$MoF_6(\ell)$	-388.6 [405]	[405] meas. ΔHf^o_{298} by soln. calorimetry. [242] meas. ΔH fus. [222] meas. v.p. and calc. ΔH fus. [9] lists ΔH fus. [15, 20] est. ΔHf^o_{298} = -405.
$MoF_6(c)$		[242] meas. ΔH trans. [222] meas. v.p. and calc. ΔH trans.
$Mo_2F_9(c)$		
$NF(g)$		[24, 27] est. ΔHf^o_{298} = 58.6 ± 10. [243] est. 62.4 ± 4.2. [25] est. 63. See $NF_2(g)$, $NF_3(g)$.
$NF_2(g)$	8.9 [244, 550] 9.8 [243]	From studies of the equilibrium: $N_2F_4 = 2NF_2$, [244, 550] calc. ΔH = 19.8 ± 0.8. [243] finds 21.5. [25] est. ΔHf^o_0 = 17. See $N_2F_4(g)$.

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
$NF_3(g)$	-27.2 [9] -29.7 ± 1.8 [47]	For the reactions: $NF_3(g) + 4NH_3(g) = 3NH_4F(c) + N_2(g)$, and $NF_3(g) + 3/2H_2(g) = 1/2N_2(g) + 3HF(aq)$, [47] meas. ΔH = -259.5 ± 1.0 and -205.3 ± 3.2 respectively. [243, 551] discuss dissoc. by electron impact and give bond energies. [246] meas. ΔH vap. [245] calc. ΔH vap. [9] lists ΔH vap. Other reviews give for ΔHf^o_{298}: -26 [12], -27.2 [22], -29 [25], -29.7 ± 1.8 [27, 28].
$NF_3(l)$		[245, 246] meas. v.p. [246] meas. ΔH fus.
$NF_3(c)$		[246] meas. ΔH trans.
N_2F_2(g, trans)	19.4 ± 1.3 [247] ≥19 ± 20 [243]	For the reaction: $N_2F_2(g) + 8/3NH_3(g) = 2NH_4F(c) + 4/3N_2(g)$, [247] meas. ΔH = -211.7 ± 0.2. [243] meas. dissoc. by electron impact and gives D(FN=NF). [248] meas. equil. (active = trans) and calc. ΔH = 27.5. [247] recalc. ΔH to be 2.1. [248] calc. ΔH vap.
N_2F_2(l, trans)		[248] meas. v.p.
N_2F_2(g, active)[b]	16.4 ± 1.2 [247] ≥19 ± 20 [243]	See N_2F_2(g, trans). For the same reaction with $NH_3(g)$, [247] meas. ΔH = -209 ± 0.02. [243] meas. dissoc. by electron impact. [248] calc. ΔH vap.
N_2F_2(l, active)[b]		[248] meas. v.p.
$N_2F_4(g)$	-2.0 ± 2.5 [250]	For the reaction: $N_2F_4(g) + 16/3NH_3(g) = 4NH_4F(c) + 5/3N_2(g)$, [250] meas. ΔH = -383.1 ± 0.2. [243, 244, 249, 552] meas. $F_2N - NF_2$ bond dissoc. energy. [251] calc. ΔH vap.
$N_2F_4(l)$		[251] meas. v.p.
$N_3F(g)$		
NaF(g)	-69.2 [17]	[11, 14] list D_o. [203] reports D_o. See also [64]. [190, 191, 227, 253, 512] calc. ΔH sub. [121, 144, 253] calc. ΔH vap. [9] lists ΔH vap. and ΔH sub. [19] reviews sub. and dissoc. data. Other reviews give for ΔHf^o_{298}: -67.00 [21, 27], -68.7 [25], -68.9 ± 2 [26], -72 [9]. See $(NaF)_2(g)$, $(NaF)_3(g)$, $(NaF)_4(g)$, $BeF_3Na(g)$.
NaF(l)		[608] calc. ΔF hydr. [121, 144, 253] meas. v.p. [124, 553] meas. ΔH fus. [254, 255] calc. ΔH fus. [9, 19] list ΔH fus. See $AlF_6Na_3(l)$, $F_3MgNa(l)$.
NaF(c)	-136.0 [9] -136.3 [256]	[259] gives ΔH for the reaction: $3NaF + 2Al_2O_3 = 3NaAlO_2 + AlF_3$. [194, 257] correlate ΔH for exchange reactions: NaF + MX. [256] meas. ΔH soln. in HCl(aq). [258] meas. ΔH soln. in water and $HClO_4(aq)$. [212] meas. ΔH soln. in HF(l). [192] meas. ΔH soln. in Na. [195] correlates ΔH soln. and hydration. [514] meas. e.m.f. of Al-NaF electrode. [544, 613] calc. lattice energy. [190, 191, 227, 253, 512] meas. v.p. [38, 138, 545] correlate ΔHf^o_{298}. Other reviews give for ΔHf^o_{298}: -136.0 [20], -136.0 ± 0.2 [12], -136.17 ± 0.3 [175], -136.3 [17, 21, 25, 26, 27], -136.5 ± 0.5 [15]. See NaF(aq), $F_2HNa(c)$, $F_9Na_3U(c)$, $SiF_4(g)$.
$(NaF)_2(g)$	-197.5 ± 4 [26]	For the reaction: $(NaF)_2(g) = 2NaF(g)$, [190] reports $\Delta H_{1170°K} = 54.3$; [191] gives $\Delta E_{1098°K} = 52$; [227] gives $\Delta H_{1121°K} = 62.0$; [252] gives $\Delta E_{1146°K} = 42.9$. See also [512, 554]. [512] compares ΔH dissoc. of Na_2F_2, Li_2F_2, K_2F_2. [546] calc. dissoc. energy. [19] reviews dissoc. and sub. data. [189, 190, 191, 227, 252, 512, 543, 554] meas. v.p. or obs. species abundance in vapor. [190, 191, 227, 512] calc. ΔH sub. Other reviews give for ΔHf^o_{298}: -197.5 [25]. See $(NaF)_3(g)$, $F_2LiNa(g)$, $F_2KNa(g)$.
$(NaF)_3(g)$		For the reaction: $(NaF)_3(g) = (NaF)_2(g) + NaF(g)$, [252, 554] report ΔE = 86.5. [196] calc. binding energy. [189, 512, 543] obs. species abundance in vapor.
$(NaF)_4(g)$		[543] obs. species abundance in vapor.
$NbF_5(g)$		[260] calc. ΔH sub. [260, 261] calc. ΔH vap. [9] lists ΔH vap.

[b] "active" N_2F_2 has been identified by some workers as cis-1,2-difluorodiazine and by others as 1,1-difluorodiazine.

TABLE 2 - BINARY FLUORIDES (continued)

Compound	ΔHf^o_{298} (kcal/mole	Remarks
$NbF_5(\ell)$		[260, 261] meas. v.p. [242] meas. ΔH fus. [260] calc. ΔH fus.
$NbF_5(c)$	-432 [405]	[405] meas. ΔHf^o_{298} and reports ΔFf^o_{298} = -405. [260, 261] meas. v.p. [20] est. ΔHf^o_{298} = -342.
$NdF_3(c)$		[12, 20] est. ΔHf^o_{298} = -410 ± 7.
$NiF_2(g)$		[262] calc. ΔH sub., ΔS vap.
$NiF_2(\ell)$		
$NiF_2(c)$	-159.5 [9]	For the reaction: $NiF_2(c) + H_2(g) = Ni(c) + 2HF(g)$, [263] meas. ΔH^o_{298} = 30.06. For the reaction: $NiCl_2(c) + 2HF(g) = NiF_2(c) + 2HCl(g)$, [264] meas. ΔF. [262] meas. v.p. Other reviews give for ΔHf^o_{298}: -156 ± 2 [17], -158 [12, 15, 20].
$NpF_3(c)$		[9, 15, 20] est. ΔHf^o_{298} = -360 ± 8. [555] est. -360 ± 2.
$NpF_4(c)$		[9, 20] est. ΔHf^o_{298} = -428. [555] est. -428 ± 3.
$NpF_5(c,\alpha)$		[20] est. ΔHf^o_{298} = -467. [555] est. -467 ± 3.
$NpF_6(g)$		[265] calc. ΔH sub. and ΔH vap. See v.p. studies for $NpF_6(\ell,c)$. [555] est. ΔHf^o_{298} = -463 ± 3.
$NpF_6(\ell)$		[265, 267] meas. v.p. [265, 266] calc. ΔH fus.
$NpF_6(c)$		[265, 266, 267] meas. v.p. [20] est. ΔHf^o_{298} = -472.
$OF(g)$		[14] lists D_o. [80, 268, 556] est. D_o. [25] est. ΔHf^o_{298} = 26.6. [24, 27] est. 32.4 ± 10.
$OF_2(g)$	+7.6 ± 2 [102]	[76, 80, 268, 557] give dissoc. energy. [9] lists ΔH vap. [75] gives thermodyn. prop. Other reviews give for ΔHf^o_{298}: 5.5 [9, 24], 7 ± 2 [12], 7.6 ± 2 [25, 28].
$OF_2(\ell)$		[270] meas. v.p.
$OF_4(g)$		
$O_2F(g)$		For the reaction: $FO_2(g) = F(g) + 2O(g)$, [271] est. ΔH^o_{298} <100.
$O_2F_2(g)$	+4.73 ± 0.3 [273]	[272] est. ΔH vap. and calc. ΔHf^o_{298} = 4.65. [1] discusses dissoc. energy. [558] lists ΔHf^o = 16.0.
$O_2F_2(\ell)$		For the reaction: $O_2F_2(\ell) = O_2(g) + F_2(g)$, [273] meas. ΔE.
$O_3F_2(g)$	+6.24 ± 0.75 [273]	[272] est. ΔH vap. and calc. ΔHf^o_{298} = +6.18. [558] est. ΔHf^o_{298} = -24.1.
$O_3F_2(\ell)$		For the reaction: $O_3F_2(\ell) = O_2F_2(\ell) + \frac{1}{2}O_2(g)$, [273] meas. ΔE.
$O_4F_2(g)$		
$O_4F_2(\ell)$		[274] meas. v.p.
$O_5F_2(g)$		[558] est. ΔHf^o_{298} = -53.6.
$O_6F_2(g)$		
$OsF_2(c)$		[20] est. ΔHf^o_{298} = -100.
$OsF_3(c)$		[20] est. ΔHf^o_{298} = -150.
$OsF_4(c)$		[12] est. ΔHf^o_{298} = -180. [20] est. -200.
$OsF_5(g)$		[240] calc. ΔH vap.
$OsF_5(\ell)$		[240] meas. v.p.
$OsF_6(g)$		[222] calc. ΔH vap. and ΔH sub.
$OsF_6(\ell)$		[222] meas. v.p. and calc. ΔH fus.

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
$OsF_6(c)$		[222] meas. v.p. and calc. ΔH trans. [12, 20] est. $\Delta Hf^o_{298} = -225$.
$OsF_8(g)$		[9] lists ΔH vap.
$OsF_8(\ell)$		
$OsF_8(c)$		[12] est. $\Delta Hf^o_{298} = -240$. [20] est. -300.
$PF(g)$		[275] calc. D(P-F). [25, 26, 27] est. $\Delta Hf^o_{298} = -17 \pm 15$.
$PF_2(g)$		[26, 27] est. $\Delta Hf^o_{298} = -109 \pm 15$. [25] est. -120.
$PF_3(g)$		[10] lists ΔH soln. in KOH(aq). [26] calc. $\Delta Hf^o_{298} = -220.7 \pm 10$, based on corrected soln. data reported in [10]. [275, 566] est. (P-F) bond energy. [2] lists v.p. studies. [9] lists ΔH vap. [20] est. $\Delta Hf^o_{298} = -170$. [4] est. -189. [25, 27] list -220.7 ± 10.
$PF_3(\ell)$		
$PF_5(g)$	-381.4 ± 0.4 [40]	[40] meas. ΔH for direct combination of the elements. [276] meas. ΔHf^o_{298}. [9] lists ΔH sub. and ΔH vap. [25] est. $\Delta Hf^o_{298} = -420$. [38] est. -315.
$PF_5(\ell)$		[9] lists ΔH fus.
$PF_5(c)$		

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
PaF_3(c)		
PaF_4(c)		[106] est. ΔHf^o_{298} = -477 from consideration of the high temp. reaction: PaF_4(c) + 2Ba(g) = Pa(c) + $2BaF_2$(g). [277] gives chem. properties.
PaF_5(c)		
PbF(g)		[11, 14] list D_o. [279, 559] report D_o. [17] lists ΔHf^o_{298} = -27 ±9.
PbF_2(g)		[280] calc. ΔH sub. [9] lists ΔH vap.
PbF_2(ℓ)		[281] meas. ΔH fus. [9] lists ΔH fus.
PbF_2(c)	-158.9 [9]	[115, 119] meas. ΔH for reaction: 3/2 PbF_2(c) + Al(c) = AlF_3(c) + 3/2 Pb(c). [115] meas. ΔH for the reaction: PbF_2(c) + Mg(c) = MgF_2(c) + Pb(c). [116] (see also [118]) meas. ΔH for the reaction: 3/2 PbF_2(c) + Al(c) + 3NaF(c) = 3/2 Pb(c) + Na_3AlF_6(c). [178] reports ΔFf = -149.3. [282] studied thermodyn. properties and obs. transition. [280] meas. v.p. [178] meas. v.p. of system: PbF_2 - HF. Other reviews give for ΔHf^o_{298}: -158 ±2 [12], -158.5 [20], -158.5 ±0.8 [15]. See ClFPb(c).
PbF_3(c)		
PbF_4(c)	-222.3 [9]	Other reviews give for ΔHf^o_{298}: -222 ±2 [12, 20], -222.3 ±2.5 [15].
PdF_2(c)		[12, 15, 20] est. ΔHf^o_{298} = -112 ±10.
PdF_3(c)		[12, 20] est. ΔHf^o_{298} = -122 ±20.
PmF_3(c)		[12] est. ΔHf^o_{298} = -408 ±7.
PrF_3(c)		For the reaction: PrF_3(c) + 1/2 F_2(g) = PrF_4(c), [283] est. ΔF = -72 ±24. [12, 20] est. ΔHf^o_{298} = - 413 ±7.
PrF_4(c)		[283] est. ΔFf^o_{298} = -454 ±21. See PrF_3(c).
PtF(c)		
PtF_2(c)		[20] est. ΔHf^o_{298} = -82.
PtF_3(c)		[20] est. ΔHf^o_{298} = -135.
PtF_4(c)		[20] est. ΔHf^o_{298} = -190.
PtF_5(c)		
PtF_6(c)		[284] meas. v.p.
PuF_3(g)		[128, 286, 287, 560] calc. ΔH sub. See v.p. studies on PuF_3(c). [286, 560] calc. ΔH vap. [9] lists ΔH sub. and ΔH vap. [106] compares ΔS sub. with that of AmF_3.
PuF_3(ℓ)		[289, 561, 571] meas. $\Delta Ff_{1573°K}$ = 93. [286, 560] meas. v.p. and calc. ΔH fus. See UF_3(c), UF_4(ℓ).
PuF_3(c)	-375.0 ±3 [15] -375 [288]	[288] reports ΔH pptn. of PuF_3. [290, 291] studied the equilibrium: $3PuF_4$ + PuO_2 = $4PuF_3$ + O_2. For this reaction [290] reports $\Delta F^o_{298°K}$ = 14.8 and $\Delta F^o_{1000°K}$ = 10.6. [126, 127, 128, 286, 287, 560] meas. v.p. [20] lists ΔHf^o_{298} = -374.6. See PuF_4(c).
PuF_4(g)		[562] lists ΔH sub. and ΔH vap. See also [563].
PuF_4(ℓ)		
PuF_4(c)		For the reaction: $3PuF_4$ + PuO_2 = $4PuF_3$ + O_2, [290] meas. $\Delta F_{298°K}$ = 14.8, $\Delta F_{1000°K}$ = 10.6 and calc. $\Delta Ff_{298°K}$ = 400, $\Delta Ff_{1000°K}$ = 354. On this basis, [106] reports ΔHf^o_{298} = -400. [291] discusses relative stabilities of PuF_3, PuF_4, PuF_5. [148, 506] meas. v.p. [562] lists ΔHf^o_{298} = -424 ±4. (See also [563]). [20] lists -424. See PuF_5(c), PuF_6(g).

Compound	ΔHf°_{298} (kcal/mole)	Remarks
$PuF_5(g)$		[562] lists $\Delta Hf^\circ_{298} = -453 \pm 5$ (est.). See [563].
$PuF_5(c)$		[291] discusses relative stabilities of $PuF_3(c)$, $PuF_4(c)$, and $PuF_5(c)$.
$PuF_6(g)$		For the reaction: $PuF_4(c) + F_2(g) = PuF_6(g)$, [292] meas. $\Delta H = 6.09$, [294] meas. 8.3. [265, 293] calc. ΔH sub. and ΔH vap. See v.p. studies for $PuF_6(c)$.
$PuF_6(l)$		[265, 293] meas. v.p. [265, 266, 293] calc. ΔH fus.
$PuF_6(c)$		[265, 293, 295] meas. v.p.
$Pu_4F_{17}(c)$		
$RaF_2(c)$		[12, 20] est. $\Delta Hf^\circ_{298} = -287 \pm 3$.
$RbF(g)$	-77.7 [17]	[11, 14] list D_0. [55, 64] report dissoc. energy. [190, 191] give species abundance and calc. ΔH sub. See v.p. studies for $RbF(c)$. [9] lists ΔH vap. See v.p. studies for $RbF(l)$. [25] est. $\Delta Hf^\circ_{298} = -87$. See $(RbF)_2$, F_9RbZr_2, F_6Rb_2Zr.
$RbF(l)$		[228, 229] meas. v.p. [193, 296] meas. ΔH fus. [9, 19] list ΔH fus.
$RbF(c)$	-131.28 [9]	[194] correlates ΔH for the exchange reactions: $RbF(c) + MCl(c)$ (M = Li, K, Na, Cs). [195] reviews heats of solution and hydration. [544, 613] calc. lattice energy. [190, 191, 228, 229] meas. v.p. [545] correlates ΔHf. Other reviews give for ΔHf°_{298}: -131.3 ±2 [15], -133.2 [12, 20].
$RbF_3(c)$		
$(RbF)_2(g)$		For the reaction: $(RbF)_2(g) = 2RbF(g)$, [190] calc. $\Delta H_{951^\circ K} = 42.0 \pm 6$; [189, 512] calc. $\Delta H_{1121^\circ K} = 48.3 \pm 3.0$; [546] calc. ΔH. [512] compares dimerization energy of RbF with those of KF, CsF, LiF. [19] reviews dissoc. and sub. data. [190] calc. ΔH sub.
$(RbF)_3(g)$		[189] meas. species abundance.
$ReF_3(c)$		[20] est. $\Delta Hf^\circ_{298} = -170$.
$ReF_4(c)$		[12] est. $\Delta Hf^\circ_{298} < -186$. [20] est. -220.
$ReF_5(g)$		[240] calc. ΔH vap.
$ReF_5(l)$		[240] meas. v.p.
$ReF_5(c)$		[12, 20] est. $\Delta Hf^\circ_{298} = -225 \pm 15$.
$ReF_6(g)$	-273 [9]	[222] calc. ΔH sub. and ΔH vap. See v.p. studies for $ReF_6(c)$. [9] lists ΔH vap. [17] lists $\Delta Hf^\circ_{298} = -273$. See $ReF_7(g)$.
$ReF_6(l)$	-278 ±3 [12]	[222, 297] meas. v.p. [222] calc. ΔH fus. [9] lists ΔH fus. Other reviews give for ΔHf°_{298}: -278 ±12 [15], -278 [20].
$ReF_6(c)$		[222, 297] meas. v.p. [222] calc. ΔH trans.
$ReF_7(g)$		[297] discusses the reactions: $ReF_6(g) + \frac{1}{2}F_2(g) = ReF_7(g)$, and $6ReF_7(g) + Re(c) = 7ReF_6(g)$.
$ReF_7(c)$		[297] meas. v.p.
$RhF(c)$		
$RhF_2(c)$		[12] est. $\Delta Hf^\circ_{298} = -110 \pm 10$. [20] est. -117.
$RhF_3(c)$		[12] est. $\Delta Hf^\circ_{298} = -160 \pm 20$. [20] est. -175.
$RhF_4(c)$		
$RhF_5(c)$		

Compound	ΔHf°_{298} (kcal/mole)	Remarks
RuF_3(c)		[20] est. ΔHf°_{298} = -180.
RuF_4(c)		[20] est. ΔHf°_{298} = -230.
RuF_5(c)		[20] est. ΔHf°_{298} = -300.
RuF_6(c)		
RuF_8(c)		
SF(g)		[25, 26] est. ΔHf°_{298} = -1 ±10. See also [300].
SF_2(g)		[25, 26] est. ΔHf°_{298} = -68 ±10. See also [300].
SF_4(g)	-171.7 ±2.5 [298]	[298] meas. ΔH of the reaction with H_2. [299] calc. ΔH vap. [9] lists ΔH vap. See v.p. studies on SF_4(ℓ). [25] est. ΔHf°_{298} = -156. See also [300].
SF_4(ℓ)		[299, 564] meas. v.p.
SF_5(g)		For the reaction: SF_6(g) + Na(g) = SF_5(g) + NaF(g), [300] states ΔH ≅ -37.
SF_6(g)	-262 [9] -288.5 ±0.7 [568]	[568] meas. ΔH of the direct combination of the elements. See also [39, 301]. [9] lists ΔH sub. and ΔH vap. See v.p. studies on SF_6(ℓ). Other reviews give for ΔHf°_{298}: -262 [22, 25], -262.0 ±0.4 [15], -277.5 [12], -288.5 [27], -289 [17].
SF_6(ℓ)		[303, 304, 305] meas. v.p. [9] lists ΔH fus.
SF_6(c)		[9] lists ΔH trans.
S_2F_2(g)		[25, 26] est. ΔHf°_{298} = -63 ±10.
S_2F_{10}(g)	-485 [12]	[9] lists ΔH vap.
S_2F_{10}(ℓ)	-492 [12]	
SbF(g)	0 [9]	[11, 14] list D_o.
SbF_3(c)	-217.2 [9]	Other reviews give for ΔHf°_{298}: -216.6 [12, 20], -217.2 ±4.0 [15].
SbF_5(g)		[306] calc. ΔH vap. See v.p. studies for SbF_5(ℓ).
SbF_5(ℓ)		[306, 307] meas. v.p. [20] est. ΔHf°_{298} = -305.
Sb_2F_8(c)		
Sb_3F_{11}(c)		
Sb_4F_{11}(c)		
Sb_5F_{17}(c)		
Sb_6F_{20}(c)		
ScF_3(c)		[12, 20] est. ΔHf°_{298} = -367 ±7.
SeF_4(g)		[308] calc. ΔH vap. See v.p. studies for SeF_4(ℓ).
SeF_4(ℓ)		[308, 565] meas. v.p.
SeF_4(c)		[308] meas. v.p.
SeF_6(g)	-246 [9]	[9] lists ΔH vap. and ΔH sub. Other reviews list for ΔHf°_{298}: -246 [12, 17, 20], -246.0 ±3 [15].
SeF_6(ℓ)		[9] lists ΔH fus.
SeF_6(c)		
Se_2F_2(g)		

Compound	ΔHf°_{298} (kcal/mole)	Remarks
SiF(g)		[11, 12, 14] list D_0. [204] est. D_0. [309] reports D_0. [21] lists ΔHf°_{298} = 2.20. [26] lists 9.2. [25, 27] list 10.3.
SiF_2(g)		For the reaction: $6AlF(g) + 3SiC(c) = Al_4C_3(c) + 3SiF_2(g) + 2Al(\ell)$. [114] reports $\Delta F_{1150-1200}$ = 83.0. [26, 27] est. ΔHf°_{298} = -118 ±10. [21, 25] est. -127.
SiF_3(g)		[26] est. ΔHf°_{298} = -246 ±10. [25] est. -249.
SiF_4(g)	-370 [9] -370.8 [310] -372.4 ±0.4 [311]	[310] meas. ΔH for reactions of SiF_4(g) with (HF + HCl)(aq) and HCl (aq). [311] meas. ΔH for reactions of SiF_4(g) with Na(c), HF (aq), and H_2O. [312] meas. K (200°-800°) for the equilibrium: $SiF_4(g) + 2H_2O(g) = SiO_2(c) + 4HF(g)$. [612] calc. ΔF for reaction with CaH_2 to form CaF_2 and SiH_4. [313] lists $\Delta F_{1300°K}$ for several reactions. [314] calc. ΔH for several reactions. [201] compares ΔHf of Ge and Si halides. [9] lists ΔH vap. and ΔH sub. Other reviews give for ΔHf°_{298}: -360 ±2 [12], -370.8 [20], -372.5 [17], -372.9 [21, 25, 26, 27], -374.0 ±6.0 [15]. See $F_4H_6N_2Si$(c), F_6Na_2Si(c), $AlF_6Na_3(\ell)$.
$SiF_4(\ell)$		[135] meas. ΔH fus. [9] lists ΔH fus.
SiF_4(c)		
Si_2F_6(g)		[9] lists ΔH sub. and ΔH vap.
$Si_2F_6(\ell)$		[9] lists ΔH fus.
Si_2F_6(c)		
SmF_2(c)		[20] est. ΔHf°_{298} = -237. [12] est. -290 ±7.
SmF_3(c)		[12, 20] est. ΔHf°_{298} = -405 ±7.
SnF(g)		[11, 14] list D_0. [25] lists ΔHf°_{298} = 0.
SnF_2(c)		[12, 20] est. ΔHf°_{298} = -158 ±4.
SnF_4(c)		[20] est. ΔHf°_{298} = -259.
SrF(g)	-5 [9]	[11, 14] list D_0. [547] calc. binding energy.
$SrF_2(\ell)$		[140] meas. ΔH fus. [9] lists ΔH fus.
SrF_2(c)	-290.3 [9]	[139] reports ΔH reac. for SrF_2 + $CaCl_2$ and other reactions. [315] calc. ΔFf° and ΔSf°. [138] correlates ΔHf. Other reviews give for ΔHf°_{298}: -289.0 ±0.1 [12, 20], -289.0 ±0.4 [15].
TaF_2(c)		[20] est. ΔHf°_{298} = -180.
TaF_3(c)		[20] est. ΔHf°_{298} = -260.
TaF_5(g)		[261] calc. ΔH vap. [9] lists ΔH vap.
$TaF_5(\ell)$		[261] meas. v.p.
TaF_5(c)		[12] est. ΔHf°_{298} = -300. [20] est. -360.
TbF_3(c)		[12] est. ΔHf°_{298} = -400 ±7.
TcF_3(c)		[20] est. ΔHf°_{298} = -190.
TcF_4(c)		[20] est. ΔHf°_{298} = -250.
TcF_5(c)		[20] est. ΔHf°_{298} = -270.
TcF_6(c)		[20] est. ΔHf°_{298} = -300.

Compound	ΔHf°_{298} (kcal/mole)	Remarks
$TeF_4(g)$		[316] calc. ΔH vap. and ΔH sub.
$TeF_4(\ell)$		[316] meas. v.p. and calc. ΔH fus.
$TeF_4(c)$		[316] meas. v.p. [20] est. ΔHf°_{298} = -205.
$TeF_6(g)$	-315 [9]	[9] lists ΔH vap. and ΔH sub. Other reviews give for ΔHf°_{298}: -315 [12, 17, 20], -315.0 ±3.0 [15].
$TeF_6(\ell)$		[9] lists ΔH fus.
$TeF_6(c)$		[9] lists ΔH trans.
$Te_2F_{10}(g)$		[317] calc. ΔH vap.
$Te_2F_{10}(\ell)$		[317] meas. v.p.
$ThF_3(c)$		[20] est. ΔHf°_{298} = -355.
$ThF_4(g)$		[319] calc. ΔH sub., ΔH vap. See F_2OTh.
$ThF_4(\ell)$		[319] meas. v.p.
$ThF_4(c)$	-482.4 [318]	For the equilibrium: $ThF_4(c) + SiO_2(c) = ThO_2(c) + SiF_4(g)$, [318] found ΔF = -459.9. See [43] for ΔHf. [319] meas. v.p. [9, 20] est. ΔHf°_{298} = -477. [12] est. -477 ±10. [15] est. -477 ±15. See $F_4HO_{\frac{1}{2}}Th(c)$, $F_4H_5O_{5/2}Th(c)$.
$TiF(g)$		[11] lists D_0.
$TiF_2(g)$		[25, 26, 27] est. ΔHf°_{298} = -132 ±10.
$TiF_2(c)$		[114] reports $\Delta F_{1150-1200}$ = 198.5 for the reaction: $6AlF(g) + 3SiC(c) = Al_4C_3(c) + 3TiF_2(c) + 2Al(\ell)$. [9, 12, 20] est. ΔHf°_{298} = -198 ±15. [26, 27] est. -218.0 ±5.
$TiF_3(g)$		[25, 26, 27] est. ΔHf°_{298} = -255.3 ±10.
$TiF_3(\ell)$		[27] lists ΔHf°_{298} = -324.078.
$TiF_3(c)$		For the reaction: $TiF_4(g) + Hg(\ell) = \frac{1}{2} Hg_2F_2(c) + TiF_3(c)$, [217] meas. ΔH = -24.4, and est. ΔHf°_{298} [$TiF_4(c)$] - ΔHf°_{298} [$TiF_3(c)$] = -57.3. [9, 12, 20] est. ΔHf°_{298} = -315 ±15. [26, 27] est. -335 ±3.
$TiF_4(g)$		[320] calc. ΔH sub. [25, 26, 27] list ΔHf°_{298} = -369.6 ±2. See $TiF_3(c)$.
$TiF_4(c)$	-392.5 [568]	[568] meas. ΔH for the reaction: $Ti(c) + 2F_2(g) = TiF_4(c)$. See also [39, 43, 301]. [320] meas. v.p. [9, 12, 15, 20] est. ΔHf°_{298} = -370 ±20. [26, 27] list -392.5 ±0.1.
$TlF(g)$	-33 [9]	[278] meas. D_0 and est. ΔHf. [110] meas. D_0. [14] lists D_0. [547] calc. binding energy. [321] calc. ΔH sub.
$TlF(c)$	-74.0 ±1.5 [15]	[56] meas. ΔH soln. [569] calc. lattice energy. [321] meas. v.p. Other reviews list for ΔHf°_{298}: -65 ±5 (est.) [12, 20], -74 ±5 [17].
$TlF_3(c)$	-136.9 ±2.5 [15] -136.9 [131]	[131] meas. ΔH hydr. = -8.4. Other reviews est. for ΔHf°_{298}: -175 ±10 [12, 20].
$(TlF)_2(g)$		
$TmF_3(c)$		[12] est. ΔHf°_{298} = -391 ±7.
$UF_3(g)$		[569] est. ΔH sub. and ΔH vap.
$UF_3(\ell)$		[569] est. ΔH fus.
$UF_3(c)$	-357 [9]	[289] determined K for the equilibrium: $1/3\ Pu(\ell) + 1/3\ UF_3(c) = 1/3\ PuF_3(\ell) + 1/3\ U(\ell)$. [20] est. ΔHf°_{298} = -340. [569] lists -357 ±4. [15] lists -357.

Compound	ΔHf°_{298} (kcal/mole)	Remarks
$UF_4(g)$		[570] calc. ΔH sub. [9, 569] list ΔH sub. and ΔH vap. See $UF_4(l)$, $UF_4(c)$ for v.p. studies.
$UF_4(l)$		[289) detd. K for the equilibrium: $1/3Pu(l) + \frac{1}{4}UF_4(l) = 1/3PuF_3(l) + \frac{1}{4}U(l)$. [322] meas. v.p. See also [329]. [569] reviews v.p. data and lists ΔH fus.
$UF_4(c)$	-443 [9]	[325] studied free energy changes in the reaction $UF_4(c)$ and O_2. [326] studied K for the equilibrium: $UF_6(g) + H_2(g) = UF_4(c) + 2HF(g)$. [323] studied equilibria in the disproportionation of intermediate U-F compds. [324, 572] review thermodynamic data and calc. ΔF for several reactions. [329, 570] meas v.p. [328] meas. ΔH trans. Other reviews list for ΔHf°_{298}: -443 [15, 17, 20], -443 ±3 [569], -443.5 ±2 [323]. See $F_4H_5O_{5/2}U(c)$, UF_5.
$UF_5(g)$		[330] calc. ΔH sub. and ΔH vap. [569] est. ΔH sub. and ΔH vap.
$UF_5(l)$		[330] meas. v.p. and calc. ΔH fus. [569] est. ΔH fus.
$UF_5(c)$	-488 [9] (α) -483.7 ±1.3 [323] (β) -485.2 ±1.4 [323]	[323] meas. disproportionation equil. of $UF_5(c, \alpha)$ and $UF_5(c, \beta)$. From a study of the disproportionation equilibrium: $2UF_5(c) = UF_4(c) + UF_6(g)$, [327] calc. ΔH = 15.53. [330] meas. v.p. Other reviews give for ΔHf°_{298}: -488 [15, 20, 569].
$UF_6(g)$	-505 [9]	See [43] for ΔHf°. [331] meas. ΔH sub. and ΔH vap. [265, 332, 333] calc. ΔH sub. and ΔH vap. [9, 569] list ΔH sub. and ΔH vap. See also $UF_6(c)$ for v.p. studies. [334] calc. thermodyn. prop. and compares with calorimetric values. [335] gives a general review of thermodyn. prop. Other reviews give for ΔHf°_{298}: -504 ±3 [323], -505 [25, 569]. See UF_4, UF_5, U_2F_9, U_4F_{17}, F_2O_2U, F_5NaU, F_6NaU, F_7NaU, F_8Na_3U, F_9Na_3U.
$UF_6(l)$		[332, 333] meas. v.p. and ΔH fus. [266] calc. ΔH fus. [331] correlates v.p. and ΔH fus. [336] correlates v.p. [9, 569] list ΔH fus. See [335].
$UF_6(c)$	-517 [9]	[265, 332, 333, 337, 338] meas. v.p. [331] correlates v.p. Other reviews list for ΔHf°_{298}: -516 [20]. See [335] for a review. See $F_2O_2U(c)$, $F_6H_4O_2U(aq)$.
$U_2F_9(c)$	-933.8 ±3 [323]	[323] meas. disproportionation pressure of $UF_6(g)$ over U_2F_9.
$U_4F_{17}(c)$	-1820.5 ±4 [323]	[323] meas. disproportionation pressure of $UF_6(g)$ over $U_4F_{17}(c)$.
$VF_2(c)$		[12] est. ΔHf°_{298} = -180 ±20. [20] est. -200.
$VF_3(c)$		[20] est. ΔHf°_{298} = -271. [12] est. -285 ±30.
$VF_4(c)$		[12, 20] est. ΔHf°_{298} = -325 ±30.
$VF_5(g)$		[339, 340] calc. ΔH vap.
$VF_5(l)$		[339, 340] meas. v.p. [340] calc. ΔH fus.
$VF_5(c)$		[340] meas. v.p. [12, 20] est. ΔHf°_{298} = -335 ±20.
$WF_4(c)$		[20] est. ΔHf°_{298} = -250.
$WF_5(c)$		[20] est. ΔHf°_{298} = -280.
$WF_6(g)$	-416 [405]	[405] reports ΔHf°_{298} on the basis of solution calorimetry. [222, 341] calc. ΔH vap. [222] calc. ΔH sub. [20] est. ΔHf°_{298} = -300. [17] lists -416.
$WF_6(l)$		[405] reports ΔFf°_{298} = -397. [222, 341] meas. v.p. [222] calc. ΔH fus. [9] lists ΔH fus.
$WF_6(c)$		[222] meas. v.p. and calc. ΔH trans. [9] lists ΔH trans.
$YF_3(c)$		[12, 20] est. ΔHf°_{298} = -397 ±7.
$YbF_2(c)$		[12] est. ΔHf°_{298} = -280 ±7.
$YbF_3(c)$		[12] est. ΔHf°_{298} = -376 ±7.

Compound	ΔHf°_{298} (kcal/mole)	Remarks
$ZnF_2(g)$		[9] lists ΔH vap.
$ZnF_2(l)$		
$ZnF_2(c)$	-176 ±5 [15]	[138] correlates ΔHf. [223] est. ΔHf°_{298} = -186. Other reviews give for ΔHf°_{298}: -176 ±3 [12, 20].
$ZrF_2(g)$		[26, 27] est. ΔHf°_{298} = -146.7 ±25. [25] est. -147.
$ZrF_2(l)$		[27] est. ΔHf°_{298} = -220 ±25.
$ZrF_2(c)$		[9, 12, 20, 25, 26, 27] est. ΔHf°_{298} = -230 ±25.
$ZrF_3(g)$		[25] est. ΔHf°_{298} = -271. [26, 27] est. -271.1 ±25.
$ZrF_3(l)$		[27] est. ΔH fus. and est. ΔHf°_{298} = -346 ±30.
$ZrF_3(c)$		[9, 12, 20, 25] est. ΔHf°_{298} = -350. [26, 27] est. -350 ±25.
$ZrF_4(g)$	-401.1 ±3 [122]	[122, 342, 343] calc. ΔH sub. See also [237]. [25, 26] est. ΔHf°_{298} = -381.5 ±30. [27] est. -391.
$ZrF_4(l)$		See [574] for ΔH fus. [27] est. ΔH fus. [27] lists ΔHf°_{298} = -447.919
$ZrF_4(c)$	-456.80 ±0.25 [567]	[567] meas. ΔH for direct combination of the elements. See also [41, 43]. [122, 342, 343] meas. v.p. See also [237]. [229] meas. v.p. of RbF-ZrF_4 and LiF-ZrF_4 systems. See also [147]. See [575]. [9, 12, 15, 20, 25, 26] est. ΔHf°_{298} = -445 ±30. [27] lists -456.9 ±0.1. See $F_9RbZr_2(g)$, $F_9LiZr_2(g)$, $F_9NaZr_2(g)$, $F_5NaZr(g)$, $F_6RbZr(g)$, $F_4H_2OZr(c)$, $F_4H_6O_3Zr(c)$, $F_7H_{12}N_3Zr(c)$, $F_6H_8N_2Zr(c)$, $F_5H_4NZr(c)$.

TABLE 3. TERNARY FLUORIDES

Species	ΔHf^o_{298} (kcal/mole)	Remarks
AcFO(c)		[106] gives ΔHf^o_{298} ~ -265 from consideration of the equilibrium: $AcF_3(c) + H_2O(g) = AcOF(c) + 2HF(g)$, at 1000° K.
$AgAuF_4(c)$	-149.4 [131]	[131] meas. ΔH hydr.
$AgF_2H(c)$ ($AgF\cdot HF$)		For the reaction: $Ag(c) + \frac{1}{2} F_2(g) + HF(\ell) = AgF\cdot HF(c)$, [178] est. ΔF^o_0 = -49.0 on the basis of electrode potentials.
AlClF(g)		[25] est. ΔHf^o_{298} = -121. [24, 27] est. -123 ± 15. [26] est. -124 ± 20.
$AlClF_2(g)$		[24, 26, 27] est. ΔHf^o_{298} = -235 ± 15. [25] est. -235.5.
$AlCl_2F(g)$		[27] est. ΔHf^o_{298} = -181.8 ± 15. [24, 26] est. -186 ± 15. [25] est. -186.3.
AlFO(g)		[24] est. ΔHf^o_{298} = -103 ± 20. [25] est. -110. [26, 27] est. -121 ± 20.
$AlF_4K(c)$ ($KAlF_4$)		See $AlF_5H_2K_2O(c)$.
$AlF_4Li(g)$ ($LiAlF_4$)		For the reaction: $LiF\cdot AlF_3(g) = LiF(g) + AlF_3(g)$, [125] meas. ΔH^o_{1000} = 73 ± 4. [122] calc. ΔH sub. [122] est. ΔHf^o_{298} = -447 ± 7.
$AlF_4Li(c)$		[122] meas. v.p. [122] est. ΔHf^o_{298} = -512 ± 5.
$AlF_4Na(g)$ ($NaAlF_4$)		[121] meas. ΔH vap. See $AlF_4Na(\ell)$ for v.p. studies.
$AlF_4Na(\ell)$		For the reaction: $Na_3AlF_6(\ell) = NaF(\ell) + NaAlF_4(\ell)$, [344] meas. ΔH^o_{1000} = 22. [121, 577] meas. v.p.
$AlF_4Na(c)$		[345] discusses stability.
$AlF_6K_3(c)$ (K_3AlF_6)	-777.9 [9]	
$AlF_6Na_3(g)$ (Na_3AlF_6)		See $AlF_6Na_3(\ell)$ for v.p. meas.
$AlF_6Na_3(\ell)$		[121, 238, 577] meas. v.p. [259] calc. ΔFf and ΔHf vs. T. [616] calc. ΔF of reactions with $SiO_2 + Al_2O_3$. [608, 609] calc. ΔF of reaction: $AlF_3(c) + 3NaF(\ell) = Na_3AlF_6(\ell)$. [124] meas. ΔH fus. [9] lists ΔH fus. See also [604]. See $AlF_4Na(\ell)$.
$AlF_6Na_3(c)$	-759.6 [9] -784.8 [256] -784.95 [116]	[256] meas. ΔH soln. of Na_3AlF_6, Al, NaF, and NaCl in HCl(aq). [116] meas. ΔH for the reaction: $\frac{3}{2} PbF_2(c) + Al(c) + 3NaF(c) = \frac{3}{2} Pb(c) + Na_3AlF_6(c)$. See also [118]. [259, 313] calc. ΔF for several reactions. [124] meas. ΔH trans. [9] lists ΔH trans.
$Al_3F_{14}Na_5(c)$ ($3AlF_3\cdot 5NaF$)		See [345].
$AsBrF_2(\ell)$ $AsBrF_2(c)$		[623] calc. ΔH fus.
$AsBr_2F(\ell)$ $AsBr_2F(c)$		[623] calc. ΔH fus.
$AsClF_2(\ell)$ $AsClF_2(c)$		[623] calc. ΔH fus.
$AsCl_2F(\ell)$ $AsCl_2F(c)$		[623] calc. ΔH fus.
$BBrF_2(g)$		[25] est. ΔHf^o_{298} = -194.4. [31] est. -198.71[a].
$BBr_2F(g)$		[25] est. ΔHf^o_{298} = -118.8. [31] est. -129.59[a].

a Value based upon $Br_2(g)$ as standard state.

Species	ΔHf°_{298} (kcal/mole)	Remarks
$BClF(g)$		[25] est. ΔHf°_{298} = -76. [27] est. -77.8 ± 6. [31] est. -77.81. [26] est. -90 ± 15. [24] est. -91 ± 20.
$BClF_2(g)$	-211.65 [31]	[346] est. ΔHf° = -211.53 by considering the equilibria: $2BF_2Cl = BF_3 + BFCl_2$, and $2BFCl_2 = BF_2Cl + BCl_3$. [346, 347] meas. K for the reaction: $BF_3(g) + BCl_3(g) = BClF_2(g) + BCl_2F(g)$. See also [348]. Other reviews give for ΔHf°_{298}: -210.3 (est.) [25], -211.65 [28], -212 ± 15 (est.) [24, 26].
$BCl_2F(g)$	-153.97 [31]	[346] est. ΔHf° = -153.9. [346, 347] meas. K for the reaction: $BF_3(g) + BCl_3(g) = BClF_2(g) + BCl_2F(g)$. See also [348]. Other reviews give for ΔHf°_{298}: -133 ± 15 (est.) [24], -153.7 (est.) [25], -153.97 [28], -155 ± 15 (est.) [26]. See $BClF_2(g)$.
$BCsF_4(l)$ ($CsBF_4$)		[520] lists dissoc. pressure.
$BCsF_4(c)$		[349] meas. ΔH soln.
$BFO(g)$	-145.3 ± 3 [231]	From an equilibrium study of the reaction: $\frac{1}{2} MgF_2(c) + \frac{1}{2} B_2O_3(l) = BOF(g) + \frac{1}{2} MgO(c)$, [231] calc. ΔH_{298} = 66.4 ± 1. [24] est. ΔHf°_{298} = -129 ± 20. [31] est. -139.9. [27] lists -142.923 ± 8. [26] est. -146 ± 15. [25] est. -172.
$BF_4K(l)$ (KBF_4)		[520] lists dissoc. pressure.
$BF_4K(c)$	-451.6 [350]	From solution calorimetry, [350] meas. ΔHf°_{298} = -451.6. [349] calc. ΔH soln. [351] calc. lattice energy and ΔH soln. [29] lists ΔHf°_{298} = -433. [351] est. -424.
$BF_4Na(c)$ ($NaBF_4$)		[29, 520] list v.p. and dissoc. pressure.
$BF_4Rb(l)$ ($RbBF_4$)		[520] lists dissoc. pressure.
$BF_7S(g)$ ($BF_3 \cdot SF_4$)		[352] calc. ΔH sub.
$BF_7S(c)$		[352] meas. v.p.
$B_3F_3O_3(g)$ ($(BOF)_3$)	-567 ± 8 [31] -566.2 [237]	[237] studied the reaction of $BF_3(g)$ and B_2O_3. See also [224]. Other reviews list for ΔHf°_{298}: -567 ± 8 [28]. [31] reviews unpublished values for ΔHf°_{298}.
$B_3F_3O_3(c)$	-582 ± 8 [31]	[31] reviews unpublished work.
$BaClF(c)$		See $Ba_2Cl_2F_2(c)$.
$BaF_6Si(c)$ ($BaSiF_6$)	-691.6 [9]	
$Ba_2Cl_2F_2(c)$ ($BaF_2 \cdot BaCl_2$)	-508.4 [257]	[257] meas. ΔH soln. of $BaF_2 + BaCl_2$ and $Ba_2Cl_2F_2$ in $AgNO_3(aq)$. [139] reports ΔH for several reactions of $Ba_2Cl_2F_2$.
$BeClF(g)$		[24, 27] est. ΔHf°_{298} = -124 ± 15. [26] est. -132 ± 15. [25] est. -138.
$BeF_3Li(g)$		From ion abundances [353] calc. bond energy ≅ 53 at 900° K.
$BeF_3Na(g)$ ($NaBeF_3$)		See [147, 149].
$BeF_3Na(l)$		See $BeF_4Na_2(l)$
$BeF_4Na_2(g)$ (Na_2BeF_4)		See [147, 149].
$BeF_4Na_2(l)$		For the dissoc. to $2NaF + BeF_2$, [144] reports ΔH = 48.646. [144] obs. insignificant dissoc. to $NaBeF_3(l)$.
$BrCF(g)$		[357] meas. ion abundance and appearance potential from CF_3Br.

Species	ΔHf°_{298} (kcal/mole)	Remarks
$BrCF_2(g)$ ($CBrF_2$)		[357] meas. ion abundance and appearance potential from CF_3Br. [177] est. $D(CF_2Br-F)$.
$BrCF_3$ ($CBrF_3$)		[357, 532] meas. ion appearance potentials or abundances. [177] est. (C-F) bond energy. [104, 177 , 357, 358,.359] report (C-Br) bond energy. [355, 356] calc. ΔH vap. [354] est. ΔHf°_{298} = -156. [177] est. -132.
$BrCF_3(\ell)$		[355, 356] meas. v.p.
$BrFHg(c)$ ($HgBrF$)		[216] est. ΔHf°_{298} = -55.
$BrFHg_2(c)$ (Hg_2BrF)		[216] est. ΔHf°_{298} = -53.
$BrF_2P(g)$ ($PBrF_2$)		[9] lists ΔH vap. [623] calc. ΔH vap.
$BrF_2P(\ell)$		
$BrF_3Si(g)$ ($SiBrF_3$)		[9] lists ΔH vap.
$BrF_3Si(\ell)$		
$BrF_4K(c)$ ($KBrF_4$)		[360] meas. dissoc. pressure.
$BrF_4Ta(g)$ ($TaBrF_4$)		[623] calc. ΔH vap.
$BrF_4Ta(\ell)$		
$BrF_8Sb(c)$ (BrF_2SbF_6)		[360] meas. dissoc. pressure.
$Br_2CF(g)$		[624] est. ΔHf°_{298} = -14.2.
$Br_2CF_2(g)$ (CBr_2F_2)		[355] calc. ΔH vap. [354] est. ΔHf°_{298} = -100.
$Br_2CF_2(\ell)$		[355] meas. v.p.
$Br_2FP(g)$ (PBr_2F)		[9] lists ΔH vap. [623] calc. ΔH vap.
$Br_2FP(\ell)$		
$Br_2F_2Si(g)$ ($SiBr_2F_2$)		[9] lists ΔH vap.
$Br_2F_2Si(\ell)$		
$Br_2F_3Ta(g)$ ($TaBr_2F_3$)		[623] calc. ΔH vap.
$Br_2F_3Ta(\ell)$		
$Br_3CF(g)$ (CBr_3F)		[354] est. ΔHf°_{298} = -44. [624] lists $D(CBr_3-F)$.
$Br_3FSi(g)$ ($SiBr_3F$)		[9] lists ΔH vap.
$Br_3FSi(\ell)$		
$Br_3F_2Ta(g)$ ($TaBr_3F_2$)		[623] calc. ΔH vap.
$Br_3F_2Ta(\ell)$		

Species	ΔHf°_{298} (kcal/mole)	Remarks
$Br_4FTa(g)$ ($TaBr_4F$)		[623] calc. ΔH vap.
$Br_4FTa(\ell)$		
CClF(g)		[26] est. ΔHf°_{298} = 33 ± 10.
$CClF_2(g)$		[177] meas. D($CClF_2$-Cl), D($CClF_2$-F), and D(ClF_2C-$CClF_2$). [26] est. ΔHf°_{298} = -60 ± 5.
$CClF_3(g)$	-167 [171] -171 ± 1 [174]	[171, 174] meas. ΔH of reaction with K. [580, 581] list ion abundances and appearance potentials. [166, 167, 169, 177] report D(C-Cl). [177] reports D(C-F). [365, 366, 579] calc. ΔH vap. [362, 363, 364] list thermo. prop. [367] est. $\Delta H^\circ f_{298}$ = -163.2. [354] est. -166. [25] lists -169.8. [26, 361] list -171 ± 1. [27] lists -171.9 ± 2.
$CClF_3(\ell)$		[363, 364] report thermodyn. properties of sat. liquid.
$CCl_2F(g)$		[177] meas. D($CFCl_2$-Cl) and D($CFCl_2$-F). [26] est. ΔHf°_{298} = -18 ± 10. [624] est. -29.0.
$CCl_2F_2(g)$	-113 [171] -112 ± 2 [174]	[171, 174] meas. ΔH of the reaction with K. [177] meas. D(C-Cl) and D(C-F). [580, 581] obs. ion abundances and appearance potentials. [365, 369, 579] calc. ΔH vap. [446] meas. dissoc. pressure of solid hydrate. [9] lists ΔH vap. [371, 372, 373, 374] list thermo. prop. [26, 361] list ΔHf°_{298} = -112 ± 2. [367] est. -112.5. [354] est. -119. [25] est. -121.7.
$CCl_2F_2(\ell)$		[371, 372, 445] list v.p. [9] lists ΔH fus. See also [370, 373].
$CCl_2F_2(c)$		
$CCl_3F(g)$	-67 [171] -70 ± 4 [174] -66.2 [176]	[171, 174] meas. ΔH of the reaction with K. [176] meas. ΔH of the bomb reaction with Mg. [580, 581] meas. ion abundance and appearance potential. [166, 177] meas. D(C-F). [177] meas. D(C-Cl). [446] meas. dissoc. pressure of solid hydrate. [368, 365, 579] calc. ΔH vap. [9] lists ΔH vap. [367] est. ΔHf°_{298} = -67.7. [26, 361] list -70 ± 4. [27] lists -71 ± 2. [354] est. -72. [25] lists -73.6.
$CCl_3F(\ell)$		[368, 445] meas. v.p. [9] lists ΔH fus.
$CCl_3F(c)$		
$CDF_3(g)$		[362] calc. thermo. properties.
CFH(g)		[26] est. ΔHf°_{298} = 34 ± 10.
$CFH_2(g)$		[169] meas. D(CFH_2-Cl). [177] est. D(CFH_2-H) and D(CFH_2-F). [26] est. ΔHf°_{298} = -5 ± 5.
$CFH_3(g)$		[88] calc. ΔHf°_{298} = -59 from mass spectrometric and calorimetric studies. [376] meas. ΔH soln. and ΔH hydration. [177, 375] list D(CH_3-F). [177] lists D(CH_2F-H). [365, 579] calc. ΔH vap. [9] lists ΔH vap. [223] est. ΔHf°_{298} = -44. [367] est. -57. [625] est. -58.5. [21, 25] list -59. [26] lists -59 ± 5. [177] est. -60. [354] est. -67. [22, 23]list -67.8. [375] lists -69.
$CFH_3(\ell)$		
CFI(g)		[357] meas. ion abundance and appearance potential from CF_3I.
$CFI_3(g)$		[624] lists D(CF_3-I). [354] calc. ΔHf°_{298} = 2.
CFN(g)		[9] lists ΔH sub. [26] est. ΔHf°_{298} = 4 ± 15. [367] est. -8.7. [28] est. -12.8 [22, 23, 25] est. -18.7. [24] est. -25 ± 15.
CFN(c)		
CFO(g)		[177] est D(COF-F) and D(CH_3COF). [26] est. ΔHf°_{298} = -49 ± 15.
$CF_2H(g)$		[169] meas. D(CF_2H-Cl). [177] est. D(CF_2H-H) and D(CF_2H-F). [26] est. ΔHf°_{298} = -60 ± 5.

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$CF_2H_2(g)$	-105.50 ± 0.22 [377]	[377] meas. ΔH of reaction with oxygen in a bomb calorimeter. See also [176]. [177] est. $D(CH_2F-F)$ and $D(CHF_2-F)$. [21, 25] list ΔHf^o_{298} =-105.50. [26] lists -105.5 ± 1. [177] est. -110. [354] calc. -115. [22,23] est. -117.9.
$CF_2I(g)$		[357] meas. ion abundance and appearance potential from CF_3I. [624] est. ΔHf^o_{298} = -50.2.
$CF_2I_2(g)$		[354] calc. ΔHf^o_{298} = -70.
$CF_2O(g)$ (COF_2)	-149.9 ± 3.0 [15] -150.35 ± 0.5 [170] -166.6 [172]	[170] meas. ΔH hydr. = 26.73 ± 0.2. [172, 176] meas. heat of combustion of fluoro-carbons, forming some COF_2. [378] discusses heat of formation. [177] meas. D(COF-F). [9] lists ΔH vap. [176] calc. ΔHf^o_{298} = -143. Other reviews give for ΔHf^o_{298}: -149.9 ± 3 [26], -150.2 ± 5 [27], -150.45 [21], -159.7 [22,25].
$CF_2O(l)$		
$CF_3H(g)$	-162.6 ± 0.6 [377]	[377] meas. ΔH of reaction with oxygen in a bomb calorimeter. See also [176]. [362, 379] list thermo. properties. [104, 166, 168, 177] list $D(CF_3-H)$. [177] est. $D(CF_2H-F)$. See also [80]. [9] lists ΔH vap. [21, 25] list ΔHf^o_{298} = -162.6. [26] lists -162.6 ±1. [354] calc. -164. [22, 23, 177] est. -168.0. [166] lists -169.
$CF_3H(l)$		
$CF_3I(g)$		[357] meas. ion abundances and appearance potentials and calc. $D(CF_3-I)$. [354] calc. ΔHf^o_{298} = -141.
$CF_3O(g)$		[381] gives $D(CF_3O-F)$ = 47.
$CF_4O(g)$ (CF_3OF)	-177.3 [381]	For the reaction: $CF_4O(g) = CF_2O(g) + F_2(g)$ [381] meas. K and calc. ΔH^o_{298} = 26.9. See $CF_3O(g)$.
$CF_5N(g)$ (CF_3NF_2)		[382] calc. ΔH vap.
$CF_5N(l)$		[382] meas. v.p.
$CF_5N(c)$ (CF_3NF_2)		[382] meas. v.p.
$CF_{12}S_2(g)$ ($CF_2(SF_5)_2$)		
$CF_{12}S_2(l)$		[383] meas. v.p.
CdClF(g)		[623] calc. ΔH vap.
CdClF(l)		
ClFHg(c) (HgClF)		[216] est. ΔHf^o_{298} = -62.
$ClFHg_2(c)$ (Hg_2ClF)		[216] est. ΔHf^o_{298} = -70.
$ClFLi_2(g)$ hyp. (Li_2ClF)		[27, 33] est. ΔHf^o_{298} = -180.2. [25, 34, 37] est. -183.3.
ClFMg(g) hyp. (MgClF)		[26] est. ΔHf^o_{298} = -137 ± 15. [27] est. -138.9. [24] est. -139 ±20. [25] est. -145.2.
$ClFNa_2(g)$ hyp. (Na_2ClF)		[25] est. ΔHf^o_{298} = -167.
$ClFO_2(g)$ (ClO_2F)		[9] lists ΔH vap.

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$ClFO_2(\ell)$		
$ClFO_3(g)$ (ClO_3F)	-5.12 ± 0.68 [53]	[53] meas. ΔH of reaction with $H_2(g)$. See also [176]. [384] meas. ion appearance potentials and est. ΔHf = -5.3. [384] est. $D(O_3Cl\text{-}F)$. [385] reports decomposition energy studies. [388] meas. ΔH vap. [386, 387] calc. ΔH vap. [28] lists ΔHf^o_{298} = -5.12 ± 0.68.
$ClFO_3(\ell)$		[386, 387, 388, 389] meas. v.p. [388] meas. ΔH fus.
$ClFO_3(c)$		
ClFP(g) (PClF)		[25, 26] est. ΔHf^o_{298} = -61 ± 15.
ClFPb(c) (PbClF)		[282] meas. heat of formation from PbF_2 and $PbCl_2$. [264] meas. ΔF for exchange reaction producing PbCℓF. [390] tabulates K sp and related thermodynamic functions.
ClFS(g) hyp. (SClF)		[26] est. ΔHf^o_{298} = -37 ± 15. [25] est. -41.
ClFSr(c)		See $Cl_2F_2Sr_2(c)$.
ClFZn(g)		[623] calc. ΔH vap.
ClFZn(ℓ)		
$ClF_2Li_3(g)$ hyp. (Li_3ClF_2)		[25] est. ΔHf^o_{298} = -305.
$ClF_2N(g)$ ($NClF_2$)		[391] calc. ΔH vap.
$ClF_2N(\ell)$		[391] meas. v.p.

Compounds	ΔHf°_{298} (kcal/mole)	Remarks
$ClF_2P(g)$ ($PClF_2$) $ClF_2P(l)$		[9] lists ΔH vap. [623] calc. ΔH vap. [25, 26] est. $\Delta Hf^\circ_{298} = -171 \pm 15$.
$ClF_3Si(g)$ ($SiClF_3$) $ClF_3Si(l)$		[9] lists ΔH vap. [26, 27] est. $\Delta Hf^\circ_{298} = -315 \pm 15$.
$ClF_4H(g)$		For the reaction: $HF + ClF_3 = HF{\cdot}ClF_3$, [392] meas. K and calc. ΔH = -3.9. For this same reaction [393] gives ΔH = -4.
$ClF_4Sb(g)$ (SbF_4Cl) $ClF_4Sb(l)$		[623] calc. ΔH vap.
$ClF_4Ta(g)$ (TaF_4Cl) $ClF_4Ta(l)$		[623] calc. ΔH vap.
$ClF_5S(g)$ ($SClF_5$)	-245 [394]	[394] meas. ΔH hydr. in NaOH(aq). [395] calc. ΔH vap.
$ClF_5S(l)$		[395] meas. v.p.
$Cl_2FLi_3(g)$ hyp. (Li_3Cl_2F)		[25] est. $\Delta Hf^\circ_{298} = -266$.
$Cl_2FP(g)$ (PCl_2F) $Cl_2FP(l)$		[9] lists ΔH vap. [623] calc. ΔH vap. [25, 26] est. $\Delta Hf^\circ_{298} = -121 \pm 15$.
$Cl_2F_2Ge(g)$ ($GeCl_2F_2$) $Cl_2F_2Ge(l)$		[9] lists ΔH vap.

Species	ΔHf°_{298} (kcal/mole)	Remarks
$Cl_2F_2Si(g)$ $(SiCl_2F_2)$ $Cl_2F_2Si(\ell)$		[9] lists ΔH vap. [26] est. ΔHf°_{298} = -258 ±15.
$Cl_2F_2Sr_2(\ell)$ $(SrCl_2\cdot SrF_2)$	-498 [257]	[257] meas. ΔH soln. of SrF_2 + $SrCl_2$, and $Sr_2Cl_2F_2$ in $AgNO_3(aq)$. [139] reports ΔH for several reactions of $Sr_2Cl_2F_2$.
$Cl_2F_3Sb(g)$ $(SbCl_2F_3)$ $Cl_2F_3Sb(\ell)$		[623] calc. ΔH vap.
$Cl_2F_3Ta(g)$ $(TaCl_2F_3)$ $Cl_2F_3Ta(\ell)$		[623] calc. ΔH vap.
$Cl_3FGe(g)$ $(GeCl_3F)$ $Cl_3FGe(\ell)$		[9] lists ΔH vap.
$Cl_3FSi(g)$ $(SiCl_3F)$ $Cl_3FSi(\ell)$		[9] lists ΔH vap. [26, 27] est. ΔHf°_{298} = -201 ±15.
$Cl_3F_2Sb(g)$ $(SbCl_3F_2)$ $Cl_3F_2Sb(\ell)$		[623] calc. ΔH vap.
$Cl_3F_2Ta(g)$ $(TaCl_3F_2)$ $Cl_3F_2Ta(\ell)$		[623] calc. ΔH vap.
$Cl_4FSb(g)$ $(SbCl_4F)$ $Cl_4FSb(\ell)$		[623] calc. ΔH vap.
$Cl_4FTa(g)$ $(TaCl_4F)$ $Cl_4FTa(\ell)$		[623] calc. ΔH vap.
$CrF_2O_2(g)$ $CrF_2O_2(\ell)$ $CrF_2O_2(c)$		[396] calc. ΔH sub. and ΔH vap. [396] meas. v.p. and calc. ΔH fus. [396] meas. v.p.
$CsF_2H(c)$ $(CsHF_2)$	-216.1 [9]	
$CsF_2Li(g)$ $(CsF\cdot LiF)$		[196] calc. energy of formation.
$CsF_2Rb(g)$ $(CsF\cdot RbF)$		For the equilibrium: $Cs_2F_2(g)$ + $Rb_2F_2(g)$ = $2CsRbF_2(g)$. [512] meas. K (883-925°K) = 4.3 ±1.0.
$Cs_2F_6Si(c)$ (Cs_2SiF_6)	-669.5 [9]	
FHO(g)		[223] est. ΔHf°_{298} = -9. [24, 27] est. -26.1 ±15.
$FH_2N(g)$ (NH_2F)		[223] est. ΔHf°_{298} = -5.

Species	ΔHf°_{298} (kcal/mole)	Remarks
$FH_3Si(g)$ ($SiFH_3$)		[9] lists ΔH vap. [25] est. ΔHf°_{298} = -86.8. [26, 27] est. -105 ±15. See $BF_2H_6NSi_2$ and BCF_2H_6NSi.
$FH_3Si(\ell)$		[397] meas. v.p.
$FH_4N(g)$ (NH_4F)		[398] calc. ΔH sub.
$FH_4N(c)$	-111.6 [9] -111.0 [212]	[212] meas. ΔH soln. of NH_3 and $NH_4F(c)$ in $HF(\ell)$. [399] calc. lattice energy and ΔF soln. [398] meas. v.p. [400] reports thermodyn. study of the system $NH_4F - NH_4HF_2$.
FHgI(c) (HgFI)		[216] calc. ΔHf°_{298} = -47.
FLiO(g) (LiOF)		[24, 27] est. ΔHf°_{298} = -10 ±20.
$FMnO_3(g)$ (MnO_3F)		
$FMnO_3(\ell)$ (MnO_3F)		[401] meas. v.p.
FNO(g) (NOF)	-15.8 [402]	[402] meas. the heat of reaction of NO(g) and $F_2(g)$. See also [582]. [9] lists ΔH vap. [22, 25] est. ΔHf°_{298} = -14.9. [26, 27] list -15.65 ±1. [24] est. -32.7 ±15.
$FNO(\ell)$		
$FNO_2(g)$		[9] lists ΔH vap.
$FNO_2(\ell)$		
$FNO_3(g)$		[583] meas. rate of thermal decompn. vs. temp. and est. $D(NO_3-F)$ = 29.7. See also [584].
FNS(g) (NSF)		[403] calc. ΔH vap.
$FNS(\ell)$		[403] meas. v.p.
FOP(g) (POF)		[25, 26] est. ΔHf°_{298} = -88 ±15.
FOS(g) (SOF)		[25, 26] est. ΔHf°_{298} = 24 ±15.
FPS(g) (PSF)		[25, 26, 27] est. ΔHf°_{298} = -41 ±15.
$F_2HK(\ell)$ (KHF_2)		[404] meas. ΔH fus. [9] lists ΔH fus.
$F_2HK(c)$	-219.98 [9]	For ΔH soln. in $HF(\ell)$, [212] meas. -9.81. For the reaction: $KHF_2(c) = KF(c) + HF(g)$ [404] meas. $\Delta H_{226.8^\circ C}$ = 18.52 ±0.05. [404] meas. ΔH trans. (β-α) = 2.682 ± 0.010. See also [585]. [9] lists ΔH trans. See $AlF_5H_2K_2O(c)$.
$F_2HLi(c)$ ($LiHF_2$)	-224.2 ±1 [34]	For the reaction: $LiHF_2(c) = LiF(c) + HF(g)$, [406] meas. ΔH = 13.7. [406] meas. ΔH trans. See also [409]. Other reviews list ΔHf°_{298} = -224.2 [25, 37].
$F_2HN(g)$ (NHF_2)		[407, 623] calc. ΔH vap. [25] est. ΔHf°_{298} = -23.
$F_2HN(\ell)$		[407] meas. v.p.
$F_2HNa(c)$ ($NaHF_2$)	-216.6 [9] -218.0 [212]	[212] meas. ΔH soln. of NaF(c) and $NaHF_2(c)$ in $HF(\ell)$. For the reaction: $NaHF_2(c) = NaF(c) + HF(g)$, [408] meas. K and calc. ΔH = 16.1.

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$F_2HRb(c)$ ($RbHF_2$)	-217.3 [9]	
$F_2HTl(c)$ ($TlHF_2$)		[409] reports thermodyn. studies.
$F_2H_2Si(g)$ (SiF_2H_2)		[9] lists ΔH vap. [25] est. ΔHf^o_{298} = -181.2. [26, 27] est. -194 ±15.
$F_2H_2Si(l)$ $F_2H_2Si(c)$		[9] lists ΔH fus.
$F_2H_5N(c)$ (NH_4HF_2)	-191.4 [212] -190.8 [410]	[212] meas. ΔH soln. of NH_3, NH_4F, and NH_4HF_2 in HF(l). [410] meas. ΔH neutralization of NH_3(aq) and HF(aq), ΔH soln. and ΔH diln. of NH_4HF_2. [400, 409] report thermodynamic studies. See $F_4H_7N(c)$.
$F_2KNa(g)$ ($KNaF_2$)		For the equilibrium: $K_2F_2(g) + Na_2F_2(g) = 2KNaF_2(g)$, [512] meas. K (891-951°K) = 4.9 ± 2.0.
$F_2KRb(g)$ ($KRbF_2$)		For the equilibrium: $Rb_2F_2(g) + K_2F_2(g) = 2KRbF_2(g)$, [512] meas. K (965-994°K) = 4.2 ±1.0.
$F_2LiNa(g)$ ($LiNaF_2$)		For the reaction: $Na_2F_2(g) + Li_2F_2(g) = 2LiNaF_2(g)$, [227] calc. ΔH ≅ 0. See [512]. [227, 512] meas. ion abundances. [546] calc. energy of formation from the ions.
$F_2LiRb(g)$ ($LiRbF_2$)		For the equilibrium: $Li_2F_2(g) + Rb_2F_2(g) = 2LiRbF_2(g)$, [512] meas. K (897-958°K) = 25.3 ±7.
$F_2N_2S(g)$ (SN_2F_2)		[412] calc. ΔH vap.
$F_2N_2S(l)$		[412] meas. v.p.
$F_2OP(g)$ hyp. (POF_2)		[25, 26] est. ΔHf^o_{298} = -180 ±15.
$F_2OS(g)$ (SOF_2) $F_2OS(l)$		[9] lists ΔH vap. [25, 26, 27] est. ΔHf^o_{298} = -113 ±10.
$F_2OSi(g)$ ($SiOF_2$)		[25] est. ΔHf^o_{298} = -222.
$F_2OTh(c)$ ($ThOF_2$)	-389.6 [413]	[413] meas. dissoc. pressure of the reaction: $2ThOF_2(c) = ThO_2(c) + ThF_4(g)$.
$F_2OTi(g)$ ($TiOF_2$)		[25] est. ΔHf^o_{298} = -220.
$F_2O_2S(g)$ (SO_2F_2) $F_2O_2S(l)$ $F_2O_2S(c)$	-205 [414]	[414] meas. appearance potential of SO_2^+ ion, as well as other ions. [415] meas. ΔH vap. [416] lists ΔH vap. [27] est. ΔHf^o_{298} = -150. [25, 26] list -205 ±5. [415, 417] meas. v.p. [416] lists v.p. [415] meas. ΔH fus. [417] meas. v.p.
$F_2O_2Se(g)$ (SeO_2F_2)		[418] calc. ΔH vap.
$F_2O_2Se(l)$		[418] meas. v.p.
$F_2O_2U(c)$ (UO_2F_2)	-391.4 ±3.6 [419]	[419] meas. ΔH soln. of $UF_6(g)$ in H_2O and $UO_2F_2(c)$ in HF(aq). [325] calc. ΔF vs. T for several reactions.

Species	ΔHf°_{298} (kcal/mole)	Remarks
$F_2O_3S(g)$ (SO_3F_2)		
$F_2O_3S(\ell)$		[420] meas. v.p.
$F_2O_6S_2(g)$ ($S_2O_6F_2$)		
$F_2O_6S_2(\ell)$		[421] meas. v.p.
$F_2O_8S_3(g)$ ($S_3O_8F_2$)		[422] calc. ΔH vap.
$F_2O_8S_3(\ell)$		[422] meas. v.p.
$F_2PS(g)$ (PSF_2)		[25, 26] est. $\Delta Hf^\circ_{298} = -133 \pm 15$.
$F_3HSi(g)$ (SiF_3H)		[9] lists ΔH vap. [25] est. $\Delta Hf^\circ_{298} = -275.6$. [26, 27] est. -283 ± 15.
$F_3HSi(\ell)$		
$F_3H_2K(c)$ ($KF \cdot 2HF$)	-296.7 [9]	
$F_3H_2Na(c)$ ($NaF \cdot 2HF$)	-292.5 [212]	[212] meas. ΔH soln. of NaF and $NaF \cdot 2HF$ in $HF(\ell)$.
$F_3MgNa(\ell)$		[609] calc. ΔF for the reactions: $NaF + MgF_2 = NaMgF_3$, and $\frac{1}{3}Na_3AlF_6 + MgF_2 = NaMgF_3 + \frac{1}{3}AlF_3$.
$F_3NS(g)$ (SNF_3)		[423] calc. ΔH vap.
$F_3NS(\ell)$		[423] meas. v.p.
$F_3OP(g)$ (POF_3)		For the reaction: $PF_3(g) + \frac{1}{2}O_2(g) = POF_3(g)$, [275] gives $\Delta H = -129.8$. [275] est. D(P-F) and D(P=O). See also [566]. [9] lists ΔH vap. and ΔH sub. See $F_3OP(\ell)$ for v.p. [425] lists thermodyn. properties. [25, 26] est. $\Delta Hf^\circ_{298} = -292.5 \pm 10$.
$F_3OP(\ell)$		[424] meas. v.p. [9] lists ΔH fus.
$F_3OP(c)$		
$F_3O_2Re(g)$ (ReO_2F_3)		[240] calc. ΔH vap.
$F_3O_2Re(\ell)$		[240] meas. v.p.
$F_3PS(g)$ (PF_3S)		[9] lists ΔH vap. [425] lists thermodyn. prop. [25, 26] est. $\Delta Hf^\circ_{298} = -245 \pm 10$.
$F_3PS(\ell)$		
$F_4H_3K(c)$ ($KF \cdot 3HF$)	-373.0 [9]	
$F_4H_7N(\ell)$ ($NH_4F \cdot 3HF$)		[426] meas. ΔH fus.
$F_4H_7N(c)$	-337.4 [212]	[212] meas. ΔH soln. of NH_3 and $NH_4F \cdot 3HF$ in $HF(\ell)$. [426] meas. dissoc. pressure and calc. for the reaction: $NH_4H_3F_4(c) = 2HF(g) + NH_4HF_2(c)$, $\Delta H = 10.5 \pm 1$. [426] meas. ΔH trans. (3 transitions).
$F_4MoO(g)$ ($MoOF_4$)		[240] calc. ΔH sub. and ΔH vap.
$F_4MoO(\ell)$		[240] meas. v.p. and calc. ΔH fus.
$F_4MoO(c)$		[240] meas. v.p.

Species	ΔHf^{o}_{298} (kcal/mole)	Remarks
$F_4ORe(g)$		[240] calc. ΔH sub. and ΔH vap. [9] lists ΔH sub.
$(ReOF_4)$		
$F_4ORe(\ell)$		[240] meas. v.p. and calc. ΔH fus.
$F_4ORe(c)$		[240] meas. v.p.
$F_4OS(g)$		
(SOF_4)		
$F_4OS(\ell)$		[427] meas. v.p.
$F_4OW(g)$		[240] calc. ΔH vap. and ΔH sub.
(WOF_4)		
$F_4OW(\ell)$		[240] meas. v.p. and calc. ΔH fus.
$F_4OW(c)$		[240] meas. v.p.
$F_5NaU(c)$		[433] obs. the dissoc. $UF_5 \cdot NaF(c) = UF_4NaF(c) + \frac{1}{2}F_2(g)$ above 450°.
$(NaUF_5)$		
$F_5ORe(g)$		[240] calc. ΔH sub. and ΔH vap.
$(ReOF_5)$		
$F_5ORe(\ell)$		[240] meas. v.p. and calc. ΔH fus.
$F_5ORe(c)$		[240] meas. v.p. and calc. ΔH trans.
$F_6K_2Si(c)$	-671 [9]	
(K_2SiF_6)		
$F_6K_2Ti(c)$		[428] meas. ΔH trans. $\gamma = \beta$ (623°K) and $\beta = \alpha$ (873°K).
(K_2TiF_6)		
$F_6Li_2Si(c)$	-688.9 [9]	
(Li_2SiF_6)		
$F_6N_3P_3(g)$		[429, 430, 431] calc. ΔH sub. [429, 430] calc. ΔH vap.
$((PNF_2)_3)$		
$F_6N_3P_3(\ell)$		[429, 430] meas. v.p. and calc. ΔH fus.
$F_6N_3P_3(c)$		[429, 430, 431] meas. v.p.
$F_6NaU(c)$		See F_5UNa.
$(NaUF_6)$		
$F_6Na_2Si(c)$	-677 [9]	For the reaction: $Na_2SiF_6(c) = 2NaF(c) + SiF_4(g)$, [432] meas. ΔH = 26.83.
(Na_2SiF_6)	-659 [432]	For the reaction: $SiF_4(g) + 2NaF(aq) = Na_2SiF_6(c)$, [311] meas. ΔH = -37.01.
	-681.1 [311]	
$F_6OS(g)$		
(SF_5OF)		
$F_6OS(\ell)$		[427] meas. v.p.
$F_6OSi_2(g)$		[9] lists ΔH vap.
(Si_2OF_6)		
$F_6OSi_2(\ell)$		
$F_6Rb_2Si(c)$	-678.4 [9]	
(Rb_2SiF_6)		
$F_7NaU(c)$		[433] meas. v.p. of UF_6 over $UF_6 \cdot NaF$.
$(UF_6 \cdot NaF)$		
$F_8N_4P_4(g)$		[429, 430] calc. ΔH sub. and ΔH vap.
$((PNF_2)_4)$		
$F_8N_4P_4(\ell)$		[429, 430] meas. v.p. and calc. ΔH fus.

Species	ΔHf^{o}_{298} (kcal/mole)	Remarks
$F_8N_4P_4$(c)		[429, 430] meas. v.p.
F_8Na_3U(c) ($UF_5 \cdot 3NaF$)		[433] obs. the dissociation: $UF_6 \cdot 3NaF(c) = UF_5 \cdot 3NaF(c) + \frac{1}{2}F_2(g)$, (200 - 450°C).
$F_9H_5Pb_2$(c) ($2PbF_2 \cdot 5HF$)		[178] meas. decomp. pressure at 0°C.
F_9LiZr_2(g) ($LiF \cdot 2ZrF_4$)		[229] meas. ion abundances in vapor. See also [147, 228].
F_9NaZr_2(g) ($NaF \cdot 2ZrF_4$)		[229] meas. ion abundance in vapor. See also [147, 228].
F_9Na_3U(c) ($UF_6 \cdot 3NaF$)		For the reaction: $UF_6(g) + 3NaF(c) = UF_6 \cdot 3NaF(c)$, [433] meas. K and calc. $\Delta H = -23.2$
F_9RbZr_2(g) ($RbF \cdot 2ZrF_4$)		[229] meas. ion abundance in vapor. See also [147, 228].
$F_{10}O_2S_2$(g) ($(SOF_5)_2$)		
$F_{10}O_2S_2$(l)		[617] meas. v.p.
$F_{12}NiP_4$(g) ($Ni(PF_3)_4$)		
$F_{12}NiP_4$(l)		[434] meas. v.p.

TABLE 4. QUATERNARY AND HIGHER FLUORIDES

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
a. Compounds of four elements.		
$AgFH_2O$(c) ($AgF\cdot H_2O$)	-120.4 [9]	
$AgFH_4O_2$ ($AgF\cdot 2H_2O$)	-191.2 [9]	
$AgFH_8O_4$(c) ($AgF\cdot 4H_2O$)	-331.5 [9]	
$AlF_3HO_{\frac{1}{2}}$(c) ($AlF_3\cdot\frac{1}{2}H_2O$)	-357.4 [9]	See $AlF_3H_6O_3$(c, α).
$AlF_3H_6O_3$(c, α) ($AlF_3\cdot 3H_2O$-α)	-549.1 [9]	[9] does not distinguish α- and β-crystals. See [2] pp 585 ff for a discussion of stability of this and other AlF_3 hydrates.
$AlF_3H_6O_3$(c, β)		See $AlF_3H_6O_3$(c, α).
$AlF_3H_7O_{7/2}$(c, α) ($AlF_3\cdot 7/2H_2O$-α)		See $AlF_3H_6O_3$(c, α).
$AlF_3H_7O_{7/2}$(c, β)		See $AlF_3H_6O_3$(c, α).
$AlF_3H_{18}O_9$(c) ($AlF_3\cdot 9H_2O$)		See $AlF_3H_6O_3$(c, α).
AsBrClF(ℓ)		[623] calc. ΔH fus.
AsBrClF(c)		
$AsCCl_2F_3$(g) (CF_3AsCl_2)		
$AsCCl_2F_3$(ℓ)		[435] meas. v.p.
$AsCF_2H_3$(g) (CH_3AsF_2)		[9] lists ΔH vap.
$AsCF_2H_3$(ℓ)		
BCF_2H_3(g) (CH_3BF_2)		[9] lists ΔH vap.
BCF_2H_3(ℓ)		[520] reviews v.p.
BCF_3H_2(g) (CH_2FBF_2)		[436] calc. ΔH vap.
BCF_3H_2(ℓ)		[436] meas. v.p.
BCF_3O (g) (BF_3CO)		For the reaction: BF_3(g) + CO(g) = BF_3CO(g), [513] est. ΔH_{300} = 17. [29] est. ΔHf^o_{298} = -307.
BCl_3F_3P(ℓ) hyp. ($BF_3\cdot PCl_3$)		[437] reports v.p. studies showing non-existence of this complex.
BD_3F_3P(g) ($BD_3\cdot PF_3$)		[438] calc. ΔH vap.
BD_3F_3P(ℓ)		[438] meas. v.p. See [520].
BF_3H_3N(g) ($BF_3\cdot NH_3$)		For the reaction: BF_3(g) + NH_3(g) = $BF_3\cdot NH_3$(g), [439] reports ΔH = -27.5.
BF_3H_3N(ℓ)		[440] reports v.p. studies.
BF_3H_3N(c)	-318.9 [29]	

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
$BF_3H_3P(g)$ ($BH_3 \cdot PF_3$)		For the equilibrium: $2F_3PBH_3(g) = 2PF_3(g) + B_2H_6(g)$, [438] est. K. [438] calc. ΔH vap.
$BF_3H_3P(l)$		[438] meas. v.p. See [520].
$BF_3H_6N_2(l)$ ($BF_3 \cdot 2NH_3$)		[440] reports v.p. studies.
$BF_3H_9N_3(l)$ ($BF_3 \cdot 3NH_3$)		[440] reports v.p. studies.
$BF_3H_{12}N_4(l)$ ($BF_3 \cdot 4NH_3$)		[440] reports v.p. studies.
$BF_4H_4N(l)$ (NH_4BF_4)		[520] reviews v.p.
$BF_4H_5O_2(c)$ ($BF_4(H_3O) \cdot H_2O$)		[441] reports ΔH dissoc. = 22.3.
$B_3F_6Na_3O_3(c)$ ($Na_3B_3O_3F_6$)		[442] reports ΔH soln.
$BrCClF_2(g)$ ($CBrClF_2$)		[355] calc. ΔH vap. [354] est. ΔHf^o_{298} = -110.
$BrCClF_2(l)$		[355] meas. v.p.
$BrCCl_2F(g)$ ($CBrCl_2F$)		[354] est. ΔHf^o_{298} = -63.
$BrCFH(g)$ ($CHBrF$)		[624] est. ΔHf^o_{298} = -15.5.
$BrCFH_2(g)$ (CH_2BrF)		[354] est. ΔHf^o_{298} = -59.
$BrCFI_2(g)$ ($CBrFI_2$)		[354] est. ΔHf^o_{298} = -14.
$BrCFO(g)$ ($COBrF$)		[25] est. ΔHf^o_{298} = -94.8.
$BrCF_2H(g)$ (CHF_2Br)		[354] est. ΔHf^o_{298} = -108.
$BrCF_2I(g)$ ($CBrF_2I$)		[354] est. ΔHf^o_{298} = -85.
$BrClFP(g)$ ($PBrClF$)		[623] calc. ΔH vap.
$BrClFP(l)$		
$BrClF_3Ta(g)$ ($Ta\ BrClF_3$)		[623] calc. ΔH vap.
$BrClF_3Ta(l)$		
$BrCl_2FSi(g)$ ($SiBrCl_2F$)		[9] lists ΔH vap.
$BrCl_2FSi(l)$		
$BrCl_3FTa(g)$ ($TaBrCl_3F$)		[623] calc. ΔH vap.
$BrCl_3FTa(l)$		

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
BrFOS(g) (SOFBr)		[623] calc. ΔH vap.
BrFOS(ℓ)		
$BrFO_3S$(g) ($BrSO_3F$)		[443] calc. ΔH vap.
$BrFO_3S$(ℓ)		[443] meas. v.p.
BrF_2OP(g) ($POBrF_2$)		[9] lists ΔH vap. [623] calc. ΔH vap.
BrF_2OP(ℓ)		
BrF_2PS(g) ($PSBrF_2$)		[9] lists ΔH vap. [623] calc. ΔH vap.
BrF_2PS(ℓ)		
Br_2CClF(g) (CBr_2ClF)		[354] est. ΔHf^o_{298} = -54.
Br_2CFH(g) ($CHBr_2F$)		[354] est. ΔHf^o_{298} = -52.
Br_2CFI(g) (CBr_2FI)		[354] est. ΔHf^o_{298} = -29.
Br_2ClFSi(g) ($SiBr_2ClF$)		[9] lists ΔH vap.
Br_2ClFSi(ℓ)		
Br_2FOP(g) ($POBr_2F$)		[623] calc. ΔH vap. [9] lists ΔH vap.
Br_2FOP(ℓ)		
Br_2FPS(g) ($PSBr_2F$)		[623] calc. ΔH vap.
Br_2FPS(ℓ)		
Br_3ClFTa(g) ($TaBr_3ClF$)		[623] calc. ΔH vap.
Br_3ClFTa(ℓ)		
CClFH(g)		[26] est. ΔHf^o_{298} = -9 ± 10.
$CClFH_2$(g)		From the reaction: Na(atoms) + CH_2ClF(g), [169] reports D(CFH_2-Cl). [9] lists ΔH vap. [26, 27] est. ΔHf^o_{298} = -58 ± 15. [625] est. -63. [354] calc. -68. See CFH_2(g).
$CClFH_2$(ℓ)		
CClFI(g)		[624] est. ΔHf^o_{298} = -8.
$CClFI_2$(g)		[354] est. ΔHf^o_{298} = -23.
CClFO(g)		[9] lists ΔH vap. [26] est. ΔHf^o_{298} = -96 ± 15. [25, 27] est. -106.5.
CClFO(ℓ)		
$CClF_2H$(g)		From the reaction: Na(atoms) + CHF_2Cl(g), [169] reports D(CHF_2-Cl). [446] meas. dissoc. pressure of solid hydrate. [444] meas. ΔH vap., [9] lists ΔH vap. See v.p. studies of $CHClF_2$(ℓ). [625] est. ΔHf^o_{298} = -109 to -112. [26, 27] est. -112 ± 5. [354] calc. -117.
$CClF_2H$(ℓ)		[445] meas. v.p. [444] meas. ΔH fus.
$CClF_2H$(c)		[444] meas ΔH trans.

Compounds	ΔHf^o_{298} (kcal/mole)	Remarks
$CClF_2I(g)$		[354] est. ΔHf^o_{298} = -94.
$CClF_3S(l)$ (F_3CSCl)		[447] meas. v.p.
$CCl_2FH(g)$		[476] meas. dissoc. pressure of the hydrate. [365] calc. ΔH vap. [9] lists ΔH vap. See v.p. studies of $CCl_2FH(l)$. [26, 27] est. ΔHf^o_{298} = -61 ± 10. [625] est. -66.5. [354] calc. -70.
$CCl_2FH(l)$		[445] meas. v.p.
$CCl_2FI(g)$		[354] est. ΔHf^o_{298} = -48.
$CFHI_2(g)$		[9] lists ΔH vap. [354] est. ΔHf^o_{298} = -21.
$CFHI_2(l)$		
$CFHO(g)$		[26] est. ΔHf^o_{298} = -78 ± 15. [25, 27] est. -94. [223] est. -103.
$CFH_2I(g)$		[354] est. ΔHf^o_{298} = -44.
$CFK_3O_3(c)$ (K_3CO_3F)		[586] discusses energy of formation.
$CFRb_3O_3(c)$ (Rb_3CO_3F)		[586] discusses energy of formation.
$CF_2HI(g)$		[9] lists ΔH vap. [354] est. ΔHf^o_{298} = -92.
$CF_2HI(l)$		
$CF_2H_3N(g)$ (CH_3NF_2)		[448] calc. ΔH vap.
$CF_2H_3N(l)$		[448] meas. v.p.
$CF_3HS(g)$		[449] calc. ΔH vap.
$CF_3HS(l)$		[449] meas. v.p. and ΔH fus.
$CF_3HS(c)$		
$CF_3H_3Si(g)$ ($SiF_3(CH_3)$)		[9] lists ΔH vap. [27] lists ΔHf^o_{298} = -294.625.
$CF_3H_3Si(l)$		
$CF_3NO(g)$ [trifluoronitrosomethane]		[450, 451, 452, 453] calc. ΔH vap. [9] lists ΔH vap.
$CF_3NO(l)$		[450, 451, 452, 453] meas. v.p.
$CF_3NO(g)$ ($FCONF_2$) [N,N-difluoro-fluoroformamide]		[9] lists ΔH vap.
$CF_3NO(l)$		
$CF_3NO_2(g)$		[451, 452, 453] calc. ΔH vap.
$CF_3NO_2(l)$		[451, 452, 453] meas. v.p.
$CF_4O_2S(g)$ (CF_3SO_2F)		[454] calc. ΔH vap.
$CF_4O_2S(l)$		[454] meas. v.p.
$Ca_5FO_{12}P_3(c)$		[455] gives a summary of reactions leading to formation or decomposition of $Ca_5FO_{12}P_3$. See $Ca_{10}F_2O_{24}P_6(c)$.

Compounds	ΔHf^o_{298} (kcal/mole)	Remarks
$Ca_{10}F_2O_{24}P_6(c)$ ($CaF_2 \cdot 3Ca_3(PO_4)_2$)	-3,262 [456]	[456] meas. ΔH for reaction with $HNO_3(aq)$.
$CeF_3HO_{\frac{1}{2}}(c)$ ($CeF_3 \cdot \frac{1}{2}H_2O$)		For the reaction: $Ce^{+3}(aq) + 3HF(aq) + \frac{1}{2}H_2O(\ell) = CeF_3 \cdot \frac{1}{2}H_2O(c) + 3H^+(aq)$, [181] meas. ΔH = 10.0 ±0.7. From soln. data [181] reports ΔFf^o_{298} = -425.3. See $CeF_3(aq)$.
ClFOP(g) (POFCl)		[25, 26] est. ΔHf^o_{298} = -128 ±15.
ClFOS(g) (SOFCl) ClFOS(ℓ)		[623] calc. ΔH vap. [9] lists ΔH vap. [25, 26] est. ΔHf^o_{298} = -82 ±15.
$ClFO_2S(g)$ (SO_2FCl) $ClFO_2S(\ell)$		[9] lists ΔH vap.
$ClFO_5S_2(g)$ (S_2O_5ClF) $ClFO_5S_2(\ell)$		[457] calc. ΔH vap. [457] meas. v.p.
ClFPS(g) (PSFCl)		[25, 26] est. ΔHf^o_{298} = -82 ±15.
$ClF_2OP(g)$ (POF_2Cl) $ClF_2OP(\ell)$		[623] calc. ΔH vap. [9] lists ΔH vap. [25, 26] est ΔHf^o_{298} = -240 ±15.
$ClF_2PS(g)$ (PSF_2Cl) $ClF_2PS(\ell)$		[9] lists ΔH vap. [25, 26] est. ΔHf^o_{298} = -193 ±15.
$Cl_2FHSi(g)$ ($SiHCl_2F$) $Cl_2FHSi(\ell)$		[9] lists ΔH vap.
$Cl_2FOP(g)$ ($POFCl_2$) $Cl_2FOP(\ell)$		[623] calc. ΔH vap. [9] lists ΔH vap. [25, 26] est. ΔHf^o_{298} = -188 ±15.
$Cl_2FPS(g)$ ($PSFCl_2$) $Cl_2FPS(\ell)$		[9] lists ΔH vap. [25, 26] est. ΔHf^o_{298} = -142 ±15.
$Cl_2F_4OSi_2(g)$ ($Si_2OF_4Cl_2$) $Cl_2F_4OSi_2(\ell)$		[9] lists ΔH vap.
$Cl_2F_6N_4P_4(g)$ ($N_4P_4Cl_2F_6$) $Cl_2F_6N_4P_4(\ell)$		[9] lists ΔH vap.
$Cl_3F_3OSi_2(g)$ ($Si_2OF_3Cl_3$) $Cl_3F_3OSi_2(\ell)$		[9] lists ΔH vap.
$CoF_2H_8O_4(c)$ ($CoF_2 \cdot 4H_2O$)		[9] lists ΔFf^o_{298}.

Compounds	ΔHf^o_{298} (kcal/mole)	Remarks
$CrFK_3O_4$(c) (K_3CrO_4F)		[458] meas. ΔH soln. of K_3CrO_4F and of an equimolar mixt. of KF and K_2CrO_4, and reported for: KF(c) + K_2CrO_4(c) = K_3CrO_4F(c), ΔH = +0.39.
$CrFO_4Rb_3$(c) (Rb_3CrO_4F)		[458] meas. ΔH soln. of Rb_3CrO_4F and of an equimolar mixt. of RbF and Rb_2CrO_4, and reported for: RbF(c) + Rb_2CrO_4(c) = Rb_3CrO_4F(c), ΔH = -0.78.
$CsFH_{4/3}O_{2/3}$(c) ($CsF\cdot 2/3H_2O$)	-176.8 [9]	
$CsFH_3O_{3/2}$(c) ($CsF\cdot 3/2H_2O$)	-237.2 [9]	
Cs_3FO_4S(c) (Cs_3SO_4F)		[586] discusses energy of formation.
$Cs_3F_3MoO_3$(c) ($Cs_3MoO_3F_3$)		[459] calc. ΔFf.
$Cs_3F_3O_3W$(c) ($Cs_3WO_3F_3$)		[460] calc. ΔFf.
$Cs_8F_2O_{15}Ti_6$(c) ($3Cs_2Ti_2O_5\cdot 2CsF$)		[587] discusses energy of formation.
$CuF_2H_4O_2$(c) ($CuF_2\cdot 2H_2O$)	-274.5 [9]	
$FH_{2/3}O_{1/3}Rb$(c) ($RbF\cdot 1/3H_2O$)	-156.12 [9]	
FHO_2S(g) ($SO_2\cdot HF$)		For the reaction: SO_2(g) + HF(g) = $SO_2\cdot HF$(g), [393] reports ΔH = -2.
FHO_3S(ℓ) (HSO_3F)	-184 [461]	[461] meas. heat of mixing HF and SO_3 in HSO_3F.
$FH_3Mo_4O_{13}$(c) ($H_3Mo_4O_{13}F$)		[464] reports heat effects of formation and decomposition.
$FH_3O_{3/2}Rb$(c) ($RbF\cdot 3/2H_2O$)	-240.33 [9]	
FH_4KO_2(c) ($KF\cdot 2H_2O$)	-277.00 [9]	
FH_8KO_4(c) ($KF\cdot 4H_2O$)	-418.0 [9]	
FKO_3S(c) (KSO_3F)		[462] reports ΔH soln.
FK_3MoO_4(c) (K_3MoO_4F)		See $F_3K_3MoO_3$(c).
FK_3O_4S(c)		[586] discusses energy of formation.
FNO_3S(g) ($NOSO_2F$)		[463] meas. dissoc. of vapor at 19°.
FNO_3S(ℓ)		
FNO_3S(c)		[463] meas. v.p.

Compound	ΔHf^o_{298} (kcal/mole)	Remarks
$FNa_3O_4W(c)$		[460] discusses energy of formation.
$FO_4Rb_3S(c)$		[460] discusses energy of formation.
$F_2H_4MoO_4(c)$ ($H_2MoO_3F_2 \cdot H_2O$)		[464] reports ΔH soln. [464] reports endothermic effect of loss of H_2O and HF.
$F_2H_8MnO_4(c)$ ($MnF_2 \cdot 4H_2O$)		[239] meas. ΔH soln.
$F_2H_8NiO_4(c)$ ($NiF_2 \cdot 4H_2O$)		[9] lists ΔFf^o_{298}.
$F_2O_{15}Rb_8Ti_6(c)$ ($3Rb_2Ti_2O_5 \cdot 2RbF$)		[587] discusses energy of formation.
$F_3HLaO_{\frac{1}{2}}(c)$ ($LaF_3 \cdot \frac{1}{2}H_2O$)		[181] reports ΔFf^o_{298} = -428.1.
$F_3H_3NSb(c)$ ($SbF_3 \cdot NH_3$)	-242.3 [9]	
$F_3H_6N_2Sb(c)$ ($SbF_3 \cdot 2NH_3$)	-265.5 [9]	
$F_3H_9N_3Sb(c)$ ($SbF_3 \cdot 3NH_3$)	-285.7 [9]	
$F_3H_{12}N_4Sb(c)$ ($SbF_3 \cdot 4NH_3$)	-304.4 [9]	
$F_3H_{18}N_6Sb(c)$ ($SbF_3 \cdot 6NH_3$)	-341.4 [9]	
$F_3K_3MoO_3(c)$ ($K_3MoO_3F_3$)		For the reaction: $K_3MoO_3F_3(c) + 1/2O_2(g) = K_3MoO_4F(c) + F_2(g)$, [465] reports ΔH = -358. [459] calc. ΔFf.
$F_3K_3O_3W(c)$ ($K_3WO_3F_3$)		[460] calc. ΔFf.
$F_3Li_3MoO_3(c)$ ($Li_3MoO_3F_3$)		[459] calc. ΔFf.
$F_3Li_3O_3W(c)$ ($Li_3WO_3F_3$)		[460] calc. ΔFf.
$F_3MoNa_3O_3$ ($Na_3MoO_3F_3$)		[459] calc. ΔFf.
$F_3MoO_3Rb_3(c)$ ($Rb_3MoO_3F_3$)		[459] calc. ΔFf.
$F_3Na_3O_3W(c)$ ($Na_3WO_3F_3$)		[460] calc. ΔFf.
$F_3O_3Rb_3W(c)$ ($Rb_3WO_3F_3$)		[460] calc. ΔFf.
$F_4HO_{\frac{1}{2}}Th(c)$ ($ThF_4 \cdot \frac{1}{2}H_2O$)		From calorimetric hydration measurements on samples containing varying amounts of H_2O, [466] calc. for the process: $ThF_4(c)$(from $ThF_4 \cdot \frac{1}{2}H_2O$) + $\frac{1}{2}H_2O(l)$ = $ThF_4 \cdot \frac{1}{2}H_2O(c)$, ΔH = -1.174.

Compounds	ΔHf°_{298} (kcal/mole)	Remarks
$F_4H_5O_{5/2}Th(c)$ ($ThF_4 \cdot 5/2H_2O$)		From calorimetric hydration measurements on samples containing varying amounts of H_2O, [466] calc. for the process: $ThF_4(c)$(from $ThF_4 \cdot 5/2H_2O$) + $5/2H_2O(\ell)$ = $ThF_4 \cdot 5/2H_2O(c)$, $\Delta H = -2.073$.
$F_4H_5O_{5/2}U(c)$ ($UF_4 \cdot 5/2H_2O$)		For the reaction: $UF_4(c) + 5/2H_2O(\ell) = UF_4 \cdot 5/2H_2O(c)$ [419] meas. $\Delta H = -8.21$. From dissoc. pressure meas. [467] gives, for the reverse reaction, $\Delta H = 7.23$.
$F_4H_6N_2Si(c)$ ($SiF_4 \cdot 2NH_3$)		From dissoc. pressure meas. [468] reports for: $SiF_4 \cdot 2NH_3(c) = SiF_4(g) + 2NH_3(g)$, $\Delta H = 18.2$.
$F_4H_6O_3Zr(c)$ ($ZrF_4 \cdot 3H_2O$)		For the reaction: $ZrF_4(c) + 3H_2O(\ell) = ZrF_4 \cdot 3H_2O(c)$, [469] meas. $\Delta H = -1.644$.
$F_5H_4NZr(c)$ (NH_4ZrF_5)		From thermal decompn. studies [470] reports $\Delta H \cong 25$ for the decomposition to $ZrF_4(c)$.
$F_6H_7N_2P(c)$ ($NH_4PF_6 \cdot NH_3$)		[471, 472] report v.p. studies of the system $NH_4PF_6 - NH_3$.
$F_6H_8N_2Si(c)$ ($(NH_4)_2SiF_6$)	-629.7 [9]	[588] meas. the solubility in H_2O vs. T.
$F_6H_8N_2Zr(c)$ ($(NH_4)_2ZrF_6$)		For the decomposition to NH_4ZrF_5, [470] reports $\Delta H \cong 21$.
$F_7H_{12}N_3Zr(c)$ ($(NH_4)_3ZrF_7$)		For the decomposition to $(NH_4)_2ZrF_6$, [470] reports $\Delta H \cong 21$.

b. Compounds of five elements.

Compounds	ΔHf°_{298} (kcal/mole)	Remarks
$AlF_5H_2K_2O(c)$ ($AlF_3 \cdot 2KF \cdot H_2O$)		[576] studied thermal decomposition. [576] studied equilibrium with HF(aq).
$AlF_5H_{11}N_2O_{3/2}(c)$ ($AlF_3 \cdot 2NH_4F \cdot 3/2H_2O$)	-673.7 [9]	
$AlF_6H_7K_3O_{7/2}(c)$ ($AlF_3 \cdot 3KF \cdot 7/2H_2O$)	-1033.6 [9]	
$AlF_6H_7Na_3O_{7/2}(c)$ ($Na_3AlF_6 \cdot 7/2H_2O$)	-1021.0 [9]	
$BCF_2H_3O(g)$ (BF_2OCH_3)		[473] calc. ΔH vap.
$BCF_2H_3O(\ell)$		[473] meas. v.p. See [520].
$BCF_3HN(c)$ ($HCN \cdot BF_3$)	-264.9 [29]	[520] reviews dissoc. pressure meas.
$BF_2H_6NSi_2(g)$ ($(SiH_3)_2NBF_2$)		
$BF_2H_6NSi_2(\ell)$		[397] meas. v.p., and est. ΔH association = +7.5. [520] reviews v.p. data.
$BF_3HKO(c)$ (KBF_3OH)	-430.3 [29] -419.3 [475]	[475] meas. ΔH hydr.

Compounds	ΔHf°_{298} (kcal/mole)	Remarks
$BF_3HNaO(c)$		[29, 520] review v.p. and dissoc. pressure.
$BF_3H_9NSi_3(\ell)$ ($(SiH_3)_3N \cdot BF_3$)		[474] meas. the dissoc. pressure for: $(SiH_3)_3NBF_3(\ell) = (SiH_3)_3N(\ell) + BF_3(g)$. [520] reviews dissoc. pressure meas.
$B_3F_3H_9N_3Si_3(c)$ ($(SiH_3NBF)_3$)		[397] meas. v.p.
$B_3F_4HK_2O_4(c)$ ($K_2B_3F_4O_3OH$)	-889.8 [29] -857.7 [475]	[475] meas. ΔH hydr.
BrCClFH(g) (CHFClBr)		[354] est. $\Delta Hf^\circ_{298} = -61$.
BrCClFI(g) (CFClBrI)		[354] est. $\Delta Hf^\circ_{298} = -38$.
BrCFHI(g) (CHFBrI)		[354] est. $\Delta Hf^\circ_{298} = -36$.
CClFHI(g) (CHFClI)		[354] est. $\Delta Hf^\circ_{298} = -46$.
$CClF_2H_{2n+1}O_n(c)$ ($CHClF_2 \cdot nH_2O$)		See [446] for dissoc. pressures.
$CCl_2FH_3Si(g)$ (SiH_3CFCl_2) $CCl_2FH_3Si(\ell)$		[9] lists ΔH vap.
$CCl_2FH_{35}O_{17}(c)$ ($CHCl_2F \cdot 17H_2O$)		[476] meas. dissoc. pressure.
$CCl_2F_2H_{2n}O_n(c)$ ($CCl_2F_2 \cdot nH_2O$)		See [446] for dissoc. pressures.
$CCl_3FH_{2n}O_n(c)$ ($CCl_3F \cdot nH_2O$)		See [446] for dissoc. pressures.
$CF_2H_3OP(\ell)$ (CH_3POF_2)		[477] meas. ΔH fus.
$CF_2H_3OP(c)$		[478] meas. v.p.
$CF_2NPS(g)$ $CF_2NPS(\ell)$		[9] lists ΔH vap.
$CoF_3H_{17}N_5O(c)$ ($[Co(NH_3)_5H_2O]F_3$)	-435.7 [9]	
$F_6H_{12}MgO_6Si(c)$ ($MgSiF_6 \cdot 6H_2O$)		[588] meas. solubility vs. T.
$F_6H_{12}O_6SiZn(c)$ ($ZnSiF_6 \cdot 6H_2O$)		[588] meas. solubility vs. T.

Compounds	ΔHf^{o}_{298} (kcal/mole)	Remarks
c. Compounds of six elements.		
$AlF_2KMg_3O_{10}Si_3(\ell)$ ($KMg_3AlSi_3O_{10}F$)		[480] reports ΔH fus. [481] reports ΔH crystn.
$AlF_2KMg_3O_{10}Si_3(c)$	-1498.1 ± 1 [480]	[480] meas. ΔH soln. in HF(aq). [17] list ΔHf^{o}_{298} = -1497.0 ± 1.
$BCF_2H_6NSi(c)$ ($CH_3SiH_3NBF_2$)		[397] meas. v.p. and est. ΔH association = -1.5.
$B_2F_6K_2Mg_6O_{21}Si_7(c)$		[482] reports ΔH crystn.
$BeF_6K_2Mg_6O_{19}Si_7(c)$		[482] reports ΔH crystn.
$CClFH_3OP(g)$ (CH_3POClF)		
$CClFH_3OP(\ell)$		[477] meas. ΔH fus.
$CClFH_3OP(c)$		[478] meas. v.p.
$F_6Fe_2K_2Mg_6O_{19}Si_6(c)$		[482] reports ΔH crystn.
d. Compounds of seven elements.		
$Al_2BaCF_6Mg_6O_{21}Si_6(c)$		[482] reports ΔH crystn.
$Al_2F_6Fe_3K_2Mg_3O_{19}Si_6(c)$		[482] reports ΔH crystn.
$BBaF_2LiMg_2O_{10}Si_3(c)$		[481, 482] report ΔH crystn.
$BCF_3H_3NOS(c)$ ($CH_3NSO\cdot BF_3$)		[483] meas. dissoc. pressure for; $CH_3NSO\cdot BF_3(c) = CH_3NSO(g) + BF_3(g)$. Using the data of [483], [29] reported ΔH dissoc. = 32.8. See [520].
$CF_6K_2Mg_6O_{22}Si_7Zn_2(c)$		[482] reports ΔH crystn.
e. Compounds of eight elements.		
$Al_4CF_{12}K_4Mg_{11}NiO_{40}Si_{12}(c)$		[482] reports ΔH crystn.
$B_2Ba_2CF_4Li_2Mg_4O_{22}Si_6(c)$		[481, 482] report ΔH crystn.
$B_2CCa_2F_4Li_2Mg_4O_{22}Si_6(c)$		[482] reports ΔH crystn.
$B_2CF_4Li_2Mg_4O_{22}Si_6Sr_2(c)$		[482] reports ΔH crystn.
$Ca_{3/2}FHMg_{9/2}Mn_{1/2}NaO_{23}Si_8(c)$ (Richterite)		[479] meas. decomposition to pyroxene, glass, and water and reports ΔH = 6.85.

TABLE 5. AQUEOUS FLUORIDE ION

Species	ΔHf^o_{298} (kcal/mole)	Remarks
F^-(aq)	-78.66 [9]	For the equilibrium: H^+(aq) + F^-(aq) $\rightleftarrows$ HF(aq), [16] lists ΔH = 3.05, 3.18; log K (25 values). [195, 589] calc. ΔH hydration of F^-(g). See also HF_2^-(aq), HF(aq), and individual metal ion species.

TABLE 6. BINARY AQUEOUS SPECIES

Species	ΔHf^o_{298} (kcal/mole)	Remarks
AgF(aq)	-53.35 [9] (var)	For the equilibrium: Ag^+(aq) + F^-(aq) $\rightleftarrows$ AgF(aq), [16] lists ΔH = -2.4; log K (5 values).
AlF^{+2}(aq)		For the equilibrium: Al^{+3}(aq) + F^-(aq) $\rightleftarrows$ AlF^{+2}(aq), [16] lists ΔH = 1.15; log K (3 values). [484] recalc. the data for this reaction and reports ΔH = 1.17. [488] calc. ΔH = 1.06. See AlF_2^+(aq).
AlF_2^+(aq)		For the equilibrium: AlF^{+2}(aq) + F^-(aq) $\rightleftarrows$ AlF_2^+(aq), [16] lists ΔH = 0.78; log K (2 values). [488] calc. ΔH = 0.92. [484] recalc. data for the equilibrium: Al^{+3}(aq) + $2F^-$(aq) $\rightleftarrows$ AlF_2^+(aq), and reports ΔH = 1.97. See AlF_3(aq).
AlF_3(aq)	-361.4 [9]	For the reaction: Al(c) + 3HF(aq,12%) = AlF_3(aq) + 3/2 H_2(g), [485] meas. ΔH = -124.4 ± 1. For the reaction: Al(c) + 3HF(aq,10%) = AlF_3(aq) + 3/2 H_2(g), [486] meas. ΔH = -139.2. For the equilibrium: AlF_2^+(aq) + F^-(aq) $\rightleftarrows$ AlF_3(aq), [16] lists ΔH = 0.19; log K (2 values). [484] calc. ΔH = 0.18. [484] recalc. data for the equilibrium: Al^{+3}(aq) + $3F^-$(aq) $\rightleftarrows$ AlF_3(aq), and reports ΔH = 2.18. See AlF_4^-(aq), (Al_2F_6)(aq).
AlF_4^-(aq)		For the equilibrium: AlF_3(aq) + F^-(aq) $\rightleftarrows$ AlF_4^-(aq), [16] lists ΔH = 0.28; log K (2 values). [488] calc. ΔH = 0.04. [484] recalc. data for the equilibrium: Al^{+3}(aq) + $4F^-$(aq) $\rightleftarrows$ AlF_4^-(aq), and reports ΔH = 2.14. See AlF_5^{-2}(aq), AlF_6^{-3}(aq).
AlF_5^{-2}(aq)		For the equilibrium: AlF_4^-(aq) + F^-(aq) $\rightleftarrows$ AlF_5^{-2}(aq), [16] lists ΔH = -0.75; log K (2 values). [484] calc. ΔH = -0.36. [484] recalc. data for the equilibrium: Al^{+3}(aq) + $5F^-$(aq) $\rightleftarrows$ AlF_5^{-2}(aq), and reports ΔH = 2.27. See AlF_6^{-3}(aq).
AlF_6^{-3}(aq)		For the equilibrium: AlF_5^{-2}(aq) + F^-(aq) $\rightleftarrows$ AlF_6^{-3}(aq), [16] lists ΔH = -1.55; log K (1 value). [488] discusses the equilibrium. For the equilibrium: Al^{+3}(aq) + $6F^-$(aq) $\rightleftarrows$ AlF_6^{-3}(aq), [16] lists log K. [484] recalc. data for this reaction and reports ΔH = -1.24. See Al_2F_6(aq).
AlF_n^{3-n}(aq)		See [488] for a general review of Al-F complexes.
Al_2F_6(aq) ($Al(AlF_6)$)		For the equilibrium: Al^{+3}(aq) + AlF_6^{-3}(aq) $\rightleftarrows$ $Al(AlF_6)$(c), [16] lists log K sp (1 value).
AmF_2(aq)		See [106].
AmF_3(aq)		See [106].
AuF_3(aq)		[131] meas. ΔH hydr. of AuF_3(c)
BF_3(aq)	-289.8 [9] -292.2 [29]	See BF_4^-(aq).

TABLE 6. BINARY AQUEOUS SPECIES (continued)

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$BF_4^-(aq)$	-365 [9] -371.7 [29]	[351] calc. ΔHf^o_{298} =-342. For the equilibrium: $BF_3(aq) + F^-(aq) \rightleftarrows BF_4^-(aq)$, [16] lists log K. For the equilibrium: $BF_3OH^-(aq) + HF(aq) \rightleftarrows BF_4^-(aq) + H_2O(\ell)$, [16] lists $\Delta H = -3.23$; log K (8 values). For the equilibrium: $BF_4^-(aq) + 3H_2O(\ell) \rightleftarrows H_3BO_3(aq) + 3H^+(aq) + 3F^-(aq)$, [489] meas. K, and reports ΔF reac., and ΔFf^o_{298} of $BF_4^-(aq)$ = -352. For this reaction, [16] lists log K (1 value).
$BaF^+(aq)$		For the equilibrium: $Ba^{+2}(aq) + F^-(aq) \rightleftarrows BaF^+(aq)$, [16] lists log K (2 values).
$BaF_2(aq)$	-286.0 [9]	For the equilibrium: $Ba^{+2}(aq) + 2F^-(aq) \rightleftarrows BaF_2(c)$, [16] lists log K sp (4 values).
$BeF^+(aq)$		For the equilibrium: $Be^{+2}(aq) + F^-(aq) \rightleftarrows BeF^+(aq)$, [16] lists log K (2 values). For the equilibrium: $Be^{+2}(aq) + HF(aq) \rightleftarrows BeF^+(aq) + H^+(aq)$, [16] lists $\Delta H = -3.40$; log K (4 values). See $BeF_2(aq)$.
$BeF_2(aq)$	-251.4 [9]	For the equilibria: $BeF^+(aq) + F^-(aq) \rightleftarrows BeF_2(aq)$, and $Be^{+2}(aq) + 2F^-(aq) \rightleftarrows BeF_2(aq)$, [16] lists log K (1 value, each). For the equilibrium: $BeF^+(aq) + HF(aq) \rightleftarrows BeF_2(aq) + H^+(aq)$, [16] lists $\Delta H = -1.735$: log K (4 values). See $BeF_3^-(aq)$.
$BeF_3^-(aq)$		For the equilibria: $BeF_2(aq) + F^-(aq) \rightleftarrows BeF_3^-(aq)$, and $BeF_2(aq) + HF(aq) \rightleftarrows BeF_3^-(aq) + H^+(aq)$, [16] lists log K (1 and 4 values, resp.). See $BeF_4^{-2}(aq)$.
$BeF_4^{-2}(aq)$		For the equilibrium: $BeF_3^-(aq) + F^-(aq) \rightleftarrows BeF_4^{-2}(aq)$, [16] lists log K (1 value).
$CaF^+(aq)$		For the equilibrium: $Ca^{+2}(aq) + F^-(aq) \rightleftarrows CaF^+(aq)$, [16] lists log K (2 values).
$CaF_2(aq)$	-287.09 [9]	For the equilibria: $CaF_2(c) \rightleftarrows Ca^{+2}(aq) + 2F^-(aq)$, and $CaF_2(c) + H^+(aq) \rightleftarrows Ca^{+2}(aq) + 2HF(aq)$, [16] lists log K (6 values, and 2 values, resp.).
$CdF^+(aq)$		[16] lists log K (2 values) for the equilibrium: $Cd^+(aq) + F^-(aq) \rightleftarrows CdF^+(aq)$. See $CdF_2(aq)$.
$CdF_2(aq)$	-173.6 [9]	[16] lists log K (1 value) for the equilibrium: $CdF^+(aq) + F^-(aq) \rightleftarrows CdF_2(aq)$.
$CdF_{12}^{-10}(aq)$		[16] lists log K (1 value) for the equilibrium: $Cd^{+2}(aq) + 12F^-(aq) \rightleftarrows CdF_{12}^{-10}(aq)$.
$CeF^{+2}(aq)$		[16] lists log K (3 values) for the equilibrium: $Ce^{+3}(aq) + F^-(aq) \rightleftarrows CeF^{+2}(aq)$. For the equilibrium: $Ce^{+3}(aq) + HF(aq) \rightleftarrows CeF^{+2}(aq) + H^+(aq)$, [16] lists $\Delta H = -0.5$; log K (1 value). [181] calc. ΔFf^o_{298} of $CeF^{+2}(aq)$ = -242.
$CeF_3(aq)$		[181] meas. K sp for the equilibrium: $CeF_3 \cdot \frac{1}{2}H_2O(c) \rightleftarrows Ce^{+3}(aq) + 3F^-(aq) + \frac{1}{2}H_2O(\ell)$.
$CmF_2(aq)$		See [106].
$CmF_3(aq)$		See [106].
$CoF_2(aq)$	-173.6 [9]	
$CrF^{+2}(aq)$		[16] lists log K (2 values) for the equilibrium: $Cr^{+3}(aq) + F^-(aq) \rightleftarrows CrF^{+2}(aq)$. For the equilibrium: $Cr^{+3}(aq) + HF(aq) \rightleftarrows CrF^{+2}(aq) + H^+(aq)$, [16] lists $\Delta H = -0.6$; log K (1 value). See $CrF_2^+(aq)$.
$CrF_2^+(aq)$		[16] lists log K (1 value) for the equilibrium: $CrF^{+2}(aq) + F^-(aq) \rightleftarrows CrF_2^+(aq)$. For the equilibrium: $CrF^{+2}(aq) + HF(aq) \rightleftarrows CrF_2^+(aq) + H^+(aq)$, [16] lists $\Delta H = -0.1$; log K (1 value). See $CrF_3(aq)$.
$CrF_3(aq)$		[16] lists log K (1 value, each) for the equilibria: $CrF_2^+(aq) + F^-(aq) \rightleftarrows CrF_3(aq)$, and $CrF_2^+(aq) + HF(aq) \rightleftarrows CrF_3(aq) + H^+(aq)$.
$CsF(aq)$	-137.9 [9] (var)	[195, 619] calc. ΔH hydration of ions. [487] calc. free energy of hydration of ions.

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$CuF^+(aq)$		For the equilibrium: $Cu^{+2}(aq) + F^-(aq) \rightleftarrows CuF^+(aq)$, [16] lists $\Delta H = 0.9$; log K (5 values). [490] meas. $\Delta H = 0.9 \pm 2.7$, and K. For the equilibrium: $Cu^{+2}(aq) + HF(aq) \rightleftarrows CuF^+(aq) + H^+(aq)$, [490] meas. $\Delta H = -2.6 \pm 2.7$, and K.
$FeF^+(aq)$		[16] lists log K (1 value) for the equilibrium: $Fe^{+2}(aq) + F^-(aq) \rightleftarrows FeF^+(aq)$.
$FeF^{+2}(aq)$		For the equilibrium: $Fe^{+3}(aq) + F^-(aq) \rightleftarrows FeF^{+2}(aq)$, [16] lists $\Delta H = 7.5$, and 2.33; log K (11 values). For the equilibrium: $Fe^{+3}(aq) + HF(aq) \rightleftarrows FeF^{+2}(aq) + H^+(aq)$, [484] meas. $\Delta H = -0.58 \pm 0.07$. For the same reaction [16] lists $\Delta H = -0.62$; log K (5 values). [491] meas. K. See $FeF_2^+(aq)$.
$FeF_2^+(aq)$		For the equilibrium: $FeF^{+2}(aq) + HF(aq) \rightleftarrows FeF_2^+(aq) + H^+(aq)$, [484] meas. $\Delta H = -1.66 \pm 0.1$. For the same reaction [16] lists $\Delta H = -1.65$; log K (5 values). [491] meas. K. For the equilibrium: $FeF^{+2}(aq) + F^-(aq) \rightleftarrows FeF_2^+(aq)$, [16] lists $\Delta H = 1.77$; log K (7 values). See $FeF_3(aq)$.
$FeF_2(aq)$	-177.8 [9]	
$FeF_3(aq)$	-243.1 [9]	For the equilibrium: $FeF_2^+(aq) + HF(aq) \rightleftarrows FeF_3(aq) + H^+(aq)$, [484] meas. $\Delta H = -2.03 \pm 0.20$. For this reaction [16] lists log K (5 values). [491] meas. K. For the equilibrium: $FeF_2^+(aq) + F^-(aq) \rightleftarrows FeF_3(aq)$, [16] lists $\Delta H = 2.98$; log K (6 values). See $FeF_4^-(aq)$.
$FeF_4^-(aq)$		For the equilibrium: $FeF_3(aq) + F^-(aq) \rightleftarrows FeF_4^-(aq)$, [16] lists log K (1 value). See $FeF_5^{-2}(aq)$.
$FeF_5^{-2}(aq)$		For the equilibrium: $FeF_4^-(aq) + F^-(aq) \rightleftarrows FeF_5^{-2}(aq)$, [16] lists log K (1 value).
$FeF_6^{-3}(aq)$		[16] lists log K for the equilibrium: $HFeF_6^{-2}(aq) \rightleftarrows FeF_6^{-3}(aq) + H^+(aq)$.
$GaF^{+2}(aq)$		For the equilibrium: $Ga^{+3}(aq) + F^-(aq) \rightleftarrows GaF^{+2}(aq)$, [16] lists log K (2 values). For the equilibrium: $Ga^{+3}(aq) + HF(aq) \rightleftarrows GaF^{+2}(aq) + H^+(aq)$, [16] lists $\Delta H = -0.5$, and -1.30; log K (5 values). See $GaF_2^+(aq)$.
$GaF_2^+(aq)$		For the equilibrium: $GaF^{+2}(aq) + HF(aq) \rightleftarrows GaF_2^+(aq) + H^+(aq)$, [16] lists $\Delta H = -1.49$; log K (4 values). See $GaF_3(aq)$.
$GaF_3(aq)$		For the equilibrium: $GaF_2^+(aq) + HF(aq) \rightleftarrows GaF_3(aq) + H^+(aq)$, [16] lists $\Delta H = -5.50$; log K (4 values).
$GdF^{+2}(aq)$		For the equilibria: $Gd^{+3}(aq) + F^-(aq) \rightleftarrows GdF^{+2}(aq)$, and $Gd^{+3}(aq) + HF(aq) \rightleftarrows GdF^{+2}(aq) + H^+(aq)$, [16] lists log K (2 values, and 1 value, resp.). [181] reports $\Delta Ff^o_{298} = -236.5$.
$HF(aq)$	-78.66 [9] (var)	For the equilibrium: $H^+(aq) + F^-(aq) \rightleftarrows HF(aq)$, [16] lists $\Delta H = 3.05$, and 3.18; log K (25 values). [491] meas. ΔH ionization. [590] meas. pH vs. concentration. Heats of soln. of various substances in HF(aq) have been determined by [310, 311, 498, 591, 592, 593, 594, 595, 596, 597, 598]. See $HF_2^-(aq)$.
$HF_2^-(aq)$	-153.6 [9]	For the equilibrium: $HF(aq) + F^-(aq) \rightleftarrows HF_2^-(aq)$, [16] lists $\Delta H = 5.07$; log K (19 values).
$HgF^+(aq)$		For the equilibrium: $Hg^{+2}(aq) + F^-(aq) \rightleftarrows HgF^+(aq)$, [16] lists $\Delta H = 0.85$; log K (4 values).
$Hg_2F^+(aq)$		For the equilibrium: $Hg_2^{+2}(aq) + F^-(aq) \rightleftarrows Hg_2F^+(aq)$, [16] lists log K (2 values).
$InF^{+2}(aq)$		For the equilibrium: $In^{+3}(aq) + F^-(aq) \rightleftarrows InF^{+2}(aq)$, [16] lists $\Delta H = 2.47$; log K (6 values). For the equilibrium: $In^{+3} + HF(aq) \rightleftarrows InF^{+2}(aq) + H^+(aq)$, [16] lists $\Delta H = -0.51$; log K (3 values). See also [599]. See $InF_2^+(aq)$.

Species	ΔHf^{o}_{298} (kcal/mole)	Remarks
InF_2^+(aq)		For the equilibrium: InF^{+2}(aq) + F^-(aq) ⇄ InF_2^+(aq), [16] lists ΔH = 4.0: log K (6 values). For the equilibrium: InF^{+2}(aq) + HF(aq) ⇄ InF_2^+(aq) + H^+(aq), [16] lists ΔH = 1.0: log K (3 values). See also [599]. See InF_3(aq).
InF_3(aq)		For the equilibrium: InF_2^+(aq) + F^-(aq) ⇄ InF_3(aq), [16] lists log K (2 values). See also [599]. See InF_4^-(aq).
InF_4^- (aq)		For the equilibrium: InF_3(aq) + F^-(aq) ⇄ InF_4^-(aq), [16] lists log K (1 value). See also [599].
KF(aq)	-138.7 [9] (var)	[492] reports ΔH dilution. [195] calc. ΔH soln. [619] calc. ΔH hydration of ions. [487, 600] calc. ΔF hydration of ions. [601] reviews degree of dissoc.
LaF^{+2}(aq)		For the equilibria: La^{+3}(aq) + F^-(aq) ⇄ LaF^{+2}(aq), and La^{+3}(aq) + HF(aq) ⇄ LaF^{+2}(aq) + H^+(aq), [16] lists log K (2 values and 1 value, resp.).
LaF_3(aq)		[181] gives K sp, and ΔH soln.
LiF(aq)	-145.21 [9] (var)	[622] meas. ΔH neutralization of LiOH(aq) and HF(aq). [622, 233] meas. ΔH soln. [195, 619, 620] calc. ΔH hydration of ions. [487] calc. ΔF hydration of ions.
MgF^+(aq)		For the equilibrium: Mg^{+2}(aq) + F^-(aq) ⇄ MgF^+(aq), [16] lists ΔH = 4: log K (3 values). See [493]. For the equilibrium: Mg^{+2}(aq) + HF(aq) ⇄ MgF^+(aq) + H^+(aq), [493] lists K.
MgF_2(aq)		For the equilibrium: MgF_2(c) ⇄ Mg^{+2}(aq) + $2F^-$(aq), [16] lists K sp (2 values).
MnF^{+2}(aq)		For the equilibrium: Mn^{+3}(aq) + HF(aq) ⇄ MnF^{+2}(aq) + H^+(aq), [16] lists log K (1 value).
MnF_2(aq)	-209.2 [9]	
MnF_3(aq)	-260 [9]	
MnF_4(aq)		[239] meas. ΔH soln. of $MnF_4 \cdot 4H_2O$.
MoF_6(aq)		See F_2MoO_2(aq).
NaF(aq)	-135.94 [9] (var)	[256] meas. ΔH soln. in HCl(aq). [195, 619] calc. ΔH hydration of ions. [487] calc. ΔF hydration of ions. See also [258].
NiF^+(aq)		For the equilibrium: Ni^{+2}(aq) + F^-(aq) ⇄ NiF^+(aq), [16] lists log K (1 value).
NiF_2(aq)	-171.5 [9]	
NpF_6(aq)		See [555].
PbF^+(aq)		For the equilibrium: Pb^{+2}(aq) + F^-(aq) ⇄ PbF^+(aq), [16] lists log K (2 values). See [490].
PbF_2(aq)	-155.7 [9]	For the equilibrium: PbF_2(c) ⇄ Pb^{+2}(aq) + $2F^-$(aq), [16] lists K sp (4 values). [602] meas. solubility of PbF_2(c). See also [282].
PuF^{+3}(aq)		For the equilibrium: Pu^{+4}(aq) + F^-(aq) ⇄ PuF^{+3}(aq), [16] lists log K (2 values).
PuF_3(aq)	-374.6 [9]	[288] meas. ΔH pptn of PuF_3(c).
RbF(aq)	-137.6 [9] (var)	[195, 619] calc. ΔH hydration of ions.
SbF_3(aq)	-216.1 [9]	

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$ScF^{+2}(aq)$		For the equilibrium: $Sc^{+3}(aq) + F^-(aq) \rightleftarrows ScF^{+2}(aq)$, [16] lists $\Delta H = 0.40$; log K (4 values). See [494]. For the equilibrium: $Sc^{+3}(aq) + HF(aq) \rightleftarrows ScF^{+2}(aq) + H^+(aq)$, [495] meas. K and calc. $\Delta H = -4.48 \pm 0.05$. See $ScF_2^+(aq)$.
$ScF_2^+(aq)$		For the equilibrium: $ScF^{+2}(aq) + F^-(aq) \rightleftarrows ScF_2^+(aq)$, [16] lists $\Delta H = -1.23$; log K (4 values). See [494]. For the equilibrium: $ScF^{+2}(aq) + HF(aq) \rightleftarrows ScF_2^+(aq) + H^+(aq)$, [495] meas. K and calc. $\Delta H = -3.23 \pm 0.05$. See $ScF_3(aq)$.
$ScF_3(aq)$		For the equilibrium: $ScF_2^+(aq) + F^-(aq) \rightleftarrows ScF_3(aq)$, [16] lists $\Delta H = -1.26$; log K (4 values). See [494]. For the equilibrium: $ScF_2^+(aq) + HF(aq) \rightleftarrows ScF_3(aq) + H^+(aq)$, [495] meas. K and calc. $\Delta H = -1.59 \pm 0.05$. See $ScF_4^-(aq)$.
$ScF_4^-(aq)$		For the equilibrium: $ScF_3(aq) + F^-(aq) \rightleftarrows ScF_4^-(aq)$, [16] lists log K (4 values). For the equilibrium: $ScF_3(aq) + HF(aq) \rightleftarrows ScF_4^-(aq) + H^+(aq)$, [495] meas. K.
$SiF_4(aq)$		For the equilibrium: $Si(OH)_4 + 4HF(aq) \rightleftarrows SiF_4(aq) + 4H_2O(\ell)$, [16] lists log K (1 value). See $SiF_6^{-2}(aq)$.
$SiF_5^-(aq)$		See $SiF_6^{-2}(aq)$, $Si_2F_{10}^{-2}(aq)$.
$SiF_6^{-2}(aq)$	-558.5 [9]	For the equilibrium: $SiF_4(aq) + 2F^-(aq) \rightleftarrows SiF_6^{-2}(aq)$, [16] lists log K (2 values) derived from the equilibria: 1) $SiF_4(aq) + F^-(aq) \rightleftarrows SiF_5^-(aq)$; 2) $SiF_5^-(aq) + F^-(aq) \rightleftarrows SiF_6^{-2}(aq)$. [16] lists log K for the equilibrium $Si(OH)_4 + 6HF(aq) \rightleftarrows SiF_6^{-2}(aq) + 2H^+(aq) + 4H_2O(\ell)$. [496] recalculated previous data for the equilibrium: $SiF_6^{-2}(aq) + 2H_2O(\ell) \rightleftarrows SiO_2(aq) + 4H^+(aq) + 6F^-(aq)$ and reported $\Delta H^o_{298} = 17.3$, and log K vs. t. See $Si_2F_{10}^{-2}(aq)$.
$Si_2F_{10}^{-2}(aq)$ $(SiF_4\text{-}SiF_6)$		For the reaction: $4H^+(aq) + 5SiF_6^{-2}(aq) + SiO_2 \rightleftarrows 2H_2O(\ell) + 3[SiF_6\text{-}SiF_4]^{-2}(aq)$, [497] meas. $\Delta H \cong -5$ kcal/mole SiO_2, and log K.
$SnF^+(aq)$		For the equilibrium: $Sn^{+2}(aq) + F^-(aq) \rightleftarrows SnF^+(aq)$, [16] lists log K (2 values).
$SnF_3^-(aq)$		For the equilibrium: $Sn^{+2}(aq) + 3F^-(aq) \rightleftarrows SnF_3^-(aq)$, [16] lists log K (2 values).
$SnF_6^{-2}(aq)$	-474.7 [9]	For the equilibrium: $Sn^{+4}(aq) + 6F^-(aq) \rightleftarrows SnF_6^{-2}(aq)$, [16] lists log K (1 value).
$SrF_2(aq)$		For the equilibrium: $SrF_2(c) \rightleftarrows Sr^{+2}(aq) + 2F^-(aq)$, [16] lists K sp (4 values). [603] meas. solubility.
$TaF_5(aq)$		For the reaction: $Ta(c) + 5HF(aq, 1.7\ H_2O) = TaF_5(aq) + 5/2\ H_2(g)$ [498] meas. $\Delta H = -99.66$.
$ThF^{+3}(aq)$		For the equilibria: $Th^{+4}(aq) + F^-(aq) \rightleftarrows ThF^{+3}(aq)$, and $Th^{+4}(aq) + HF(aq) \rightleftarrows ThF^{+3}(aq) + H^+(aq)$, [16] lists log K (1 value and 3 values, resp.). See $ThF_2^{+2}(aq)$.
$ThF_2^{+2}(aq)$		For the equilibrium: $ThF^{+3}(aq) + HF(aq) \rightleftarrows ThF_2^{+2}(aq) + H^+(aq)$, [16] lists log K (2 values). For the equilibrium: $ThF_4(H_2O)_4(c) + 2H^+(aq) \rightleftarrows ThF_2^{+2}(aq) + 2HF(aq) + 4H_2O(\ell)$, [16] lists log K (1 value). See $ThF_3^+(aq)$.
$ThF_3^+(aq)$		For the equilibrium: $ThF_2^{+2}(aq) + HF(aq) \rightleftarrows ThF_3^+(aq) + H^+(aq)$ [16] lists log K (1 value).
$T\ell F(aq)$	-77.3 [9]	[16] lists log K (1 value) for the equilibrium: $T\ell^+(aq) + F^-(aq) \rightleftarrows T\ell F(aq)$. [56] meas. ΔH soln. ($T\ell F$ in 800 H_2O) = -0.5 ± 0.2.
$T\ell F_3(aq)$		For ΔH hydrolysis [131] meas. -8.4.
$UF^{+3}(aq)$		For the equilibrium: $U^{+4}(aq) + HF(aq) \rightleftarrows UF^{+3}(aq) + H^+(aq)$ [16] lists log K (1 value).
$UF_2^{+2}(aq)$		For the equilibrium: $U^{+4}(aq) + 2HF(aq) \rightleftarrows UF_2^{+2}(aq) + 2H^+(aq)$ [16] lists log K (1 value).

TABLE 6. BINARY AQUEOUS SPECIES (continued)

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$YF^{+2}(aq)$		For the equilibrium: $Y^{+3}(aq) + F^-(aq) \rightleftarrows YF^{+2}(aq)$, [499] meas. K. For the reaction: $Y^{+3}(aq) + HF(aq) \rightleftarrows YF^{+2}(aq) + H^+(aq)$, [499] meas. K and calc. $\Delta H = -0.93 \pm 0.55$. See $YF_2^+(aq)$.
$YF_2^+(aq)$		For the equilibria: 1) $YF^{+2}(aq) + F^-(aq) \rightleftarrows YF_2^+(aq)$; 2) $YF^{+2}(aq) + HF(aq) \rightleftarrows YF_2^+(aq) + H^+(aq)$, [499] gives K. See $YF_3(aq)$.
$YF_3(aq)$		For the equilibria: $YF_2^+(aq) + F^-(aq) \rightleftarrows YF_3(aq)$, and $YF_2^+(aq) + HF(aq) \rightleftarrows YF_3(aq) + H^+(aq)$, [499] gives K.
$ZnF^+(aq)$		For the equilibrium: $Zn^{+2}(aq) + F^-(aq) \rightleftarrows ZnF^+(aq)$, [16] lists $\Delta H = 1.5$; log K (5 values). For $Zn^{+2}(aq) + HF(aq) \rightleftarrows ZnF^+(aq) + H^+(aq)$, [490] meas. K and calc. $\Delta H = -2.3 \pm 2.4$.
$ZnF_2(aq)$	-187.9 [9]	
$ZrF^{+3}(aq)$		For the equilibria: $Zr^{+4}(aq) + F^-(aq) \rightleftarrows ZrF^{+3}(aq)$, and $Zr^{+4}(aq) + HF(aq) \rightleftarrows ZrF^{+3}(aq) + H^+(aq)$, [16] lists log K (1 value each). See $ZrF_2^{+2}(aq)$.
$ZrF_2^{+2}(aq)$		For the equilibrium: $ZrF^{+3}(aq) + HF(aq) \rightleftarrows ZrF_2^{+2}(aq) + H^+(aq)$, [16] lists log K (1 value). See $ZrF_3^+(aq)$.
$ZrF_3^+(aq)$		For the equilibrium: $ZrF_2^{+2}(aq) + HF(aq) \rightleftarrows ZrF_3^+(aq) + H^+(aq)$, [16] lists log K (1 value).

TABLE 7. TERNARY AQUEOUS SPECIES

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$AgF_2H(aq)$ ($AgHF_2$)	-130.8 [9]	
$AlF_6H_3(aq)$ (H_3AlF_6)	-597.2 [9]	
$AlF_6K_3(aq)$ (K_3AlF_6)	-775.5 [9]	
$AlF_6Na_3(aq)$ (Na_3AlF_6)		[256] meas. ΔH soln. of $Na_3AlF_6(c)$.
$BCsF_4(aq)$ ($CsBF_4$)		[349] calc. ΔH soln. of $CsBF_4(c)$ from solubility.
$BF_4H(aq)$ (HBF_4)	-365 [9]	[604] meas. K hydr.
$BF_4K(aq)$ (KBF_4)		[349] calc. ΔH soln. of $KBF_4(c)$. [351] est. ΔH soln. of $KBF_4(c)$. [350] meas. ΔHf^o_{298} of $KBF_4(c)$ from solution calorimetry.
$ClFPb(aq)$ ($PbFCl$)		[390] meas. K sp and ΔF soln. for $PbClF(c)$. [282] meas. ΔH soln. of $PbClF(c)$.
$CrF_2O_2(aq)$ (CrO_2F_2)		[509] meas. K for the equilibrium: $CrO_2F_2(aq) + H_2O(\ell) \rightleftarrows CrO_3(aq) + 2HF(aq)$.
$CsF_2H(aq)$ ($CsHF_2$)	-212.8 [9]	
$FH_4N(aq)$ (NH_4F)	-110.40 [9] (var)	[399] calc. ΔF soln. of $NH_4F(c)$.
$FOTi^+(aq)$ ($TiOF^+$)		[16] lists log K (1 value) for the equilibrium: $TiO^{+2}(aq) + F^-(aq) \rightleftarrows TiOF^+(aq)$. See $F_2OTi(aq)$, $F_3OTi^-(aq)$, $F_4OTi^{-2}(aq)$.
$FOV^+(aq)$ (VOF^+)		[16] lists log K (1 value) for the equilibrium: $VO^{+2}(aq) + F^-(aq) \rightleftarrows VOF^+(aq)$.
$FO_2U^+(aq)$ (UO_2F^+)		[16] lists log K (4 values) for the equilibrium: $UO_2^{+2}(aq) + F^-(aq) \rightleftarrows UO_2F^+(aq)$. For the equilibrium: $UO_2^{+2}(aq) + HF(aq) \rightleftarrows UO_2F^+(aq) + H^+(aq)$, [16] lists ΔH = -5.4 and log K (9 values). See $UO_2F_2(aq)$.
$FO_3S^-(aq)$		[462] reports ΔH hydr. of SO_3F^- gas ion.
$F_2HK(aq, 200\ H_2O)$ (KHF_2)	-213.4 [9] (var)	[605] reports solubility of KF in HF(aq).
$F_2HLi(aq, 400\ H_2O)$ ($LiHF_2$)	-220.4 [9]	[605] reports solubility of LiF in HF(aq).
$F_2HNa(aq)$ ($NaHF_2$)	-211.2 [9]	[605] meas. solubility of NaF in HF(aq).
$F_2HRb(aq)$ ($RbHF_2$)		[9] est. ΔHf^o_{298} = -212.5.
$F_2HTl(aq)$ ($TlHF_2$)	-152.5 [9]	

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$F_2H_5N(aq)$ (NH_4HF_2)		[410] calorimetrically meas. ΔH soln. of $NH_4HF_2(c)$, ΔH diln. of NH_4HF_2, and ΔH neutralization of NH_3 and HF (1:2).
$F_2MoO_2(aq)$ (MoO_2F_2)		[509] meas. K for the equilibrium: $MoF_6(aq) + 2H_2O(\ell) \rightleftarrows MoO_2F_2(aq) + 4HF(aq)$.
$F_2OTi(aq)$ ($TiOF_2$)		[618] meas. K for the equilibrium: $TiOF^+(aq) + F^-(aq) \rightleftarrows TiOF_2(aq)$.
$F_2O_2U(aq)$ (UO_2F_2)		For the equilibrium: $UO_2F^+(aq) + F^-(aq) \rightleftarrows UO_2F_2(aq)$, [16] lists log K (3 values). [509] meas. K for the equilibrium: $UF_6(aq) + 2H_2O(\ell) \rightleftarrows UO_2F_2(aq) + 4HF(aq)$. See $F_3O_2U^-(aq)$, $F_4O_4U_2(aq)$.
$F_2O_2W(aq)$ (WO_2F_2)		[509] meas. K for the equilibrium: $WF_6(aq) + 2H_2O(\ell) \rightleftarrows WO_2F_2(aq) + 4HF(aq)$.
$F_3OTi^-(aq)$ ($TiOF_3^-$)		[618] meas. K for the equilibrium: $TiOF^+(aq) + 2F^-(aq) \rightleftarrows TiOF_3^-(aq)$.
$F_3OV(aq)$ (VOF_3)		[509] meas. K for the equilibrium: $2VOF_3(aq) + 3H_2O(\ell) \rightleftarrows V_2O_5(aq) + 6HF(aq)$.
$F_3O_2U^-(aq)$ ($UO_2F_3^-$)		[16] lists log K (2 values) for the equilibrium: $UO_2F_2(aq) + F^-(aq) \rightleftarrows UO_2F_3^-(aq)$. See $F_4O_2U^{-2}(aq)$.
$F_4OTi^{-2}(aq)$ ($TiOF_4^{-2}$)		[618] meas. K for the equilibrium: $TiOF^+(aq) + 3F^-(aq) \rightleftarrows TiOF_4^{-2}(aq)$.
$F_4O_2U^{-2}(aq)$		[16] lists log K (2 values and 1 value, resp.) for the equilibria 1) $UO_2F_3^-(aq) + F^- \rightleftarrows UO_2F_4^{-2}(aq)$; 2) $UO_2^{+2}(aq) + 4F^-(aq) \rightleftarrows UO_2F_4^{-2}(aq)$.
$F_4O_4U_2(aq)$ ($(UO_2F_2)_2$)		[500] meas. K for the equilibrium: $2UO_2F_2(aq) \rightleftarrows (UO_2F_2)_2(aq)$. [501] reviews this reaction and indicates a small positive ΔH dimerization. [16] lists log K (3 values) for this reaction.
$F_6FeH^{-2}(aq)$ ($HFeF_6^{-2}$)		See $FeF_6^{-3}(aq)$.
$F_6H_2Si(aq)$ (H_2SiF_6)	-557.2 [9] -556.2 [310] -554.6 [502]	[310] meas. ΔH soln. of SiO_2 in (HF-HCl)(aq). [502] meas. ΔH soln. of SiO_2 in HF(aq). See [311].
$F_6H_2Sn(aq)$ (H_2SnF_6)	-473.1 [9]	
$F_6H_2Ti(aq)$ (H_2TiF_6)	-555.1 [9]	
$F_6H_3Sb(aq)$ (H_3SbF_6)	-444.3 [9]	
$F_6Li_2Si(aq, 1500H_2O)$ (Li_2SiF_6)		[9] est. ΔHf^o_{298} = -691.2 in $1500H_2O$.
$F_6Na_2Si(aq, 600H_2O)$ (Na_2SiF_6)	-671.2 [9]	

TABLE 8. QUATERNARY AND HIGHER AQUEOUS SPECIES

Species	ΔHf^o_{298} (kcal/mole)	Remarks
$BF_2H_2O_2^-$(aq) ($BF_2(OH)_2^-$)		See BF_3HO^-(aq).
BF_3HO^-(aq) (BF_3OH^-)	-363.1 [29]	[503] meas. K for the equilibrium: $BF_2(OH)_2^-$(aq) + HF(aq) $\rightleftarrows$ $H_2O(\ell)$ + BF_3OH^-(aq). [16] lists log K (1 value) for this equilibrium. For the equilibrium: BF_3OH^-(aq) + HF(aq) $\rightleftarrows$ $H_2O(\ell)$ + BF_4^-(aq), [16] lists ΔH = -3.23 and log K (8 values). For the reaction: $3BF_3OH^-$(aq) $\rightleftarrows$ $2BF_4^-$(aq) + H_3BO_3(aq) + F^-(aq), [504] calc. ΔH = 4.2. For the reaction: $2BF_3OH^-$(aq) $\rightleftarrows$ $BF_2(OH)_2^-$(aq) + BF_4^-(aq), [504] calc. ΔH < 1.4.
$CrF_3H_{12}O_6$(aq) ($[Cr(6H_2O)]F_3$)	-704.3 [9]	
$CrF_6H_{15}O_6$(aq) ($H_3[Cr(6H_2O)]F_6$)	-931.9 [9]	
FHO_3S(aq) (HSO_3F)	-190.2 [461]	[461] meas. ΔH hydr. of $HSO_3F(\ell)$. [621] meas. heat of ionization.
FKO_3S(aq) (KSO_3F)		[462] meas. ΔH soln. of KSO_3F(c).
$FNaO_3S$(aq) ($NaSO_3F$)	-204.6 [461]	[461] reports ΔHf from the heat of neutralization. See also [621].
FNO_3Th^{+2}(aq) ($ThFNO_3^{+2}$)		[16] lists log K (1 value) for the equilibrium: Th^{+4}(aq) + HF(aq) + NO_3^-(aq) $\rightleftarrows$ $ThFNO_3^{+2}$(aq) + H^+(aq).
$F_2NO_3Th^+$(aq) ($ThF_2NO_3^+$)		[16] lists log K (1 value) for the equilibrium: Th^{+4}(aq) + 2HF(aq) + NO_3^-(aq) $\rightleftarrows$ $ThF_2NO_3^+$(aq) + $2H^+$(aq).
$F_4H_8O_4Th$(aq) ($ThF_4(H_2O)_4$)		[16] lists log K for the equilibrium: $ThF_4(H_2O)_4$(c) + $2H^+$(aq) $\rightleftarrows$ ThF_2^{+2}(aq) + 2HF(aq) + $4H_2O(\ell)$.
F_6HNaSi(aq, 400H_2O) ($NaHSiF_6$)	-614.1 [9]	
$F_6H_4O_2U$(aq) ($UO_2F_2 \cdot 4HF$)		[419, 573] list ΔH for reaction of UF_6(g) with H_2O and UO_2F_2(c) with HF(aq), both forming $UO_2F_2 \cdot 4HF$(aq).
$F_6H_8N_2Si$(aq) ($(NH_4)_2SiF_6$)	-622.0 [9]	
$Hf(OH,F,\frac{1}{2}O,Cl)_4$(aq)		See $Hf(OH,F,\frac{1}{2}O,Cl)_4F^-$(aq).
$Hf(OH,F,\frac{1}{2}O,Cl)_4F^-$(aq)		[16] lists log K for the equilibrium: $Hf(OH,F,\frac{1}{2}O,Cl)_4$(aq) + HF(aq) $\rightleftarrows$ $Hf(OH,F,\frac{1}{2}O,Cl)_4F^-$(aq) + H^+(aq).
$Hf(OH,F,\frac{1}{2}O,Cl)_4F_2^{-2}$(aq)		[16] lists log K for the equilibrium: $Hf(OH,F,\frac{1}{2}O,Cl)_4F^-$(aq) + HF(aq) $\rightleftarrows$ $Hf(OH,F,\frac{1}{2}O,Cl)_4F_2^{-2}$(aq) + H^+(aq).
BF_3HKO(aq) (KBF_3OH)	-423.1 [29]	[475] meas. ΔH soln. of KBF_3OH(c).

8. Bibliography.

1. Simons, J. H., Editor, Fluorine Chemistry (Academic Press, Inc., New York, Volume I, 1950, Volume II, 1954).

2. Ryss, I. G., Khimiya ftora i ego neorganicheskikh soedinenii, (Gosudarstvennoe Nauchno-Tekhnicheskoe Izdatel'stvo Khimicheskoi Literatury, Moskva, 1956).
   Available in English as:
   The Chemistry of Fluorine and its Inorganic Compounds (Translated from a publication of the State Publishing House for Scientific, Technical and Chemical Literature, Moscow 1956, Haimson, F., translator).
   AEC-tr-3927 (Parts 1 and 2)
   (Office of Technical Services, Department of Commerce, Washington, D. C., 1960).

3. Slesser, C., and Schram, S. R., Editors, Preparation, Properties, and Technology of Fluorine and Organic Fluoro Compounds (McGraw-Hill Book Company, Inc., New York, 1951).

4. George, J. W., "Halides and Oxyhalides of the Elements of Groups Vb and VIb," pp. 33-107. Progress in Inorganic Chemistry, Volume II, F. A. Cotton, Editor, (Interscience Publishers, Inc., New York, 1960).

5. Peacock, R. D., "Some Fluorine Compounds of the Transition Metals," pp. 193-249. Progress in Inorganic Chemistry, Volume II, F. A. Cotton, Editor, (Interscience Publishers, Inc., New York, 1960).

6. Stacey, M., Tatlow, J. C., Sharpe, A. G., Advances in Fluorine Chemistry, Volume I (Academic Press, Inc., New York, 1960).

7. Lovelace, A. M., Rausch, D. A., and Postelnek, W., Aliphatic Fluorine Compounds (Reinhold Publishing Corporation, New York, 1958).

8. Gmelins Handbuch der Anorganischen Chemie, Achte Auflage. Fluor, System-Nummer 5 (Verlag Chemie, GMBH, Weinheim, 1959).

9. Rossini, F. D., Wagman, D. D., Evans, W. H., Levine, S., and Jaffe, I., Selected Values of Chemical Thermodynamic Properties, NBS Circular 500 (U.S. Government Printing Office, Washington, 25, D. C. 1952).

10. Bichowsky, F. R., and Rossini, F. D., The Thermochemistry of the Chemical Substances (Reinhold Publishing Corp., New York, 1936).

11. Herzberg, G., Molecular Spectra and Molecular Structure; I. Spectra of Diatomic Molecules, 2nd Ed. (D. Van Nostrand Co., Inc., New York, 1950).

12. Brewer, L., Bromley, L. A., Gilles, P. W., and Lofgren, N., "The Thermodynamic Properties of the Halides," Paper 6, Chemistry and Metallurgy of Miscellaneous Materials: Thermodynamics, L. L. Quill, Editor, (McGraw-Hill Book Company, Inc., New York, 1950).

13. Brewer, L., "The Fusion and Vaporization Data of the Halides," Paper 7, Chemistry and Metallurgy of Miscellaneous Materials: Thermodynamics, L. L. Quill, Editor, (McGraw-Hill Book Company, Inc., New York, 1950).

14. Gaydon, A. G., Dissociation Energies, 2nd Ed. (Chapman and Hall Ltd., London, 1953).

15. Kubaschewski, A., and Evans, E. L. L., Metallurgical Thermochemistry, 3rd Ed. (John Wiley and Sons, Inc., New York, 1958).

16. Bjerrum, J., Schwarzenbach, G., and Sillen, L. G., Stability Constants, Part II. Inorganic Ligands (The Chemical Society, London, 1958).

17. Lewis, G. N., Randall, M., Pitzer, K. S., and Brewer, L., Thermodynamics, 2nd Ed. (McGraw-Hill Book Co., 1961).

18. Cottrell, T. L., The Strengths of Chemical Bonds, 2nd Ed. (Butterworths Scientific Publications, London, 1958).

19. Brewer, L., and Brackett, E., Chem. Revs. 61, 425-32 (1961).

20. Glassner, A., U. S. Atomic Energy Comm. ANL-5750 (1957).

21. Sinke, G. C., "Thermodynamic Properties of Combustion Products," Report No. AR-IS-59, April 1, 1959 (ASTIA Document AD 214587).

22. Gordon, J. S., "Thermodynamics of High-Temperature Gas Mixtures and Application to Combustion Problems," WADC Technical Report 57-33, January, 1957 (ASTIA Document AD 110735).

23. Mickle, E. A., "Collected Thermodynamic Properties of Eighty-Eight Possible Products of Reaction," December 10, 1957 (ASTIA Document AD 153644).

24. Hildenbrand, D. L., "Study of Metal Additives for Solid Propellants - Tables of Thermodynamic Data for Performance Calculations," Publication No. C-623, September 30, 1959 (ASTIA Document 233467).

25. Gordon, J. S., "Thermodynamic Data for Combustion Products," Report RMD 210-E3, January, 1960 (ASTIA Document AD 231995).

26. Henderson, C. B., and Scheffee, R. S., Atlantic Research Corp., Alexandria, Va., unpublished communication, January, 1960.

27. Stull, D. R., Dow Chemical Co., Unpublished communication, December 31, 1960.

28. Stull, D. R., Dow Chemical Co., Unpublished communication, March 31, 1961.

29. Evans, W. H., Wagman, D. D., and Prosen, E. J., NBS, unpublished communication, August 31, 1956.

30. Evans, W. H., Wagman, D. D., and Prosen, E. J., NBS, unpublished communication, December 15, 1958.

31. Evans, W. H., NBS, unpublished communication, January 1, 1961.

32. Douglas, T. B., Victor, A. C., and Beaudoin, A. R., NBS, unpublished communication, July 1, 1959.

33. Armstrong, G. T., Woolley, H. W., Wagman, D. D., Evans, W. H., Douglas, T. B., Lide, D. R., and Krieger, L. A., NBS, unpublished communication, January 1, 1959.

34. Armstrong, G. T., Woolley, H. W., Evans, W. H., and Krieger, L. A., NBS, unpublished communication, July 1, 1959.

35. Armstrong, G. T., and Krieger, L. A., NBS, unpublished communication, January 1, 1960.

36. Armstrong, G. T., and Krieger, L. A., NBS, unpublished communication, July 1, 1960.

37. Armstrong, G. T., Woolley, H. W., Evans, W. H., and Krieger, L. A., NBS, unpublished communication, July 1, 1960.

38. Kapustinskii, A. F., Izvest. Akad. Nauk S.S.S.R., Otdel. Khim. Nauk 1948, 563-580.

39. Gross, P., Intern. Symposium Fluorine Chemistry, Birmingham, July, 1959.

40. Gross, P., Hayman, C., Levi, D. L., and Stuart, M. C., Fullmer Research Inst. Report R 146/4/23, Nov., 1960.

41. Greenberg, E., Settle, J. L., Feder, H. M., and Hubbard, W. N., Am. Chem. Soc., 138th National Meeting, New York, September 11-16, 1960.

42. Wise, S. S., Feder, H. M., Hubbard, W. N., and Margrave, J. L., Am. Chem. Soc., 139th National Meeting, St. Louis, March 21-30, 1961.

43. Hubbard, W. N., Bull. Chem. Thermodynamics No. 4, 3, (1961).

44. Skinner, H. A., Ed., Experimental Thermochemistry, Volume II (Interscience Publishers, Inc., London, 1961) (In preparation).

45. Armstrong, G. T., and Domalski, E. S., NBS, unpublished work.

46. Simmons, J., Unpublished data, Atlantic Research Corp., April 11, 1961.

47. Armstrong, G. T., Marantz, S., and Coyle, C. F., J. Am. Chem. Soc. 81, 3798 (1959).

48. Armstrong, G. T., and Jessup, R. S., J. Research Natl. Bur. Standards 64A, 49-59 (1960).

49. Scott, D. W., Good, W. D., and Waddington, G., J. Am. Chem. Soc. 77, 245-6 (1955).

50. Good, W. D., Scott, D. W., and Waddington, G., J. Phys. Chem. 60, 1080 (1956).

51. Wartenberg, H.V., and Schutza, H., Z. anorg. u. allgem. Chem. 206, 65-72 (1932).

52. Jessup, R. S., McCoskey, R. E., and Nelson, R. A., J. Am. Chem. Soc. 77, 244-5 (1955).

53. Neugebauer, C. A., and Margrave, J. L., J. Am. Chem. Soc. 79, 1338-40 (1957).

54. Wicke, E., Z. Elektrochem. 53, 212-216 (1949).

55. Caunt, A. D., and Barrow, R. F., Nature 164, 753-4 (1949).

56. Caunt, A. D., and Barrow, R. F., Trans. Faraday Soc. 46, 154-6 (1950).

57. Doescher, R. N., J. Chem. Phys. 19, 1070-1 (1951).

58. Franck, E. U., and Wicke, E., Z. Elektrochem. 55, 643-7 (1951).

59. Wicke, E., J. Phys. Chem. 56, 358-60 (1952).

60. Doescher, R. N., J. Chem. Phys. 20, 330-4 (1952).

61. Wise, H., J. Chem. Phys. 20, 927 (1952).

62. Wicke, E., and Friz, H., Z. Elektrochem. 57, 9-16 (1953).

63. Gilles, P. W., and Margrave, J. L., J. Chem. Phys. 21, 381-2 (1953).

64. Barrow, R. F., and Caunt, A. D., Proc. Roy. Soc. (London) A219, 120-40 (1953).

65. Wise, H., J. Phys. Chem. 58, 389-91 (1954).

66. Wray, K. L., Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 13,194, 149 pp.; Dissertation Abstr. 15, 1328 (1955).

67. Wray, K. L., and Hornig, D. F., J. Chem. Phys. 24, 1271-2 (1956).

68. Margrave, J. L., Bull. Chem. Thermodynamics 1, 7 (1958).

69. Margrave, J. L., Private communication, March, 1958.

70. Margrave, J. L., Ann. N. Y. Acad. Sci. 67, 463-76 (1957).

71. Icskowski, E. P., and Margrave, J. L., J. Chem. Phys. 30, 403-5 (1959).

72. Brown, M. G., Trans. Faraday Soc. 55, 9-13 (1959).

73. Milne, T. A., and Gilles, P. W., J. Am. Chem. Soc. 81, 6115-20 (1959).

74. Rowlinson, H. C., and Barrow, R. F., Proc. Phys. Soc. (London) 66A, 437-46 (1953).

75. Potter, R. L., J. Chem. Phys. 17, 957-9 (1949).

76. Schumacher, H.J., Anales asoc. quim. argentina 38, 113-16 (1950).

77. Evans, M. G., Warhurst, E., and Whittle, E., J. Chem. Soc. 1950, 1524-34.

78. Butkov, K. V., and Rozenbaum, R. B., Zhur. Fiz. Khim. 24, 706-13 (1950).

79. Szwarc, M., Chem. Revs. 47, 75-173 (1950).

80. Glockler, G., J. chim. phys. 46, 103-5 (1949).

81. Nathans, M. W., J. Chem. Phys. 18, 1122 (1950).

82. Johnston, R. H., J. Chem. Phys. 19, 1391-3 (1951).

83. Bernstein, R. B., J. Chem. Phys. 19, 1612 (1951).

84. Cole, L. C., Farber, M., and Elverum, G. W., Jr., J. Chem. Phys. 20, 586-90 (1952).

85. Goldfinger, P., Ind. chim. belg. 16, 659-65 (1951).

86. Sanderson, R. T., J. Chem. Phys. 22, 345-6 (1954).

87. Dinger, H., Arkiv. Fysik 8, 527-50 (1954).

88. Margrave, J. L., J. Chem. Phys. 24, 475-6 (1956).

89. Potter, R. L., J. Chem. Phys. 26, 394 (1957).

90. Kapustinskii, A. F., Trudy Moskov. Khim. - Technol. Inst. im. D. I. Mendeleeva 1956, No. 22, 17-20.

91. Hijikata, K., Bull. Am. Phys. Soc. 2, Sec. 2, 99 (1957).

92. Rees, A. L. G., J. Chem. Phys. 26, 1567 (1957).

93. Himpan, J., Z. Naturforsch. 13a, 239 (1958).

94. Jortner, J., Stein, G., and Treiner, A., J. Chem. Phys. 30, 1110-11 (1959).

95. Trotman-Dickenson, A. F., J. Chem. Soc. 1959, 3088-9.

96. Eve, J., Proc. Roy. Soc. (London) A 246, 582-9 (1958).

97. Kobe, K. A., and Long, E. G., Petrol. Refiner 29, No. 2, 124-8 (1950).

98. Wicke, E., Angew. Chem. A 60, 65 (1948).

99. Eucken, A. and Wicke, E., Naturwissenschaften 37, 233-4 (1950).

100. Ryss, I. G., Uspekhi Khim. 21, 857-67 (1952).

101. Wicke, E., and Franck, E. U., Angew. Chem. 66, 701-10 (1954).

102. Evans, W. H., Munson, T. R., and Wagman, D. D., J. Research Natl. Bur. Standards 55, 147-64 (1955)(Research Paper No. 2614).

103. Stamper, J. G., and Barrow, R. F., Trans. Faraday Soc. 54, 1592-4 (1958).

104. Szwarc, M., Proc. Roy. Soc. (London) A207, 5-13 (1951).

105. Hu, J. H., White, D., and Johnston, H. L., J. Am. Chem. Soc. 75, 1232-6 (1953).

106. Cunningham, B. B., Proc. Intern. Conf. Peaceful Uses Atomic Energy, Geneva, 1955 7, 225-30 (Pub. 1956).

107. Owe Berg, T. G., Acta Chem. Scand. 7, 1313-22(1953).

108. R. Smoluchowski, J.E. Mayer, and W.A. Weyl, Eds., Phase Transformations in Solids, (John Wiley and Sons, Inc., New York, 1951). pp 238-56.

109. Irmann, F., Helv. chim. Acta 33, 1449 (1950).

110. Barrow, R. F., Trans. Faraday Soc. 56, 952-8 (1960).

111. Witt, W. P., and Barrow, R. F., Trans. Faraday Soc. 55, 730-5 (1959).

112. Barrow, R. F., Johns, J. W. C., and Smith, F. J., Trans. Faraday Soc. 52, 913-16 (1956).

113. Buimakov, A. Yu., Trudy Leningrad. Politekh. Inst. im. M. I. Kalinina, Elektromet. Tsvetnykh. Metal. 1957, No. 188, 156-61.

114. Semenkovich, S. A., Zhur. Priklad. Khim. 33, 552-9 (1960).

115. Gross, P., Hayman, C., and Levi, D. L., Trans. Faraday Soc. 50, 477-80 (1954).

116. Gross, P., Hayman, C., and Levi, D. L., Intern. Symp. on the Phys. Chem. in Process Metallurgy, Pittsburgh, Pa., April, 1959.

117. Gross, P., Hayman, C., and Levi, D. L., Trans. Faraday Soc. 53, 1601 (1957).

118. Gross, P., Bull. Chem. Thermodynamics No. 2, 21 (1959).

119. Kolesov, V. P., Martinov, A. M., and Skuratov, S. M., Bull. Chem. Thermodynamics No. 4, 26 (1961).

120. Evseev, A. M., Pozharskaya, G. V., Nesmeyanov, A. N., and Gerasimov, Ya. I., Zhur. Neorg. Khim. 4, 2196-7 (1959).

121. Vetyukov, M. M., Blyushtein, M. L., and Poddymov, V. P., Izvest. Vysshikh Ucheb. Zavedenii, Tsvetnaya Met. 2, No. 6, 126-33 (1959).

122. Hildenbrand, D. L., and Theard, L. P., Ford Motor Co., Newport Beach, Calif., unpublished communication, June 15, 1961.

123. Witt, W. P., Thesis, Oxford Univ., 1959.

124. O'Brien, C. J., and Kelley, K. K., J. Am. Chem. Soc. 79, 5616-18 (1957).

125. Porter, R. F., and Zeller, E. E., J. Chem. Phys. 33, 858 (1960).

126. Carniglia, S. C., and Cunningham, B. B., Rev. Sci. Instr. 26, 485-8 (1955).

127. Carniglia, S. C., U. S. Atomic Energy Comm., UCRL 2389, 4-76 (1953).

128. Carniglia, S. C., and Cunningham, B. B., J. Am. Chem. Soc. 77, 1451-3 (1955).

129. Kolditz, L., Z. anorg. u. allgem. Chem. 289, 128-40 (1957).

130. Waddington, T. C., Trans. Faraday Soc. 55, 1531-5 (1959).

131. Woolf, A. A., J. Chem. Soc. 1954, 4694-5.

132. Skinner, H. A., and Smith, N. B., Trans. Faraday Soc. 51, 19 (1955).

133. Margrave, J. L., Private Comm., April 10, 1961.

134. Mackor, E. L., Hofstra, A., and van der Waals, J., Bull. Chem. Thermodynamics No. 1, 19 (1958).

135. Kostryukov, V. N., Samorukov, O. P., and Strelkov, P. G., Zhur. Fiz. Khim. 32, 1354-61 (1958).

136. Gunn, S. R., and Green, L. M., J. Phys. Chem. 65, 178 (1961).

137. Finch, A., and Schlesinger, H. I., J. Am. Chem. Soc. 80, 3573-4 (1958).

138. Kapustinski, A. F., and Golutvin, Y. M., Izvest. Akad. Nauk. S.S.S.R., Otdel. Khim. Nauk 1951, 3-12.

139. Bukhalova, G. A., and Bergman, A. G., Zhur. Obshchei Khim. 22, 23-31 (1952).

140. Petit, G., and Cremieu, A., Compt. rend. 243, 360-3 (1956).

141. Tatenskii, V. M., Tunitskii, L. N., and Novikov, M. M., Optika i Spektroskopia 5, 520-9 (1958).

142. Kolesov, V. P., Popov, M. M., and Skuratov, S. M., Zhur. Neorg. Khim. 4, 1233-6 (1959); J. Inorg. Chem. (U. S. S. R.) 4, 557 (1959)(English translation).

143. Novoselova, A. V., Simanov, Yu. P., and Yarembash, E. I., Zhur. Fiz. Khim. 26, 1244-58 (1952).

144. Novoselova, A. V., Muratov, F. Sh., Reshetnikova, L. P., and Gordeev, I. V., Vestnik Moskov. Univ., Ser. Mat., Mekhan., Astron., Fiz.i Khim. 13, No. 6, 181-90 (1958).

145. Khandamirova, N. E., Evseev, A. M., Pozharskaya, G. V., Borisov, E. A., Nesmeyanov, A. N., and Gerasimov, Ya. I., Zhur. Neorg. Khim. 4, 2192-5 (1959).

146. Sense, K. A., Snyder, M. J., and Clegg, I. W., J. Phys. Chem. 58, 223-4 (1954).

147. Sense, K. A., Stone, R. W., and Filbert, R. B., Jr., U. S. Atomic Energy Comm. BMI-1186, 30 pp. (1957).

148. Berger, R., and Gaumann, T., Helv. Chim. Acta 44, 1084-8 (1961).

149. Sense, K. A., and Stone, R. W., J. Phys. Chem. 62, 453-7 (1958).

150. Fischer, J., and Rudzitis, E., J. Am. Chem. Soc. 81, 6375-7 (1959).

151. Steunenberg, R. K., Vogel, R. C., and Fischer, J., J. Am. Chem. Soc. 79, 1320-3 (1957).

152. Broderson, P. H., and Schumacher, H. J., Anales asoc. quim. Argentina 38, 52-60 (1950).

153. Broderson, P. H., and Sicre, J. E., Z. Physik 141, 515-24 (1955).

154. Slutsky, L., and Bauer, S. H., J. Am. Chem. Soc. 76, 270-6 (1954).

155. Greenwood, N. N., Revs. Pure and Appl. Chem. (Australia) 1, 84-120 (1951).

156. Durie, R. A., and Gaydon, A. G., J. Phys. Chem. 56, 316-19 (1952).

157. Durie, R. A., Proc. Roy. Soc. (London) A207, 388-95 (1951).

158. Cole, L. G., and Elverum, G. W., Jr., J. Chem. Phys. 20, 1543-51 (1952).

159. Oliver, G. D., and Grisard, J. W., J. Am. Chem. Soc. 74, 2705-7 (1952).

160. Stephenson, C. V., Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 3978, 93 pp.; Dissertation Abstr. 12, 667-8 (1952).

161. Liimatainen, R. C., U. S. Atomic Energy Comm. ANL-6003, 118 pp. (1959).

162. Rogers, M. T., and Spiers, J. L., J. Phys. Chem. 60, 1462-3 (1956).

163. Stein, L., J. Am. Chem. Soc. 81, 1273-76 (1959).

164. Rogers, M. T., Spiers, J. L., and Panish, M. B., J. Am. Chem. Soc. 78, 3288-9 (1956).

165. Margrave, J. L., J. Chem. Phys. 31, 1432 (1959).

166. Farmer, J. B., Henderson, I. H. S., Lossing, F. P., and Marsden, D. G. H., J. Chem. Phys. 24, 348-52 (1956).

167. Rabinovitch, B. S., and Reed, J. F., J. Chem. Phys. 22, 2092-3 (1954).

168. Pritchard, G. O., Pritchard, H. O., Schiff, H. I., and Trotman-Dickenson, A. F., Chem. & Ind. (London) 1955, 896.

169. Reed, J. F., and Rabinovitch, B. S., J. Phys. Chem. 61, 598-605 (1957).

170. Wartenberg, H. V., and Riteris, G., Z. anorg. Chem. 258, 356-60 (1949).

171. Wartenberg, H. V., and Schiefer, J., Z. anorg. u. allgem. Chem. 278, 326-32 (1955).

172. Duus, H. C., Ind. Eng. Chem. 47, 1445-9 (1955).

173. Neugebauer, C. A., and Margrave, J. L., J. Phys. Chem. 60, 1318-21 (1956).

174. Kirkbride, F. W., and Davidson, F. G., Nature 174, 79-80 (1954).

175. Vorob'ev, A. F., and Skuratov, S. M., Zhur. Neorg. Khim. 5, 1398 (1960); J. Inorg. Chem. (U.S.S.R) 5, 679 (1960) (English translation).

176. Neugebauer, C. A., Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 21224, 131 pp. Dissertation Abstr. 17, 1478-9 (1957).

177. Luft, N. W., J. Chem. Phys. 23, 973-4 (1955).

178. Koerber, G. G., and De Vries, T., J. Am. Chem. Soc. 74, 5008-11 (1952).

179. Akishin, P. A., Spiridonov, V. P., Naumov, V. A., and Rambidi, N. G., Zhur. Fiz. Khim. 30, 155-60 (1956).

180. King, E. G., and Christensen, A. U., U. S. Bur. Mines, Rept. Invest. No. 5510, 7 pp. (1959).

181. Kury, J. W., U. S. Atomic Energy Comm., UCRL-2271, 64 pp. (1953).

182. Lippincott, E. R., J. Chem. Phys. 21, 2070-1 (1953).

183. Schumacher, H. J., Schmitz, H., and Broderson, P. H., Anales asoc. quim. argentina 38, 98-112 (1950).

184. Grisard, J. W., Bernhardt, H. A., and Oliver, G. D., J. Am. Chem. Soc. 73, 5725-7 (1951).

185. Weber, A., and Ferigle, S. M., J. Chem. Phys. 20, 1497 (1952).

186. Shishkov, Yu. D., and Opalovskii, A. A., Uspekhi Khim. 29, 760-73 (1960).

187. Schmitz, H., and Schumacher, H. J., Z. Naturforsch. 2a, 358-63 (1947).

188. Jessup, R. S., Brickwedde, F. G., and Wechsler, M. T., J. Research Natl. Bur. Standards 44, 457-62 (1950). (Research Paper No. 2092).

189. Schoonmaker, R. C., and Porter, R. F., J. Chem. Phys. 30, 283-5 (1959).

190. Eisenstadt, M., Rothberg, G. M., and Kusch, P., J. Chem. Phys. 29, 797-804 (1958).

191. Pugh, A. C., and Barrow, R. F., Trans. Faraday Soc. 54, 671-8 (1958).

192. Bredig, M. A., Bronstein, H. R., and Smith, W. T., Jr., J. Am. Chem. Soc. 77, 1454-8 (1955).

193. Dworkin, A. S., and Bredig, M. A., J. Phys. Chem. 64, 269-72 (1960).

194. Diogenov, G. G., Zhur. Obshchei Khim. 23, 20-4 (1953).

195. Mishchenko, K. P., Zhur. Fiz. Khim. 26, 1736-60 (1952).

196. Milne, T. A., and Cubicciotti, D. D., Jr., J. Chem. Phys. 30, 1625-6 (1959).

197. Welti, D., and Barrow, R. F., Proc. Phys. Soc. (London) 65A, 629-39 (1952).

198. Barrow, R. F., Dodsworth, P. G., and Zeeman, P. B., Proc. Phys. Soc. (London) 70A, 34-40 (1957).

199. Akers, L. K., and Jones, E. A., Phys. Rev. 91, 236 (1953).

200. Voelz, F. L., J. Chem. Phys. 20, 1662 (1952).

201. Evans, D. F., and Richards, R. E., J. Chem. Soc. 1952, 1292-4.

202. Gaspar, R., and Tamassy-Lentei, I., Acta Phys. Acad. Sci. Hung. 9, 105-13 (1958) (in English).

203. Page, F. M., and Sugden, T. M., Nature 183, 1672 (1959).

204. Alekseev, V. Z., Zhur. Fiz. Khim. 28, 945-56 (1954).

205. Johns, J. W. C., and Barrow, R. F., Proc. Roy. Soc. (London) A 251, 504-18.(1959).

206. Franck, E. U., and Meyer, F., Z. Elektrochem. 63, 571-82 (1959).

207. Spalthoff, W., and Franck, E. U., Z. Elektrochem. 61, 993-1000 (1957).

208. Kleiss, L. M., Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 9526, 68 pp.; Dissertation Abstr. 14, 1562 (1954).

209. Jarry, R. L., and Davis, W., Jr., J. Phys. Chem. 57, 600-4 (1953).

210. Nikolaev, N. S., and Tananaev, I. V., Izvest. Sektora Fiz. Khim. Anal., Inst. Obshchei i Neorg. Khim., Akad. Nauk S.S.S.R. 20, 184-95 (1950).

211. Franck, E. U., and Spalthoff, W., Z. Elektrochem. 61, 348-57 (1957).

212. Higgins, T. L., Univ. Microfilms (Ann Arbor, Mich.), Publ. No, 21184, 98 pp.; Dissertation Abstr. 17, 1231-2 (1957).

213. Baines, A., and Davies, A., J. Appl. Chem. (London) 5, 242-4 (1955).

214. Knowles, C. H., and Langemann, R. T., Phys. Rev. 95, 306 (1954).

215. Smith, D. F., U. S. Atomic Energy Comm. K-1336 (1957).

216. Maslov, P. G., Izvest. Vysshykh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 2, No. 3, 335-9 (1959).

217. Blocher, J. M., Jr., and Hall, E. H., J. Phys. Chem. 63, 127-8 (1959).

218. Woolf, A. A., J. Chem. Soc. 1951, 231-2.

219. Rogers, M. T., Speirs, J. L., Thompson, H. B., and Panish, M. B., J. Am. Chem. Soc. 76, 4843-4 (1954).

220. Rogers, M. T., Speirs, J. L., Panish, M. B., and Thompson, H. B., J. Am. Chem. Soc. 78, 936-8 (1956).

221. Bernstein, R. B., and Katz, J. J., J. Phys. Chem. 56, 885-8 (1952).

222. Cady, G. H., and Hargreaves, G. B., J. Chem. Soc. 1961, 1563-8.

223. Smith, P., and Rao, C. N. R., Can. J. Chem. 36, 1174-80 (1958).

224. Hildenbrand, D. L., and Theard, L. P., "An Experimental Program for Obtaining the Thermodynamic Properties of Propellant Combustion Products," Quarterly technical report No. 2, Dec. 15, 1960 (ASTIA Document AD-247640).

225. Evseev, A. M., Pozharskaya, G. V., Nesmeyanov, A. N., and Gerasimov, Ya. I., Zhur. Neorg. Khim. 4, 2189-91 (1959).

226. Akishin, P. A., Gorokhov, L. N., and Sidorov, L. N., Vestnik Moskov. Univ., Ser. Mat., Mekh., Astron., Fiz. i Khim. 1959, No. 6, 194-204.

227. Porter, R. F., and Schoonmaker, R. C., J. Chem. Phys. 29, 1070-4 (1959).

228. Sense, K. A., Stone, R. W., and Filbert, R. B. , Jr., U. S. Atomic Energy Comm. BMI-1199, 35 pp. (1957).

229. Sense, K. A., and Stone, R. W., J. Phys. Chem. 62, 1411-18 (1958).

230. Scheffee, R. S., and Margrave, J. L., J. Chem. Phys. 31, 1682-3 (1959).

231. Hildenbrand, D. L., "An Experimental Program for Obtaining the Thermodynamic Properties of Propellant Combustion Products," Quarterly technical report no. 1, Sept. 15, 1960 (ASTIA Document AD-243885).

232. Gibb, T. R. P., Jr., and Winnermann, A., J. Chem. Educ. 36, 46-8 (1959).

233. Kapustinskii, A. F., and Stakhanova, M. S., Trudy Moskov. Khim.-Tekhnol. Inst. im. D. I. Mendeleeva 1956, No. 22, 21-9.

234. Haven, Y., Rec. trav. chim. 69, 1505-18 (1950).

235. Voskresenskaya, N. K., Sokolov, V. A., Banashek, E. I., and Shmidt, N. E., Izvest. Sektora Fiz. Khim. Anal., Inst. Obshchei i Neorg. Khim., Akad. Nauk S.S.S.R. 27, 233-8 (1956).

236. Douglas, T. B., and Dever, J. L., J. Am. Chem. Soc. 76, 4826-9 (1954).

237. Hildenbrand, D. L., and Theard, L. P., "An Experimental Program for Obtaining the Thermodynamic Properties of Propellant Combustion Products," Quarterly technical report no. 3, March 15, 1961 (ASTIA Document AD-253233).

238. Gunther, K. G., Glastech. Ber. 31, 9-15 (1958).

239. Ryss, I. G., and Vitukhnovskaya, B. S., Zhur. Obshchei Khim. 25, 643-7 (1955); J. Gen. Chem. (U.S.S.R.) 25, 617-20 (1955) (English translation).

240. Cady, G. H., and Hargreaves, G. B., J. Chem. Soc. 1961, 1568-74.

241. Settle, J. L., Feder, H. M., and Hubbard, W. N., J. Phys. Chem. 65, 1337 (1961).

242. Brady, A. P., Myers, O. E., and Clauss, J. K., J. Phys. Chem. 64, 588-91 (1960).

243. Herron, J. T., and Dibeler, V. H., Unpub. data, N.B.S. April 10, 1961.

244. Colburn, C. B., and Johnson, F. A., J. Chem. Phys. 33, 1869 (1960).

245. Jarry, R. L., and Miller, H. C., J. Phys. Chem. 60, 1412-13 (1956).

246. Pierce, L., and Pace, E. L., J. Chem. Phys. 23, 551-5 (1955).

247. Armstrong, G. T., and Marantz, S., Unpublished data, National Bureau of Standards.

248. Colburn, C. B., Johnson, F. A., Kennedy, A., McCallum, K., Metzger, L. C., and Parker, C. O., J. Am. Chem. Soc. 81, 6397-8 (1959).

249. Herron, J. T., and Dibeler, V. H., J. Chem. Phys. 33, 1595 (1960).

250. Armstrong, G. T., Marantz, S., and Coyle, C. F., NBS, unpublished communication, October, 1959.

251. Colburn, C. B., and Kennedy, A., J. Am. Chem. Soc. 80, 5004 (1958).

252. Miller, R. C., and Kusch, P., J. Chem. Phys. 25, 860-76 (1956).

253. Sense, K. A., Alexander, C. A., Bowman, R. E., Stone, R. W., and Filbert, R. B., Jr., J. Phys. Chem. 61, 384 (1957).

254. Sutra, G., Compt. rend. 234, 1283-4 (1952).

255. Grjotheim, K., Kgl. Norske Videnskab. Selskabs, Skrifter 2, No. 5, 1-90 (1957).

256. Coughlin, J. P., J. Am. Chem. Soc. 80, 1802-4 (1958).

257. Voskrenskaya, N. K., and Bukhalova, G. A., Zhur. Obshchei Khim. 21, 1957-61 (1951); J. Gen. Chem. U.S.S.R. 21, 2171-5 (1951) (English translation).

258. Hepler, L. G., Jolly, W. L., and Latimer, W. M., J. Am. Chem. Soc. 75, 2809-10 (1953).

259. Ivanova, L. I., Izvest. Vysshikh Ucheb. Zavedenii, Tsvetnaya Met. 9, No. 1, 67-73 (1959).

260. Junkins, J. H., Farrar, R. L., Jr., Barber, E. J., and Bernhardt, H. A., J. Am. Chem. Soc. 74, 3464-6 (1952).

261. Fairbrother, F., and Frith, W. C., J. Chem. Soc. 1951, 3051-6.

262. Farber, M., Meyer, R. T., and Margrave, J. L., J. Phys. Chem. 62, 883-4 (1958).

263. Catalano, E., and Stout, J. W., J. Chem. Phys. 23, 1284-9 (1955).

264. Hood, G. C., and Woyski, M. M., J. Am. Chem. Soc. 73, 2738-41 (1951).

265. Weinstock, B., Weaver, E. E., and Malm, J. G., J. Inorg. and Nuclear Chem. 11, 104-14 (1959).

266. Weinstock, B., and Malm, J. G., Proc. U. N. Intern. Conf. Peaceful Uses At. Energy, 2nd, Geneva, 1958 28, 125-9.

267. Malm, J. G., Weinstock, B., and Weaver, E. E. , J. Phys. Chem. 62, 1506-8 (1958).

268. Dibeler, V. H., Reese, R.M., and Franklin, J.L., J. Chem. Phys. 27, 1296-7 (1957).

269. Aoki, Y., J. Phys. Soc. Japan 10, 503-11 (1955).

270. Schnizlein, J.G., Sheard, J.L., Toole, R.C., and O'Brien, T.D., J. Phys. Chem. 56, 233-4 (1952).

271. Brewer, L., and Rosenblatt, G. M., Chem. Revs. 61, 257-63 (1961).

272. Wagman, D. D., NBS, Private communication, May 15, 1961.

273. Kirshenbaum, A. D., Grosse, A. V., and Aston, J. G., J. Am. Chem. Soc. 81, 6398-6402 (1959).

274. Grosse, A. V., Streng, A. G., and Kirshenbaum, A. D., J. Am. Chem. Soc. 83, 1004 (1961).

275. Neal, E., and Williams, L. T. D., J. Chem. Soc. 1955, 2485.

276. Dupree, W., Sinke, G. C., and Stull, D. R., Bull. Chem. Thermodynamics No. 3, 5 (1960).

277. Sellers, P. A., Fried, S., Elson, R. E., and Zackareasen, W. H., J. Am. Chem. Soc. 76, 5935-8 (1954).

278. Barrow, R. F., Cheall, H. F. K., Thomas, P. M., and Zeeman, P. B., Proc. Phys. Soc. (London) 71, 128-30 (1958).

279. Wieland, K., and Newburgh, R., Helv. Phys. Acta 22, 590-1 (1949).

280. Nesmeyanov, A. N., and Iofa, B. Z., Zhur. Neorg. Khim. 4, 486-8 (1959).

281. Blanc, M., and Petit, G., Compt. rend. 248, 1305-6 (1959).

282. Banashek, E. I., Patsukova, N. N., and Rassonskoya, I. S., Izvest. Sektora Fiz. Khim. Anal., Inst. Obshchei i Neorg. Khim., Akad. Nauk S.S.S.R. 27, 223-32 (1956).

283. Perros, T. P., Munson, T. R., and Naeser, C. R., J. Chem. Educ. 30, 402-3 (1953).

284. Weinstock, B., Claassen, H. H., and Malm, J. G., J. Am. Chem. Soc. 79, 5832 (1957).

285. Weinstock, B., Claassen, H. H., and Malm, J. G., J. Chem. Phys. 32, 181-5 (1960).

286. Phipps, T. E., Sears, G. W., Seifert, R. L., and Simpson, O. C., "The Vapor Pressure of Plutonium Halides." Paper 6.1a, The Transuranium Elements, G. T. Seaborg, J. J. Katz, and W. M. Manning, Editors, (McGraw-Hill Book Company, Inc., New York, 1949).

287. Westrum, E. F., Jr., and Wallmann, J. C., J. Am. Chem. Soc. 73, 3530-1 (1951).

288. Westrum, E. F., Jr., and Eyring, L., "The Heat of Formation of Plutonium Trifluoride." Paper 6.52, The Transuranium Elements, G. T. Seaborg, J. J. Katz, and W. M. Manning, Editors, (McGraw-Hill Book Company, Inc., New York, 1949).

289. Buyers, A. G., and Murbach, E. W., Nuclear Sci. & Eng. 2, 679-86 (1957).

290. Dawson, J. K., Elliot, R. M., Hurst, R., and Truswell, A.E., J. Chem. Soc. 1954, 558-64.

291. Fried, S., and Davidson, N. R., "Studies in the Dry Chemistry of Plutonium Fluorides." Paper 6.11, The Transuranium Elements, G. T. Seaborg, J. J. Katz, and W. M. Manning, Editors, (McGraw-Hill Book Company, Inc., New York, 1949).

292. Treverrow, L. E., Shinn, W. A., and Steunenberg, R. K., J. Phys. Chem. 65, 398 (1961).

293. Florin, A. E., Tannenbaum, I. R., and Lemons, J. F., J. Inorg. and Nuclear Chem. 2, 368-79 (1956).

294. Weinstock, B., and Malm, J. G., J. Inorg. and Nuclear Chem. 2, 380-94 (1956).

295. Mandleberg, C. J., Rae, H. K., Hurst, R., Long, G., Davies, D., and Francis, K. E., J. Inorg. and Nuclear Chem. 2, 358-67 (1956).

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

297. Malm, J. G., Selig, H., and Fried, S., J. Am. Chem. Soc. 82, 1510 (1960).

298. Vaughn, J. D., and Muetterties, E. L., J. Phys. Chem. 64, 1787 (1960).

299. Brown, F., and Robinson, P. L., J. Chem. Soc. 1955, 3147.

300. Cowen, H. C., Riding, F., and Warhurst, E., J. Chem. Soc. 1953, 4168-9.

301. Gross, P., Bull. Chem. Thermodynamics No. 3, 14 (1960).

302. Stern, G., and Brown, W. R., U. S. Atomic Energy Comm. GAT-244, 23 pp. (1959).

303. Clegg, H. P., Rowlinson, J. S., and Sutton, J. R., Trans. Faraday Soc. 51, 1327-33 (1955).

304. Otto, J., and Thomas, W., Z. physik. Chem. (Frankfurt) 23, 84-99 (1960).

305. Neudorffer, J., Compt. rend. 232, 2102-4 (1951).

306. Shair, R. C., and Schurig, W. F., Ind. Eng. Chem. 43, 1624-7 (1951).

307. Hoffman, C. J., and Jolly, W. L., J. Phys. Chem. 61, 1574-5 (1957).

308. Peacock, R. D., J. Chem. Soc. 1953, 3617-19.

309. Johns, J. W. C., and Barrow, R. F., Proc. Phys. Soc. (London) 71, 476-84 (1958).

310. Roth, W. A., and Troitzsch, H., Z. anorg. Chem. 260, 337-44 (1949).

311. Vorob'ev, A. F., Kolesov, V. P., and Skuratov, S. M., Zhur. Neorg. Khim. 5, 1402 (1960); J. Inorg. Chem. (U.S.S.R.) 5, 681 (1960) (English translation).

312. Lenfesty, F. A., Farr, T. D., and Brosheer, J. C., Ind. Eng. Chem. 44, 1448-50 (1952).

313. Ivanova, L. I., Zhur. Obshchei Khim. 21, 444-52 (1952); J. Gen. Chem. (U.S.S.R.) 21, 491-9 (1951) (English translation).

314. Schumb, W. C., and Breck, D. W., J. Am. Chem. Soc. 74, 1754-60 (1952).

315. Zhuk, N. P., Zhur. Fiz. Khim. 28, 1523-7 (1954).

316. Junkins, J. H., Bernhardt, H. A., and Barber, E. J., J. Am. Chem. Soc. 74, 5749-51 (1952).

317. English, W. D., and Dale, J. W., J. Chem. Soc. 1953, 2498-9.

318. Darnell, A. J., U. S. Atomic Energy Comm. NAA-SR-4924, 9 pp. (1960).

319. Darnell, A. J., and Keneshea, F. J., Jr., J. Phys. Chem. 62, 1143-5 (1958); U. S. Atomic Energy Comm. NAA-SR-2710, 14 pp. (1958).

320. Hall, E. H., Blocher, J. M., Jr., and Campbell, I. E., J. Electrochem. Soc. 105, 275-8 (1958).

321. Barrow, R. F., Jeffries, E. A. N. S., and Swinstead, J. M., Trans. Faraday Soc. 51, 1650-6 (1955).

322. Lange, S., and Blankenship, F. F., J. Inorg. and Nuclear Chem. 14, 26-31 (1960).

323. Agron, P. A., "Thermodynamics of Intermediate Uranium Fluorides from Measurements of Disproportionation Pressures." Paper 59, Chemistry of Uranium, J. J. Katz and E. Rabinowitch, Editors, (Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., 1958). U. S. Atomic Energy Comm. TID-5290.

324. O'Driscoll, W. G., and Tee, P. A., U. K. Atomic Energy Authority, Ind. Group Hdq. R and DB(c) TN-2, 3 pp. (1952) (Declassified 1958).

325. Fried, S., and Davidson, N. R., "The Reaction of Uranium Tetrafluoride with Dry Oxygen: A New Synthesis of Uranium Hexafluoride." Paper 67, Chemistry of Uranium, J. J. Katz and E. Rabinowitch, Editors, (Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., 1958). U. S. Atomic Energy Comm. TID-5290.

326. Dawson, J. K., Ingram, D. W., and Bircumshaw, L. L., J. Chem. Soc. 1950, 1421-2.

327. Priest, H. F., "The Vapor Pressure of Uranium Hexafluoride in Equilibrium with Uranium Pentafluoride." Paper 74, Chemistry of Uranium, J. J. Katz and E. Rabinowitch, Editors, (Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., 1958). U. S. Atomic Energy Comm. TID-5290.

328. Burns, J. H., Osborne, D. W., and Westrum, E. F., Jr., Bull. Chem. Thermodynamics No. 3, 28 (1960).

329. Popov, M. M., Kostylev, F. A., and Zubova, N. V., Zhur. Neorg. Khim. 4, 1708-9 (1959).

330. Wolf, A. S., Posey, J. C., and Rapp, K. E., U. S. Atomic Energy Comm. K-1448, 21 pp. (1960).

331. Masi, J. F., J. Chem. Phys. 17, 755-8 (1949).

332. Oliver, G. D., Milton, H. T., and Grisard, J. W., J. Am. Chem. Soc. 75, 2827-9 (1953).

333. Llewellyn, D. R., J. Chem. Soc. 1953, 28-36.

334. Gaunt, J., Trans. Faraday Soc. 49, 1122-31 (1953).

335. De Witt, R., U. S. Atomic Energy Comm. GAT-280, 164 pp. (1960).

336. Brooks, A. A., and Wood, P., U. S. Atomic Energy Comm. K - 722, Addendum 1, 7 pp. (1957).

337. Kigoshi, K., Nippon Kagaku Zasshi 72, 57-9 (1951).

338. Kigoshi, K., Bull. Chem. Soc. Japan 23, 67-8 (1950).

339. Treverrow, L. E., Fischer, J., and Steunenberg, R. K., J. Am. Chem. Soc. 79, 5167-8 (1957).

340. Clark, H. C., and Emeleus, H. J., J. Chem Soc. 1957, 2119-22.

341. Barber, E. J., and Cady, G. H., J. Phys. Chem. 60, 505-6 (1956).

342. Sense, K. A., Snyder, M. J., and Filbert, R. B., Jr., J. Phys. Chem. 58, 995-6 (1954).

343. Sense, K. A., Snyder, M. J., and Clegg, J. W., U. S. Atomic Energy Comm. AECD-3708, 18 pp. (1953).

344. Frank, W. B., and Foster, L. M., J. Phys. Chem. 64, 95-8 (1960).

345. Howard, E. H., J. Am. Chem. Soc. 76, 2041-2 (1954).

346. Gunn, S. R., and Sanborn, R. H., J. Chem. Phys. 33, 955 (1960).

347. Higgins, T. H. S., Leisegang, E. C., Raw, C. J. G., and Rossouw, A. J., J. Chem. Phys. 23, 1544 (1955).

348. Nightingale, R. E., and Crawford, B. L., Jr., J. Chem. Phys. 22, 1468 (1954).

349. Ryss, I. G., and Khordas, I. S., Zhur. Neorg. Khim. 3, 1410-15 (1958).

350. Bills, J. L., and Cotton, F. A., J. Phys. Chem. 64, 1477 (1960).

351. Altshuller, A. P., J. Am. Chem. Soc. 77, 6187-8 (1955).

352. Seel, I. F., and Detmer, O., Z. anorg. u. allgem. Chem. 301, 113-36 (1959).

353. Berkowitz, J., and Chupka, W. A., Ann. N. Y. Acad. Sci. 79, 1073-8 (1960).

354. Maslov, P. G., and Maslov, Yu. P., Khim. i Tekhnol. Topliv i Masel 3, No. 10, 50-5 (1958).

355. Badyl'kes, I. S., Congr. intern. froid, 9e, Paris, 1955, Compt. rend. trav. comm. III, 3040-50.

356. Waterman, H., Minnesota Mining and Manufacturing Co., U. S. Patent No. 2,531,372, Nov., 1950.

357. Marriott, J., and Craggs, J. D., J. Electronics 1, 405-20 (1956).

358. Szwarc, M., and Sehon, A. H., J. Chem. Phys. 18, 1685-6 (1950).

359. Sehon, A. H., and Szwarc, M., Proc. Roy. Soc. (London) A209, 118-31 (1951).

360. Sheft, I., Martin, A. F., and Katz, J. J., J. Am. Chem. Soc. 78, 1557-9 (1956).

361. Kobe, K. A., and Kobe, D. H., Petrol. Refiner 38, No. 12, 117-20 (1959).

362. Decker, C. E., Meister, A. G., and Cleveland, F. F., Phys. Rev. 81, 301 (1951).

363. Albright, L. F., Univ. Microfilms, (Ann Arbor, Mich.), Pub. No. 2372, 222 pp.; Microfilm Abstracts 11, no. 2, 235-6 (1951).

364. Albright, L. F., and Martin, J. J., Ind. Eng. Chem. 44, 188-98 (1952).

365. O'Hara, J. B., and Fahien, R. W., Ind. Eng. Chem. 43, 2924-5 (1951).

366. Kordes, E., Z. Elektrochem. 58, 424-31 (1954).

367. Glockler, G., J. Phys. Chem. 63, 828 (1959).

368. Pavlova, I. A., Kholodil'naya Tekh. Sbornik 1955, 42-58.

369. Gardy, H., Bachellier, J., and Roget, J., Compt. rend. Congr. soc. Savantes Paris et depts., Sect. sci. 78e Congr. Toulouse, 1953, 517-26.

370. Slepyan, E., Khodil'naya Tekh. 29, No. 1, 53-8 (1952).

371. Martin, J. J., Thermodynamic Transport Properties Gases, Liquids, Solids, Papers Symposium, Lafayette, Indiana (McGraw-Hill Book Co., New York, 1959), pp. 110-22.

372. Charlton, H. E., Manchester Assoc. Engrs. Trans. 1954-55, 371-408.

373. British Standards Inst., London S.W.1 Brit. Standard 1725, (1951).

374. Masi, J. F., J. Am. Chem. Soc. 75, 2276-7 (1953).

375. Vedeneev, V. I., and Purmal, A. P., Zhur. Fiz. Khim. 32, 1472-5 (1958).

376. Glew, D. N., and Moelwyn-Hughes, E. A., Discussions Faraday Soc. 1953, No. 15, 150-61.

377. Neugebauer, C. A., and Margrave, J. L., J. Phys. Chem. 62, 1043-8 (1958).

378. Ball, J. J., Mann, D. E., Thrush, B. A., Armstrong, G. T., Coyle, C. F., and Krieger, L. A., NBS, PB Rept. 151505, 69 pp. (1958); U. S. Govt. Research Reports 31, 228 (1959).

379. Hou, Yu Chun, Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 12589, 122 pp.; Dissertation Abstr. 15, 1579-80 (1955).

380. Emeleus, H. J., Bull. soc. chim. France 1953, 909-12; see also Fortschr. chem. Forsch. 2, 609-18 (1953).

381. Porter, R. F., and Cady, G. H., J. Am. Chem. Soc. 79, 5628-31 (1957).

382. Coates, G. E., Harris, J., and Sutcliffe, T., J. Chem. Soc. 1951, 2762-3.

383. Clifford, A. F., El-Shamy, H. K., Emeleus, H. J., and Hazeldine, R. N., J. Chem. Soc. 1953, 2372-5.

384. Dibeler, V. H., Reese, R. M., and Mann, D. E., J. Chem. Phys. 27, 176-9 (1957).

385. Gatti, R., Sicre, J. E., and Schumacher, H. J., Angew. Chem. 69, 638 (1957).

386. Engelbrecht, A., and Atzwanger, H., J. Inorg. and Nuclear Chem. 2, 348-57 (1956).

387. Bode, H., and Klesper, E., Z. anorg. u. allgem. Chem. 266, 275-80 (1951).

388. Koehler, J. K., and Giauque, W. F., J. Am. Chem. Soc. 80, 2659-62 (1958).

389. Jarry, R. L., J. Phys. Chem. 61, 498-9 (1957).

390. Zhuk, N. P., Zhur. Fiz. Khim. 28, 1690-7 (1954).

391. Petry, R. C., J. Am. Chem. Soc. 82, 2400-1 (1960).

392. Pemsler, J. P., and Smith, D. F., J. Chem. Phys. 22, 1834-6 (1954).

393. Smith, D. F., Proc. U. N. Intern. Conf. Peaceful Uses At. Energy, 2nd, Geneva 1958, 28, 130-8.

394. Leach, H. F., and Roberts, H. L., J. Chem. Soc. 1960, 4693-4.

395. Roberts, H. L., and Ray, N. H., J. Chem. Soc. 1960, 665-7.

396. Engelbrecht, A., and Grosse, A. V., J. Am. Chem. Soc. 74, 5262-4 (1952).

397. Sujishi, S., and Witz, S., J. Am. Chem. Soc. 79, 2447-50 (1957).

398. Luft, N. W., Ind. Chemist 31, 502-4 (1955).

399. Ladd, M. F. C., and Lee, W. H., J. Inorg. and Nuclear Chem. 13, 218-24 (1960).

400. Benjamins, E., Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 11243, 76 pp.; Dissertation Abstr. 15, 715-16 (1955).

401. Engelbrecht, A., and Grosse, A. V., J. Am. Chem. Soc. 76, 2042-5 (1954).

402. Johnson, H. S., and Bertin, H. J., Jr., J. Am. Chem. Soc. 81, 6402-4 (1959).

403. Glemser, O., and Haeseler, H., Z. anorg. u. allgem. Chem. 287, 54-60 (1956).

404. Davis, M. L., and Westrum, E. F., Jr., J. Phys. Chem. 65, 338 (1961).

405. Myers, O. E., and Brady, A. P., J. Phys. Chem. 64, 591-4 (1960).

406. Westrum, E. F., Jr., and Burney, G. A., J. Phys. Chem. 65, 344 (1961).

407. Kennedy, A., and Colburn, C. B., J. Am. Chem. Soc. 81, 2906 (1959).

408. Fischer, J., J. Am. Chem. Soc. 79, 6363-4 (1957).

409. Burney, G. A., Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 8281, 108 pp.; Dissertation Abstr. 14, 1027 (1954).

410. Schutza, H., Eucken, M., and Namsch, W., Z. anorg. u. allgem. Chem. 292, 293-7 (1957).

411. Bourlange, C., and Ziolkiewicz, S., Compt. rend. 249, 2170-1 (1959).

412. Glemser, O., Schroder, H., and Haeseler, H., Z. anorg. u. allgem. Chem. 279, 28-37 (1955).

413. Darnell, A. J., U. S. Atomic Energy Comm. NAA-SR-5045, 9 pp. (1960).

414. Reese, R. M., Dibeler, V. H., and Franklin, J. L., J. Chem. Phys. 29, 880-3 (1958).

415. Bockhoff, F. J., Petrella, R. V., and Pace, E. L., J. Chem. Phys. 32, 799-804 (1960).

416. Kenaga, E. E., J. Econ. Entomol. 50, 1-6 (1957).

417. Neudorffer, J., Compt. rend. 236, 706-7 (1953).

418. Engelbrecht, A., and Stoll, B., Z. anorg. u. allgem. Chem. 292, 20-4 (1957).

419. Popov, M. M., Kostylev, F. A., and Karpova, T. F., Zhur. Neorg. Khim. 2, 9-12 (1957).

420. Dudley, F. B., Cady, G. H., and Eggers, D. F., Jr., J. Am. Chem. Soc. 78, 290-2 (1956).

421. Dudley, F. B., and Cady, G. H., J. Am. Chem. Soc. 79, 513-14 (1957).

422. Roberts, J. E., and Cady, G. H., J. Am. Chem. Soc. 81, 4166-7 (1959).

423. Glemser, O., and Schroder, H., Z. anorg. u. allgem. Chem. 284, 97-100 (1956).

424. Parry, R. W., and Kodama, G., J. Inorg. and Nuclear Chem. 17, 125-29 (1961).

425. Ziomek, J. S., Piotrowski, E. A., and Walsh, E. N., Phys. Rev. 98, 243-4 (1955).

426. Euler, R. D., and Westrum, E. F., Jr., J. Phys. Chem. 65, 1291-6 (1961).

427. Dudley, F. B., Cady, G. H., and Eggers, D. F., Jr., J. Am. Chem. Soc. 78, 1553-7 (1956).

428. Volkova, N. M., and Gaidukov, G. V., Izvest. Sibir. Otdel. Akad. Nauk S.S.S.R. 1959, No. 6, 70-7.

429. Seel, F., and Langer, J., Z. anorg. u. allgem. Chem. 295, 315-26 (1958).

430. Haber, C. P., and Uenishi, R. K., Chem and Eng. Data Ser. 3, 323-4 (1958).

431. Holmes, W. S., Bull. Chem. Thermodynamics No. 4, 66 (1961).

432. Matveev, M. A., and Dyatlova, V. P., Zhur. Fiz. Khim. 28, 1713-19 (1954).

433. Cathers, G. I., Bennett, M. R., and Jolley, R. L., Ind. Eng. Chem. 50, 1709-10 (1958).

434. Wilkinson, G., J. Am. Chem. Soc. 73, 5501-2 (1951).

435. Walaschewski, E. G., Chem. Ber. 86, 272-7 (1953).

436. Goubeau, J., and Rohwedder, K. H., Ann. 604, 168-78 (1958).

437. Holmes, R. R., J. Inorg. and Nuclear Chem. 12, 266-75 (1960).

438. Parry, R. W., and Bissot, T. C., J. Am. Chem. Soc. 78, 1524-7 (1956).

439. Smith, F. T., and Kistiakowsky, G. B., J. Chem. Phys. 31, 621-32 (1959).

440. Brown, H. C., and Johnson, S., J. Am. Chem. Soc. 76, 1978-9 (1954).

441. Klages, F., Meuresch, H., and Steppick, W., Ann. 592, 81-119 (1955).

442. Ryss, I. G., and Bogdanova, L. P., Zhur. Neorg. Khim. 3, 1669-74 (1958).

443. Roberts, J. E., and Cady, G. H., J. Am. Chem. Soc. 82, 352-3 (1960).

444. Neilson, E. F., and White, D., J. Am. Chem. Soc. 79, 5618-21 (1957).

445. Reed, F. T., Chem. Specialties Mfrs. Assoc. Proc, 41st Ann. Meeting, Dec. (1951). pp 37-41.

446. Chinworth, H. E., and Katz, D. L., Refrig. Eng. 54, 359-63 (1947).

447. Haszeldine, R. N., and Kidd, J. M., J. Chem. Soc. 1953, 3219-25.

448. Frazer, J. W., J. Inorg. and Nuclear Chem. 16, 63-6 (1960).

449. Dininny, R. E., and Pace, E. L., J. Chem. Phys. 32, 805-9 (1960).

450. Mason, J., and Dunderdale, J., J. Chem. Soc. 1956, 754-9.

451. Jander, J., and Haszeldine, R. N., J. Chem. Soc. 1954, 912-19.

452. Banus, J., J. Chem. Soc. 1953, 3755-61.

453. Jander, J., and Haszeldine, R. N., Naturwissenschaften 40, 579 (1953).

454. Gramstad, T., and Haszeldine, R. N., J. Chem. Soc. 1956, 173-80.

455. Montel, G., Compt. rend. Congres soc. Savantes Paris et depts., Sect. sci. 78e Congr. Toulouse, 1953, 415-19.

456. Gottschal, A. J., J. S. African Chem. Inst. 11, 45-52 (1958).

457. Engelbrecht, A., Z. anorg. u. allgem. Chem. 273, 269-71 (1953).

458. Schmitz-Dumont, O., and Weeg, A., Z. anorg. u. allgem. Chem. 265, 139 (1951).

459. Schmitz-Dumont, O., and Heckmann, I., Z. anorg. u. allgem. Chem. 267, 277 (1952).

460. Schmitz-Dumont, O., Bruns, I., and Heckmann, I., Z. anorg. u. allgem. Chem. 271, 347 (1953).

461. Woolf, A. A., J. Inorg. and Nuclear Chem. 14, 21-5 (1960).

462. Ryss, I. G., and Gubanova, T. A., Zhur. Neorg. Khim. 3, 1665-8 (1958).

463. Seel, F., and Massat, H., Z. anorg. u. allgem. Chem. 280, 186-96 (1955).

464. Nikolaev, N. S., and Opalovskii, A. A., Doklady Akad. Nauk S.S.S.R. 124, 830-3 (1959).

465. Schmitz-Dumont, O., and Opgenhoff, P., Z. anorg. u. allgem. Chem. 268, 57-68 (1952).

466. Gagarinskii, Yu. V., and Mashirev, V. P., Zhur. Neorg. Khim. 4, 1246-52 (1959).

467. Popov, M. M., and Gagarinskii, Yu. V., Zhur. Neorg. Khim. 2, 3-8 (1957).

468. Miller, D. B., and Sisler, H. F., J. Am. Chem. Soc. 77, 4998-5000 (1955).

469. Gagarinskii, Yu. V., and Mashirev, V. P., Izvest. Sibir. Otdel. Akad. Nauk S. S. S. R. 1959, No. 11, 50-6.

470. Haendler, H. M., Wheeler, C. M., Jr., and Robinson, D. W., J. Am. Chem. Soc. 74, 2352-3 (1952).

471. Caglioti, V., and Silvestroni, P., Ricerca sci. 26, 2090-9 (1956).

472. Caglioti, V., Silvestroni, P., and Serreqi, J., Atti acad. nazl. Lincei, Rend., Classe sci. fis. mat. e nat. Series [8] 27, 168-77 (1959).

473. Goubeau, J., and Lucke, K. E., Ann. 575, 37-52 (1952).

474. Burg, A. B., and Kuljian, E. S., J. Am. Chem. Soc. 72, 3103 (1950).

475. Ryss, I. G., and El'kenbard, A. G., Doklady Akad. Nauk S. S. S. R. 91, 865-8 (1953).

476. Banks, W. P., Heston, B. O., and Blankenship, F. F., J. Phys. Chem. 58, 962-5 (1954).

477. Furukawa, G. T., Reilly, M. L., and Henning, J. M., Bull. Chem. Thermodynamics No. 4, 38 (1961); cf. No. 3, 36 (1960); No. 2, 46 (1959); No. 1B, 9 (1958).

478. Martin, D. R., and Pizzolato, P. J., pp. 141-4 in Inorganic Synthesis Vol. IV, J.C. Bailar, Jr., Ed., (McGraw-Hill Book Co., Inc., New York, 1953).

479. Wittels, M., Am. Mineralogist 37, 28-36 (1952).

480. Kelley, K. K., Barany, R., King, E. G., and Christensen, A. U., U. S. Bur. Mines Rept. Invest. No. 5436, 16 pp. (1959).

481. Daimon, N., Horibe, T., Mukumoto, K., and Noda, T., Kogyo Kagaku Zasshi 55, 762-4 (1952).

482. Daimon, N., Kogyo Kagaku Zasshi 55, 764-5 (1952).

483. Burg, A. B., and Woodrow, H. W., J. Am. Chem. Soc. 76, 219-20 (1954).

484. Scott, P. C., Univ. Microfilms (Ann Arbor, Mich.), L. C. Card No. 59-3764, 121 pp.; Dissertation Abstr. 20, 2008-9 (1959).

485. Wartenberg, H. V., Z. anorg. u. allgem. Chem. 269, 76 (1952).

486. Juza, R., Wainoff, G., and Uphoff, W., Z. anorg. u. allgem. Chem. 296, 157-63 (1958).

487. Kanevskii, E. A., Zhur. Fiz. Khim. 25, 1092-7 (1951).

488. King, E. L., and Gallagher, P. K., J. Phys. Chem. 63, 1073-6 (1959).

489. Ryss, I. G., and Donskaya, D. B., Zhur. Fiz. Khim, 33, 107-11 (1959).

490. Connick, R. E., and Paul, A. D., J. Am. Chem. Soc. 80, 2069-71 (1958).

491. Hepler, L. G., U. S. Atomic Energy Comm. UCRL-2202, 60 pp. (May, 1953).

492. Watari, T., Denki-Kagaku Zasshi 19, 189-92 (1951).

493. Connick, R. E., and Tsao, M. S., J. Am. Chem. Soc. 76, 5311-14 (1954).

494. Paul, A. D., Thesis, Univ. Calif. Berkeley, 1955, UCRL-2926.

495. Kury, J. W., Paul, A. D., Hepler, L. G., and Connick, R. E., J. Am. Chem. Soc. 81, 4185-9 (1959).

496. Ryss, I. G., Zhur. Fiz. Khim. 25, 654-61 (1951).

497. Thomsen, S. M., J: Am. Chem. Soc. 74, 1690-3 (1952).

498. Schafer, H., and Kahlenberg, F., Z. anorg. u. allgem. Chem. 294, 242-53 (1958).

499. Paul, A. D., Gallo, L. S., and Van Camp, J. B., J. Phys. Chem. 65, 441 (1961).

500. Johnson, J. S., and Kraus, K. A., J. Am. Chem. Soc. 74, 4436-9 (1952).

501. Johnson, J. S., Kraus, K. A., and Young, T. F., J. Am. Chem. Soc. 76, 1436-43 (1954).

502. Kapustinskii, A. F., and Samplavskaya, K. K., Trudy Moskov. Khim. Tekhnol. Inst. im. D. I. Mendeleeva 1956, No. 22, 47-52.

503. Ryss, I. G., and Ust'yanova, P. V., Ukrain. Khem. Zhur. 21, 6-15 (1955).

504. Ryss, I. G., and Slutskaya, M. M., Zhur. Obshchei Khim. 22, 41-8 (1952).

505. Stein, L., Argonne Natl. Laboratory, Argonne, Ill., Private communication, July, 1961.

506. Mandleberg, C. J., and Davies, D., J. Chem. Soc. 1961, 2031-7.

507. Smith, D. F., J. Mol. Spectroscopy 3, 473-485 (1959).

508. Altman, D., and Farber, M., J. Chem. Phys. 21, 1118 (1953).

509. Nikolaev, N. S., Vlasov, S. V., Buslaev, Yu. A., and Opalovskii, A. A., Izvest. Sibir. Otdel. Akad. Naük S.S.S.R. 1960, No. 10, 47-56.

510. Gross, P., Campbell, C. S., Kent, P. J. C., and Levi, D. L., Discussions Faraday Soc. 1948, No. 4, 206-15.

511. Porter, R. F., J. Chem. Phys. 33, 951 (1960).

512. Schoonmaker, R. C., Thesis, Cornell Univ., 1960.

513. Shepp, A., and Bauer, S. H., J. Am. Chem. Soc. 76, 265-70 (1954).

514. Nozaki, H., J. Electrochem. Soc. Japan 16, 31-3 (1948).

515. Andrews, E. B., and Barrow, R. F., Proc. Phys. Soc. (London) 63A, 185-9. (1950).

516. Formin, V. V., Zhur. Fiz. Khim. 27, 689 (1953).

517. Formin, V. V., Zhur. Fiz. Khim. 28, 1896-1900 (1954).

518. Karapet'yants, M. K., Zhur. Fiz. Khim. 28 , 353 (1954).

519. Graham, W. A. G., and Stone, F. G. A., J. Inorg. and Nuclear Chem. 3, 164 (1956).

520. Evans, W. H., Wagman, D. D., and Prosen, E. J. , NBS unpublished communication, December 3, 1957.

521. Cooke, B. A., and Mackenzie, H. A. E., J. S. African Chem. Inst. 6, 4-7 (1953).

522. Haendler, H. M., and Bernard, W. J., J. Am. Chem. Soc. 73, 5218-19 (1951).

523. Roy, D. M., Roy, R., and Osborn, E. F., J. Am. Ceram. Soc. 33, 85-90 (1950).

524. Fischer, J., Bingle, J., and Vogel, R. C., J. Am. Chem. Soc. 78, 902-4 (1956).

525. Claassen, H. H., Weinstock, B., and Malm, J. G., J. Chem. Phys. 28, 285 (1958) .

526. Andrews, E. B., and Barrow, R. F., Nature 165, 890 (1950).

527. Andrews, E. B., and Barrow, R. F., Proc. Phys. Soc. (London) 64A, 481 (1951).

528. Brewer, L., Margrave, J. L., Porter, R. F., and Wieland, K., private communication to D. R. Stull, Dow Chemical Co., Midland, Mich., July, 1960.

529. Sinke, C. G., Dow Chemical Co., Midland, Mich., unpublished calculations.

530. Farlow, M. W., U. S. Patent 2,709,192, May 24, 1955.

531. Potocki, R. M., and Mann, D. E., NBS, unpublished communication, February 15, 1952.

532. Jacobson, A., Steigman, J., Strakna, R. A., and Friedland, S. S., J. Chem. Phys. 24, 637-8 (1956).

533. Potter, R. L., J. Chem. Phys. 31, 1100-2 (1959).

534. Scheer, M. D., J. Chem. Phys. 20, 924 (1952).

535. Banks, A. A., and Rudge, A. J., J. Chem. Soc. 1950, 191.

536. Caunt, A. D., and Barrow, R. F., Nature 164, 753 (1949).

537. Neugebauer, C. A., and Margrave, J. L., Univ. of Wisconsin, Private communication.

538. Kilpatrick, M., and Luborsky, F. E., J. Am. Chem. Soc. 76, 5863-5 (1954).

539. Kilpatrick, M., and Luborsky, F. E., J. Am. Chem. Soc. 76, 5865-8 (1954).

540. Thorburn, R., Proc. Phys. Soc. (London) A73, 122-6 (1959).

541. Shaffer, J. H., Grimes, W. R., and Watson, G. M., J. Phys. Chem. 63, 1999-2002 (1959).

542. Powers, W. D., and Blalock, G. C., U. S. Atomic Energy Comm. ORNL-1956 (Del.), 31 pp. (1958).

543. Berkowitz, J., and Chupka, W. A., J. Chem. Phys. 29, 653-7 (1958).

544. Morris, D. F. C., Acta. Cryst. 9, 197 (1956).

545. Owe-Berg, T. G., J. phys. radium 13, 245 (1952).

546. Milne, T. A., and Cubicciotti, D., J. Chem. Phys. 29, 846-51 (1958).

547. Margrave, J. L., J. Phys. Chem. 58, 258 (1954).

548. Brewer, L., and Mastick, D. F., J. Am. Chem. Soc. 73, 2045 (1951).

549. Rittner, E. S., J. Chem. Phys. 19, 1030 (1951).

550. Colburn, C. B., Rohm and Haass Co., Huntsville, Ala., Private communication.

551. Reese, R. M., and Dibeler, V. H., J. Chem. Phys. 24, 1175-7 (1956).

552. Loughran, D., and Mader, C. L., J. Chem. Phys. 32, 1578-9 (1960).

553. Seyyedi, Ali, and Petit, G., Compt. rend. 249, 505-7 (1959).

554. Miller, R. C., and Kusch, P., J. Chem. Phys. 27, 981 (1957).

555. Brewer, L., Bromley, L., Gilles, P. W., and Lofgren, N. L., "The Halides of Neptunium." Paper 15.7, The Transuranium Elements, G. T. Seaborg, J. J. Katz, and W. M. Manning, Editors, (McGraw-Hill Book Company, Inc., New York, 1949).

556. Glockler, G., J. Chem. Phys. 16, 604-8 (1948).

557. Brewer, L., Chem. Revs. 52, 1-76 (1953).

558. Glockler, G., and Dawson, J. W., Private Communication, June, 1957.

559. Wieland, K., and Newburgh, R., Helv. Phys. Acta. 25, 87-106 (1952).

560. Phipps, T. E., Sears, G. W., Seifert, R. L., and Simpson, O. C., J. Chem. Phys. 18, 713-723 (1950).

561. Buyers, A. G., U. S. Atomic Energy Comm. NAASR-1649, 16 pp. (1956).

562. Cunningham, B. B., "Preparation and Properties of the Compounds of Plutonium." Chapter 10, The Actinide Elements, G. T. Seaborg and J. J. Katz, Editors, (McGraw-Hill Book Company, Inc., New York, 1954).

563. Brewer, L., Bromley, L. A., Gilles, P. W., and Lofgren, N. L., U. S. Atomic Energy Comm. UCRL-633 (March 20, 1950).

564. Tullock, C. W., Fawcett, F. S., Smith, W. C., and Coffman, D. D., J. Am. Chem. Soc. 82, 539-42 (1960).

565. Aynsley, E. E., Peacock, R. D., and Robinson, P. L., J. Chem. Soc. 1952, 1231-4.

566. Neale, E., Williams, L. T. D., and Moores, V. T., J. Chem. Soc. 1956, 422-427.

567. Greenberg, E., Settle, J. L., Feder, H. M., and Hubbard, W. N., J. Phys. Chem. 65, 1168 (1961).

568. Gross, P., Hayman, C., and Levi, D. L., XVIIth Int. Congr. Pure and Applied Chem., Abstracts, 1, 405 (1959).

569. Brewer, L., Bromley, L. A., Gilles, P. W., and Lofgren, N. L., "Thermodynamic Properties and Equilibriums of Uranium Halides, Oxides, Nitrides, and Carbides at High Temperatures." Paper 33, Chemistry of Uranium, J. J. Katz and E. Rabinowitch, Editors, (Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., 1958).

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

571. Buyers, A. G., and McCarty, N., U. S. Atomic Energy Comm. NAA-SR-1157, 32 pp. (1955).

572. O'Driscoll, W. G., and Chalder, G. H., U. K. Atomic Energy Authority, Ind. Group Hdq. R and DB(c) TN-3, 5 pp. (1959).

573. Popov, M. M., Kostylev, F. A., and Karpova, T. F., U. K. Atomic Energy Authority, 2nd Group IGRL-T/CA-56, 8 pp. (1957).

574. Powers, W. D., and Blalock, G. C., U. S. Atomic Energy Comm. ORNL-1956 (Del.), 31 pp. (1958).

575. Decroly, C., and Gerard, J., ATB Met. 1, 105-9 (1957).

576. Tananaev, I. V., and Nekhamkina, M. A., Izvest. Sektora Fiz. Khim. Anal., Inst. Obshchei i Neorg. Khim., Akad. Nauk S.S.S.R. 20, 227-37 (1950).

577. Vajna, A., and Bacchiega, R., Met. ital. 52, 481-94 (1960).

578. Ryss, I. G., and Slutskaya, M. M., Doklady Akad. Nauk S.S.S.R. 57, 689-91 (1947).

579. O'Hara, J. B., and Fahien, R. W., Am. Doc. Inst., Doc. 3327.

580. Margrave, J. L., J. Chem. Phys. 24, 476-7 (1956).

581. Warren, J. W., and Craggs, J. D., Mass Spectrometry, 1950, 36-46.

582. Bertin, H. J., Jr., Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 23184, 99 pp.; Dissertation Abstr. 17, 2432 (1957).

583. Skiens, W. E., and Cady, G. H., J. Am. Chem. Soc. 80, 5640-5 (1958).

584. Skiens, W. E., Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 22187, 79 pp.; Dissertation Abstr. 17, 1912-1913 (1957).

585. Davis, M. L., Univ. Microfilms (Ann Arbor, Mich.), Publ. No. 3487, 177 pp.; Dissertation Abstr. 12, 130-1 (1952).

586. Schmitz-Dumont, O., and Heckman, I., Z. anorg. Chem. 260, 49-64 (1949).

587. Schmitz-Dumont, O., and Schultz, A. H., Monatsh. 83, 638-49 (1952).

588. Simpson, E. A., and Glocker, E. M., J. Phys. Chem. 57, 529-30 (1953).

589. Yatsimirski, K. B., Izvest. Akad. Nauk S.S.S.R., Otdel. Khim. Nauk 1948, 398-405.

590. Savchenko, G. S., and Tananaev, I. V., Zhur. Obshchei Khim. 21, 2235-45 (1951).

591. Humphrey, G. L., and King, E. G., J. Am. Chem. Soc. 74, 2041-2 (1952).

592. Evstrop'ev, K. S., and Skornyakov, M. M., Akad. Nauk S.S.S.R., Otdel. Khim. Nauk, Akad. Nauk S.S.S.R. i Gosudarst. Opticheskii Inst., Sbornik Statei 1949, 174-181.

593. Evstrop'ev, K. S., and Skornyakov, M. M., Akad. Nauk S.S.S.R., Otdel. Khim. Nauk, Akad. Nauk S.S.S.R. i Gosudarst. Opticheskii Inst., Sbornik Statei 1949, 182-5.

594. Jeffes, J. H. E., Richardson, F. D., and Pearson, J., Trans. Faraday, Soc. 50, 364-70 (1954).

595. Neuvonen, K. J., Am. J. Sci., Bowen Vol. Pt. 2, 373-80 (1952).

596. King, E. G., J. Am. Chem. Soc. 73, 656-8 (1951).

597. Stevens, C. G., and Turkdogan, E. T., Trans. Faraday Soc. 51, 356-60 (1955).

598. Kroger, C., Janetzko, W., and Kreitlow, G., Z. anorg. u. allgem. Chem. 287, 33-44 (1956).

599. Hepler, L. G., and Hugus, Z. Z., Jr., J. Am. Chem. Soc. 74, 6115 (1952).

600. Mishchenko, K. P., and Sukhotin, A. M., Izvest. Sektora Platiny i Drug. Blagorad Metal., Inst. Obshchei i Neorg. Khim., Akad. Nauk S.S.S.R. 1951 No. 26, 203-7.

601. Ruyven, B. H. V., Rec. trav. chim. 72, 739-62 (1953).

602. Talipov, Sh. T., and Khadeev, V. A., Zhur. Obshchei Khim. 20, 774-82 (1950); J. Gen. Chem.(U.S.S.R.) 20, 813-21 (1950)(English translation).

603. Talipov, Sh. T., and Khadeev, V. A., Zhur. Obshchei Khim. 20, 783-8 (1950); J. Gen. Chem.(U.S.S.R.) 20, 821-6 (1950)(English translation).

604. Brjnestad, J., Grjotheim, K., and Urnes, S., Z. Elektrochem. 63, 707-12 (1959).

605. Tananaev, I. V., Khim. Redkikh Elementov. Akad. Nauk S.S.S.R., Inst. Obshchei i Neorg. Khim. 1954, No. 1, 33-9.

606. Wray, K. L., and Hornig, D. F., U. S. Dept. Com., Office Tech. Serv., PB Rept. 138,329, 31 pp. (1959).

607. Semenkovich, S. A., Trudy Vsesoyuz. Alyumin.- Magnievyi Inst. 1960, No. 44, 113-19.

608. Mashovets, V. P., and Novikova, N. A., Izvest. Vysshikh. Ucheb. Zavedenii, Tsvetnaya Met. 2, 83-7 (1959).

609. Sokolov, O. K., and Belyaev, A. I., Izvest. Vysshikh. Ucheb. Zavedenii, Tsvetnaya Met. 3, 72-8 (1960).

610. Krasnov, K. S., Izvest. Vysshikh. Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 4, 38-44 (1961).

611. Chari, N. C. S., Univ. Microfilms (Ann Arbor, Mich.), L. C. Card No. Mic. 60-6850, 188 pp.; Dissertation Abstr. 21, 2220 (1961).

612. Hagenmuller, P., and Pape, R. de, Compt. rend. 251, 2032-4 (1960).

613. Cubicciotti, D. D., Jr., J. Chem. Phys. 33, 1579 (1960).

614. Krasnov, K. S., Radiokhimiya 2, 668-70 (1960).

615. Akishin, P. A., Gorokhov, L. N., and Sidorov, L. N., Zhur. Fiz. Khim. 33, 2822-3 (1959).

616. Ivanova, L. I., Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khim. Tekhnol. 3, 970-4 (1960).

617. Merrill, C. I., and Cady, G. H., J. Am. Chem. Soc. 83, 298-300 (1961).

618. Caglioti, V., Ciavatta, L., and Liberti, A., J. Inorg. and Nuclear Chem. 15, 115-24 (1960).

619. Azzam, A. M., Can. J. Chem. 38, 2203-16 (1960).

620. Sutra, G., Compt. rend. Congr. soc. Savantes Paris et depts. Sect. sci. 78e Congr. Toulouse 1953, 59-63.

621. Woolf, A. A., J. Chem. Soc. 1954, 2840-3.

622. Kolesov, V. P., and Skuratov, S. M., Zhur. Neorg. Khim. 8, 1741-4 (1961).

623. Maslov, Yu. P., Zhur. Fiz. Khim. 35, 974-6 (1961).

624. Maslov, P. G., Zhur. Fiz. Khim. 35, 1551-7 (1961).

625. Skuratov, S. M., and Kolesov, V. P., Zhur. Fiz. Khim. 35, 1156-61 (1961).

APPENDIX A

IDEAL GAS THERMODYNAMIC FUNCTIONS

by

Joseph Hilsenrath and William H. Evans

The thermodynamic functions are given for the positive ions of the elements He^+ through K^+; for Ti^+, Br^+, Zr^+, Mo^+, I^+, W^+, Hg^+, and Pb^+; and for the molecules NF_2 and N_2F_4. The computations were performed on the IBM 704 using the fundamental constants of Cohen, Crowe, and Dumond [1]. The tables, which extend to 6,000 °K for the molecules and to 10,000 °K for the atomic ions, are given in units of calories (4.1840 abs. joules), gram moles, and °K. Conversion factors are given to other units.

The functions for the atomic ions were computed by a summation over energy levels given in Volume I (and as corrected in Volume III) of Atomic Energy Levels [2]. The functions for the polyatomic molecules were computed on the harmonic oscillator-rigid rotator approximation using the molecular data listed with the tables. The molecular constants for the polyatomic molecules are discussed in Chapter 2 of this report.

For the first 18 elements the table number agrees with the atomic number as in the earlier NBS Report 6928 with the addition of - 1 to designate the first ion. For the other ions and for the polyatomic molecules the numbers are consecutive to the last table in the earlier report.

The tables for the atomic ions were computed in connection with work at the National Bureau of Standards directed at properties of highly ionized gases under a contract with the Air Force Special Weapons Center, Kirtland Air Force Base. They are included here as a convenience to ARPA contractors. The tables are in close agreement with those of Green, Poland, and Margrave [3]

References

[1] Cohen, E. R., Crowe, K. M., Dumond, J. W. M., "Fundamental Constants of Physics," Interscience Pub., N. Y. (1957).

[2] Moore, C. E., "Atomic Energy Levels," National Bureau of Standards Circular 467, Vol. I. (1949), Vol. III (1958), U. S. Government Printing Office, Washington, D. C.

[3] Green, J. W., Poland, D. E., and Margrave, J. L., J. Chem. Phys. 33, 35-39 (1960)

Table A-2-1 Thermodynamic Functions for He^+

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
273.15	26.0996	4.9681	31.0678	4.9681	1357.1
298.15	26.5347	4.9681	31.5029	4.9681	1481.3
1000.	32.5470	4.9681	37.5151	4.9681	4968.1
1100.	33.0205	4.9681	37.9886	4.9681	5465.0
1200.	33.4528	4.9681	38.4209	4.9681	5961.8
1300.	33.8504	4.9681	38.8186	4.9681	6458.6
1400.	34.2186	4.9681	39.1868	4.9681	6955.4
1500.	34.5614	4.9681	39.5295	4.9681	7452.2
1600.	34.8820	4.9681	39.8502	4.9681	7949.0
1700.	35.1832	4.9681	40.1513	4.9681	8445.9
1800.	35.4672	4.9681	40.4353	4.9681	8942.7
1900.	35.7358	4.9681	40.7039	4.9681	9439.5
2000.	35.9906	4.9681	40.9588	4.9681	9936.3
2100.	36.2330	4.9681	41.2012	4.9681	10433.1
2200.	36.4641	4.9681	41.4323	4.9681	10929.9
2300.	36.6850	4.9681	41.6531	4.9681	11426.7
2400.	36.8964	4.9681	41.8646	4.9681	11923.6
2500.	37.0992	4.9681	42.0674	4.9681	12420.4
2600.	37.2941	4.9681	42.2622	4.9681	12917.2
2700.	37.4816	4.9681	42.4497	4.9681	13414.0
2800.	37.6623	4.9681	42.6304	4.9681	13910.8
2900.	37.8366	4.9681	42.8047	4.9681	14407.6
3000.	38.0050	4.9681	42.9732	4.9681	14904.4
3100.	38.1679	4.9681	43.1361	4.9681	15401.3
3200.	38.3257	4.9681	43.2938	4.9681	15898.1
3300.	38.4785	4.9681	43.4467	4.9681	16394.9
3400.	38.6269	4.9681	43.5950	4.9681	16891.7
3500.	38.7709	4.9681	43.7390	4.9681	17388.5
3600.	38.9108	4.9681	43.8790	4.9681	17885.3
3700.	39.0470	4.9681	44.0151	4.9681	18382.2
3800.	39.1794	4.9681	44.1476	4.9681	18879.0
3900.	39.3085	4.9681	44.2766	4.9681	19375.8
4000.	39.4343	4.9681	44.4024	4.9681	19872.6
4100.	39.5570	4.9681	44.5251	4.9681	20369.4
4200.	39.6767	4.9681	44.6448	4.9681	20866.2
4300.	39.7936	4.9681	44.7617	4.9681	21363.0
4400.	39.9078	4.9681	44.8759	4.9681	21859.9
4500.	40.0194	4.9681	44.9876	4.9681	22356.7
4600.	40.1286	4.9681	45.0968	4.9681	22853.5
4700.	40.2355	4.9681	45.2036	4.9681	23350.3
4800.	40.3401	4.9681	45.3082	4.9681	23847.1
4900.	40.4425	4.9681	45.4107	4.9681	24343.9
5000.	40.5429	4.9681	45.5110	4.9681	24840.7
5100.	40.6413	4.9681	45.6094	4.9681	25337.6
5200.	40.7377	4.9681	45.7059	4.9681	25834.4
5300.	40.8324	4.9681	45.8005	4.9681	26331.2
5400.	40.9252	4.9681	45.8934	4.9681	26828.0
5500.	41.0164	4.9681	45.9846	4.9681	27324.8
5600.	41.1059	4.9681	46.0741	4.9681	27821.6
5700.	41.1939	4.9681	46.1620	4.9681	28318.5
5800.	41.2803	4.9681	46.2484	4.9681	28815.3
5900.	41.3652	4.9681	46.3333	4.9681	29312.1
6000.	41.4487	4.9681	46.4168	4.9681	29808.9
6100.	41.5308	4.9681	46.4990	4.9681	30305.7
6200.	41.6116	4.9681	46.5797	4.9681	30802.5
6300.	41.6911	4.9681	46.6592	4.9681	31299.3

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 4.0025

Table A-2-1 Thermodynamic Functions for He^+ - continued

T °K	$-\frac{(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	41.7693	4.9681	46.7375	4.9681	31796.2
6500.	41.8464	4.9681	46.8145	4.9681	32293.0
6600.	41.9222	4.9681	46.8904	4.9681	32789.8
6700.	41.9969	4.9681	46.9651	4.9681	33286.6
6800.	42.0705	4.9681	47.0387	4.9681	33783.4
6900.	42.1430	4.9681	47.1112	4.9681	34280.2
7000.	42.2145	4.9681	47.1827	4.9681	34777.0
7100.	42.2850	4.9681	47.2532	4.9681	35273.9
7200.	42.3545	4.9681	47.3226	4.9681	35770.7
7300.	42.4230	4.9681	47.3912	4.9681	36267.5
7400.	42.4906	4.9681	47.4588	4.9681	36764.3
7500.	42.5573	4.9681	47.5254	4.9681	37261.1
7600.	42.6231	4.9681	47.5913	4.9681	37757.9
7700.	42.6880	4.9681	47.6562	4.9681	38254.8
7800.	42.7522	4.9681	47.7203	4.9681	38751.6
7900.	42.8154	4.9681	47.7836	4.9681	39248.4
8000.	42.8779	4.9681	47.8461	4.9681	39745.2
8100.	42.9397	4.9681	47.9078	4.9681	40242.0
8200.	43.0006	4.9681	47.9688	4.9681	40738.8
8300.	43.0608	4.9681	48.0290	4.9681	41235.6
8400.	43.1203	4.9681	48.0885	4.9681	41732.5
8500.	43.1791	4.9681	48.1473	4.9681	42229.3
8600.	43.2372	4.9681	48.2054	4.9681	42726.1
8700.	43.2947	4.9681	48.2628	4.9681	43222.9
8800.	43.3515	4.9681	48.3196	4.9681	43719.7
8900.	43.4076	4.9681	48.3757	4.9681	44216.5
9000.	43.4631	4.9681	48.4312	4.9681	44713.3
9100.	43.5180	4.9681	48.4861	4.9681	45210.2
9200.	43.5723	4.9681	48.5404	4.9681	45707.0
9300.	43.6260	4.9681	48.5942	4.9681	46203.8
9400.	43.6791	4.9681	48.6473	4.9681	46700.6
9500.	43.7317	4.9681	48.6999	4.9681	47197.4
9600.	43.7837	4.9681	48.7519	4.9681	47694.2
9700.	43.8352	4.9681	48.8034	4.9681	48191.1
9800.	43.8862	4.9681	48.8543	4.9681	48687.9
9900.	43.9366	4.9681	48.9048	4.9681	49184.7
10000.	43.9865	4.9681	48.9547	4.9681	49681.5
10100.	44.0360	4.9681	49.0041	4.9681	50178.3

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.24984
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	1.0453
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.24968

Table A-3-1 Thermodynamic Functions for Li^+

T °K	$-(F^o - H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
273.15	26.3626	4.9681	31.3307	4.9681	1357.1
298.15	26.7977	4.9681	31.7658	4.9681	1481.3
1000.	32.8099	4.9681	37.7781	4.9681	4968.1
1100.	33.2834	4.9681	38.2516	4.9681	5465.0
1200.	33.7157	4.9681	38.6839	4.9681	5961.8
1300.	34.1134	4.9681	39.0815	4.9681	6458.6
1400.	34.4816	4.9681	39.4497	4.9681	6955.4
1500.	34.8243	4.9681	39.7925	4.9681	7452.2
1600.	35.1450	4.9681	40.1131	4.9681	7949.0
1700.	35.4462	4.9681	40.4143	4.9681	8445.9
1800.	35.7301	4.9681	40.6983	4.9681	8942.7
1900.	35.9987	4.9681	40.9669	4.9681	9439.5
2000.	36.2536	4.9681	41.2217	4.9681	9936.3
2100.	36.4960	4.9681	41.4641	4.9681	10433.1
2200.	36.7271	4.9681	41.6952	4.9681	10929.9
2300.	36.9479	4.9681	41.9161	4.9681	11426.7
2400.	37.1594	4.9681	42.1275	4.9681	11923.6
2500.	37.3622	4.9681	42.3303	4.9681	12420.4
2600.	37.5570	4.9681	42.5252	4.9681	12917.2
2700.	37.7445	4.9681	42.7127	4.9681	13414.0
2800.	37.9252	4.9681	42.8934	4.9681	13910.8
2900.	38.0996	4.9681	43.0677	4.9681	14407.6
3000.	38.2680	4.9681	43.2361	4.9681	14904.4
3100.	38.4309	4.9681	43.3990	4.9681	15401.3
3200.	38.5886	4.9681	43.5568	4.9681	15898.1
3300.	38.7415	4.9681	43.7096	4.9681	16394.9
3400.	38.8898	4.9681	43.8580	4.9681	16891.7
3500.	39.0338	4.9681	44.0020	4.9681	17388.5
3600.	39.1738	4.9681	44.1419	4.9681	17885.3
3700.	39.3099	4.9681	44.2781	4.9681	18382.2
3800.	39.4424	4.9681	44.4105	4.9681	18879.0
3900.	39.5714	4.9681	44.5396	4.9681	19375.8
4000.	39.6972	4.9681	44.6654	4.9681	19872.6
4100.	39.8199	4.9681	44.7881	4.9681	20369.4
4200.	39.9396	4.9681	44.9078	4.9681	20866.2
4300.	40.0565	4.9681	45.0247	4.9681	21363.0
4400.	40.1707	4.9681	45.1389	4.9681	21859.9
4500.	40.2824	4.9681	45.2505	4.9681	22356.7
4600.	40.3916	4.9681	45.3597	4.9681	22853.5
4700.	40.4984	4.9681	45.4666	4.9681	23350.3
4800.	40.6030	4.9681	45.5712	4.9681	23847.1
4900.	40.7055	4.9681	45.6736	4.9681	24343.9
5000.	40.8058	4.9681	45.7740	4.9681	24840.7
5100.	40.9042	4.9681	45.8724	4.9681	25337.6
5200.	41.0007	4.9681	45.9688	4.9681	25834.4
5300.	41.0953	4.9681	46.0635	4.9681	26331.2
5400.	41.1882	4.9681	46.1563	4.9681	26828.0
5500.	41.2794	4.9681	46.2475	4.9681	27324.8
5600.	41.3689	4.9681	46.3370	4.9681	27821.6
5700.	41.4568	4.9681	46.4250	4.9681	28318.5
5800.	41.5432	4.9681	46.5114	4.9681	28815.3
5900.	41.6281	4.9681	46.5963	4.9681	29312.1
6000.	41.7116	4.9681	46.6798	4.9681	29808.9
6100.	41.7938	4.9681	46.7619	4.9681	30305.7
6200.	41.8745	4.9681	46.8427	4.9681	30802.5
6300.	41.9540	4.9681	46.9222	4.9681	31299.3

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 6.9395

Table A-3-1 Thermodynamic Functions for Li^+ - continued

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
6400.	42.0323	4.9681	47.0004	4.9681	31796.2
6500.	42.1093	4.9681	47.0775	4.9681	32293.0
6600.	42.1852	4.9681	47.1533	4.9681	32789.8
6700.	42.2599	4.9681	47.2280	4.9681	33286.6
6800.	42.3335	4.9681	47.3016	4.9681	33783.4
6900.	42.4060	4.9681	47.3741	4.9681	34280.2
7000.	42.4775	4.9681	47.4456	4.9681	34777.0
7100.	42.5480	4.9681	47.5161	4.9681	35273.9
7200.	42.6174	4.9681	47.5856	4.9681	35770.7
7300.	42.6860	4.9681	47.6541	4.9681	36267.5
7400.	42.7536	4.9681	47.7217	4.9681	36764.3
7500.	42.8202	4.9681	47.7884	4.9681	37261.1
7600.	42.8861	4.9681	47.8542	4.9681	37757.9
7700.	42.9510	4.9681	47.9191	4.9681	38254.8
7800.	43.0151	4.9681	47.9833	4.9681	38751.6
7900.	43.0784	4.9681	48.0465	4.9681	39248.4
8000.	43.1409	4.9681	48.1090	4.9681	39745.2
8100.	43.2026	4.9681	48.1708	4.9681	40242.0
8200.	43.2636	4.9681	48.2317	4.9681	40738.8
8300.	43.3238	4.9681	48.2919	4.9681	41235.6
8400.	43.3833	4.9681	48.3514	4.9681	41732.5
8500.	43.4421	4.9681	48.4102	4.9681	42229.3
8600.	43.5002	4.9681	48.4683	4.9681	42726.1
8700.	43.5576	4.9681	48.5258	4.9681	43222.9
8800.	43.6144	4.9681	48.5826	4.9681	43719.7
8900.	43.6705	4.9681	48.6387	4.9681	44216.5
9000.	43.7261	4.9681	48.6942	4.9681	44713.3
9100.	43.7809	4.9681	48.7491	4.9681	45210.2
9200.	43.8352	4.9681	48.8034	4.9681	45707.0
9300.	43.8890	4.9681	48.8571	4.9681	46203.8
9400.	43.9421	4.9681	48.9102	4.9681	46700.6
9500.	43.9947	4.9681	48.9628	4.9681	47197.4
9600.	44.0467	4.9681	49.0148	4.9681	47694.2
9700.	44.0982	4.9681	49.0663	4.9681	48191.1
9800.	44.1491	4.9681	49.1173	4.9681	48687.9
9900.	44.1996	4.9681	49.1677	4.9681	49184.7
10000.	44.2495	4.9681	49.2176	4.9681	49681.5
10100.	44.2989	4.9681	49.2671	4.9681	50178.3

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.14410
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.60291
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.14401

Table A-4-1 Thermodynamic Functions for Be^+

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o-H^o_0}{T}$	S^o	C^o_p	$H^o-H^o_0$
273.15	28.5192	4.9681	33.4873	4.9681	1357.1
298.15	28.9543	4.9681	33.9224	4.9681	1481.3
1000.	34.9665	4.9681	39.9347	4.9681	4968.1
1100.	35.4400	4.9681	40.4082	4.9681	5465.0
1200.	35.8723	4.9681	40.8405	4.9681	5961.8
1300.	36.2700	4.9681	41.2381	4.9681	6458.6
1400.	36.6382	4.9681	41.6063	4.9681	6955.4
1500.	36.9809	4.9681	41.9491	4.9681	7452.2
1600.	37.3016	4.9681	42.2697	4.9681	7949.0
1700.	37.6028	4.9681	42.5709	4.9681	8445.9
1800.	37.8867	4.9681	42.8549	4.9681	8942.7
1900.	38.1554	4.9681	43.1235	4.9682	9439.5
2000.	38.4102	4.9681	43.3783	4.9682	9936.3
2100.	38.6526	4.9681	43.6207	4.9682	10433.1
2200.	38.8837	4.9682	43.8519	4.9682	10929.9
2300.	39.1045	4.9682	44.0727	4.9682	11426.7
2400.	39.3160	4.9682	44.2841	4.9682	11923.6
2500.	39.5188	4.9682	44.4869	4.9682	12420.4
2600.	39.7137	4.9682	44.6818	4.9682	12917.2
2700.	39.9012	4.9682	44.8693	4.9682	13414.0
2800.	40.0818	4.9682	45.0500	4.9683	13910.8
2900.	40.2562	4.9682	45.2243	4.9683	14407.7
3000.	40.4246	4.9682	45.3928	4.9685	14904.5
3100.	40.5875	4.9682	45.5557	4.9686	15401.4
3200.	40.7452	4.9682	45.7134	4.9689	15898.2
3300.	40.8981	4.9682	45.8663	4.9692	16395.1
3400.	41.0464	4.9683	46.0147	4.9696	16892.1
3500.	41.1905	4.9683	46.1588	4.9702	17389.1
3600.	41.3304	4.9684	46.2988	4.9709	17886.1
3700.	41.4665	4.9684	46.4350	4.9719	18383.3
3800.	41.5990	4.9686	46.5676	4.9730	18880.5
3900.	41.7281	4.9687	46.6968	4.9745	19377.9
4000.	41.8539	4.9689	46.8228	4.9762	19875.4
4100.	41.9766	4.9691	46.9457	4.9783	20373.1
4200.	42.0963	4.9693	47.0657	4.9808	20871.1
4300.	42.2133	4.9696	47.1829	4.9837	21369.3
4400.	42.3275	4.9700	47.2975	4.9871	21867.9
4500.	42.4392	4.9704	47.4096	4.9910	22366.8
4600.	42.5485	4.9709	47.5194	4.9955	22866.1
4700.	42.6554	4.9715	47.6268	5.0005	23365.9
4800.	42.7601	4.9721	47.7322	5.0062	23866.2
4900.	42.8626	4.9729	47.8355	5.0125	24367.1
5000.	42.9631	4.9737	47.9368	5.0195	24868.7
5100.	43.0616	4.9747	48.0363	5.0273	25371.1
5200.	43.1582	4.9758	48.1340	5.0358	25874.2
5300.	43.2530	4.9770	48.2300	5.0451	26378.2
5400.	43.3460	4.9784	48.3244	5.0551	26883.2
5500.	43.4374	4.9799	48.4172	5.0660	27389.3
5600.	43.5271	4.9815	48.5086	5.0777	27896.5
5700.	43.6153	4.9833	48.5986	5.0902	28404.9
5800.	43.7020	4.9853	48.6873	5.1036	28914.6
5900.	43.7872	4.9874	48.7746	5.1178	29425.6
6000.	43.8711	4.9897	48.8608	5.1329	29938.1
6100.	43.9536	4.9922	48.9457	5.1488	30452.2
6200.	44.0348	4.9948	49.0296	5.1655	30967.9
6300.	44.1147	4.9977	49.1124	5.1830	31485.3

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 9.0125

Table A-4-1 Thermodynamic Functions for Be^{+} - continued

T °K	$\frac{-(F^{\circ}-H^{\circ}_{0})}{T}$	$\frac{H^{\circ}-H^{\circ}_{0}}{T}$	S°	C°_{p}	$H^{\circ}-H^{\circ}_{0}$
6400.	44.1934	5.0007	49.1941	5.2014	32004.6
6500.	44.2710	5.0039	49.2749	5.2205	32525.6
6600.	44.3474	5.0074	49.3548	5.2404	33048.7
6700.	44.4227	5.0110	49.4337	5.2611	33573.8
6800.	44.4970	5.0148	49.5119	5.2825	34100.9
6900.	44.5702	5.0189	49.5891	5.3047	34630.3
7000.	44.6425	5.0231	49.6656	5.3275	35161.9
7100.	44.7138	5.0276	49.7414	5.3510	35695.8
7200.	44.7841	5.0322	49.8164	5.3751	36232.1
7300.	44.8536	5.0371	49.8907	5.3998	36770.8
7400.	44.9221	5.0422	49.9643	5.4250	37312.1
7500.	44.9899	5.0474	50.0373	5.4508	37855.9
7600.	45.0567	5.0529	50.1097	5.4771	38402.2
7700.	45.1228	5.0586	50.1814	5.5039	38951.3
7800.	45.1881	5.0645	50.2526	5.5311	39503.0
7900.	45.2527	5.0706	50.3233	5.5586	40057.5
8000.	45.3165	5.0768	50.3934	5.5866	40614.8
8100.	45.3796	5.0833	50.4629	5.6149	41174.8
8200.	45.4420	5.0900	50.5320	5.6434	41737.8
8300.	45.5038	5.0968	50.6006	5.6723	42303.5
8400.	45.5649	5.1038	50.6687	5.7013	42872.2
8500.	45.6253	5.1110	50.7363	5.7305	43443.8
8600.	45.6851	5.1184	50.8035	5.7599	44018.3
8700.	45.7443	5.1260	50.8703	5.7894	44595.8
8800.	45.8030	5.1337	50.9366	5.8190	45176.2
8900.	45.8610	5.1415	51.0025	5.8486	45759.6
9000.	45.9185	5.1495	51.0681	5.8783	46345.9
9100.	45.9755	5.1577	51.1332	5.9080	46935.3
9200.	46.0319	5.1660	51.1979	5.9376	47527.5
9300.	46.0878	5.1745	51.2623	5.9672	48122.8
9400.	46.1432	5.1831	51.3262	5.9967	48721.0
9500.	46.1981	5.1918	51.3899	6.0260	49322.1
9600.	46.2525	5.2006	51.4531	6.0552	49926.2
9700.	46.3064	5.2096	51.5160	6.0843	50533.1
9800.	46.3599	5.2187	51.5786	6.1132	51143.0
9900.	46.4129	5.2279	51.6408	6.1418	51755.8
10000.	46.4655	5.2371	51.7026	6.1702	52371.4
10100.	46.5177	5.2465	51.7642	6.1984	52989.8

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.11096
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.46426
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.11089

Table A-5-1 Thermodynamic Functions for B^+

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
273.15	27.6866	4.9681	32.6547	4.9681	1357.1
298.15	28.1217	4.9681	33.0898	4.9681	1481.3
1000.	34.1339	4.9681	39.1021	4.9681	4968.1
1100.	34.6074	4.9681	39.5755	4.9681	5465.0
1200.	35.0397	4.9681	40.0079	4.9681	5961.8
1300.	35.4374	4.9681	40.4055	4.9681	6458.6
1400.	35.8056	4.9681	40.7737	4.9681	6955.4
1500.	36.1483	4.9681	41.1165	4.9681	7452.2
1600.	36.4690	4.9681	41.4371	4.9681	7949.0
1700.	36.7702	4.9681	41.7383	4.9681	8445.9
1800.	37.0541	4.9681	42.0223	4.9681	8942.7
1900.	37.3227	4.9681	42.2909	4.9681	9439.5
2000.	37.5776	4.9681	42.5457	4.9681	9936.3
2100.	37.8200	4.9681	42.7881	4.9681	10433.1
2200.	38.0511	4.9681	43.0192	4.9682	10929.9
2300.	38.2719	4.9681	43.2401	4.9682	11426.7
2400.	38.4834	4.9682	43.4515	4.9682	11923.6
2500.	38.6862	4.9682	43.6543	4.9682	12420.4
2600.	38.8810	4.9682	43.8492	4.9682	12917.2
2700.	39.0685	4.9682	44.0367	4.9682	13414.0
2800.	39.2492	4.9682	44.2174	4.9682	13910.8
2900.	39.4236	4.9682	44.3917	4.9682	14407.6
3000.	39.5920	4.9682	44.5601	4.9682	14904.5
3100.	39.7549	4.9682	44.7231	4.9683	15401.3
3200.	39.9126	4.9682	44.8808	4.9684	15898.1
3300.	40.0655	4.9682	45.0337	4.9686	16395.0
3400.	40.2138	4.9682	45.1820	4.9688	16891.8
3500.	40.3578	4.9682	45.3260	4.9691	17388.7
3600.	40.4978	4.9682	45.4660	4.9695	17885.7
3700.	40.6339	4.9683	45.6022	4.9700	18382.6
3800.	40.7664	4.9683	45.7348	4.9707	18879.7
3900.	40.8955	4.9684	45.8639	4.9717	19376.8
4000.	41.0213	4.9685	45.9898	4.9729	19874.0
4100.	41.1440	4.9686	46.1126	4.9744	20371.4
4200.	41.2637	4.9688	46.2325	4.9763	20868.9
4300.	41.3806	4.9690	46.3496	4.9786	21366.6
4400.	41.4948	4.9692	46.4641	4.9814	21864.6
4500.	41.6065	4.9695	46.5761	4.9848	22362.9
4600.	41.7157	4.9699	46.6857	4.9888	22861.6
4700.	41.8226	4.9704	46.7930	4.9935	23360.7
4800.	41.9273	4.9709	46.8982	4.9989	23860.3
4900.	42.0298	4.9715	47.0013	5.0053	24360.5
5000.	42.1302	4.9723	47.1025	5.0126	24861.4
5100.	42.2287	4.9732	47.2019	5.0208	25363.1
5200.	42.3253	4.9742	47.2994	5.0302	25865.6
5300.	42.4200	4.9753	47.3954	5.0407	26369.2
5400.	42.5131	4.9766	47.4897	5.0525	26873.8
5500.	42.6044	4.9781	47.5825	5.0656	27379.7
5600.	42.6941	4.9798	47.6739	5.0800	27887.0
5700.	42.7823	4.9817	47.7640	5.0959	28395.8
5800.	42.8689	4.9838	47.8527	5.1133	28906.2
5900.	42.9541	4.9862	47.9403	5.1322	29418.5
6000.	43.0380	4.9888	48.0267	5.1528	29932.7
6100.	43.1204	4.9917	48.1121	5.1749	30449.1
6200.	43.2016	4.9948	48.1964	5.1988	30967.7
6300.	43.2816	4.9982	48.2798	5.2244	31488.9

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 10.82

Table A-5-1 Thermodynamic Functions for B^+ - continued

T °K	$-(F^o - H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
6400.	43.3603	5.0020	48.3623	5.2517	32012.7
6500.	43.4379	5.0060	48.4439	5.2808	32539.3
6600.	43.5144	5.0104	48.5248	5.3116	33068.9
6700.	43.5897	5.0152	48.6049	5.3443	33601.7
6800.	43.6641	5.0203	48.6844	5.3788	34137.8
6900.	43.7374	5.0257	48.7631	5.4150	34677.5
7000.	43.8098	5.0316	48.8413	5.4531	35220.9
7100.	43.8812	5.0378	48.9190	5.4929	35768.2
7200.	43.9517	5.0444	48.9961	5.5344	36319.5
7300.	44.0213	5.0514	49.0727	5.5777	36875.1
7400.	44.0901	5.0588	49.1489	5.6227	37435.1
7500.	44.1580	5.0666	49.2247	5.6693	37999.7
7600.	44.2252	5.0749	49.3001	5.7176	38569.0
7700.	44.2916	5.0835	49.3751	5.7674	39143.2
7800.	44.3573	5.0926	49.4499	5.8187	39722.5
7900.	44.4222	5.1022	49.5244	5.8715	40307.0
8000.	44.4864	5.1121	49.5985	5.9257	40896.9
8100.	44.5500	5.1225	49.6725	5.9813	41492.2
8200.	44.6129	5.1333	49.7462	6.0381	42093.2
8300.	44.6752	5.1446	49.8198	6.0962	42699.9
8400.	44.7369	5.1562	49.8931	6.1554	43312.5
8500.	44.7980	5.1684	49.9663	6.2157	43931.0
8600.	44.8585	5.1809	50.0394	6.2769	44555.6
8700.	44.9185	5.1938	50.1123	6.3391	45186.4
8800.	44.9779	5.2072	50.1851	6.4021	45823.5
8900.	45.0368	5.2210	50.2578	6.4659	46466.9
9000.	45.0952	5.2352	50.3304	6.5303	47116.7
9100.	45.1532	5.2498	50.4030	6.5954	47773.0
9200.	45.2106	5.2648	50.4754	6.6609	48435.8
9300.	45.2676	5.2801	50.5478	6.7269	49105.2
9400.	45.3242	5.2959	50.6201	6.7932	49781.2
9500.	45.3803	5.3120	50.6923	6.8598	50463.8
9600.	45.4360	5.3285	50.7645	6.9265	51153.1
9700.	45.4913	5.3453	50.8366	6.9934	51849.1
9800.	45.5462	5.3624	50.9087	7.0603	52551.8
9900.	45.6008	5.3799	50.9807	7.1271	53261.2
10000.	45.6549	5.3977	51.0526	7.1938	53977.2
10100.	45.7087	5.4158	51.1246	7.2602	54699.9

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.092421
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.38669
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.092361

Table A-6-1 Thermodynamic Functions for C^+

T °K	$-(F°-H_0^o)/T$	$(H° - H_0^o)/T$	S°	C_p^o	$H° - H_0^o$
273.15	31.1378	5.3621	36.4999	5.0229	1464.7
298.15	31.6061	5.3333	36.9394	5.0138	1590.1
1000.	37.8857	5.0863	42.9720	4.9720	5086.3
1100.	38.3699	5.0759	43.4459	4.9713	5583.5
1200.	38.8112	5.0672	43.8784	4.9708	6080.6
1300.	39.2165	5.0598	44.2763	4.9704	6577.7
1400.	39.5912	5.0534	44.6446	4.9701	7074.7
1500.	39.9397	5.0478	44.9875	4.9698	7571.7
1600.	40.2653	5.0429	45.3082	4.9696	8068.7
1700.	40.5709	5.0386	45.6095	4.9695	8565.6
1800.	40.8588	5.0348	45.8936	4.9693	9062.6
1900.	41.1309	5.0313	46.1622	4.9692	9559.5
2000.	41.3889	5.0282	46.4171	4.9691	10056.4
2100.	41.6342	5.0254	46.6596	4.9690	10553.3
2200.	41.8679	5.0228	46.8907	4.9689	11050.2
2300.	42.0911	5.0205	47.1116	4.9689	11547.1
2400.	42.3047	5.0183	47.3231	4.9688	12044.0
2500.	42.5095	5.0163	47.5259	4.9688	12540.9
2600.	42.7063	5.0145	47.7208	4.9687	13037.7
2700.	42.8955	5.0128	47.9083	4.9687	13534.6
2800.	43.0777	5.0112	48.0890	4.9686	14031.5
2900.	43.2536	5.0098	48.2633	4.9686	14528.3
3000.	43.4234	5.0084	48.4318	4.9686	15025.2
3100.	43.5876	5.0071	48.5947	4.9685	15522.0
3200.	43.7465	5.0059	48.7524	4.9685	16018.9
3300.	43.9006	5.0048	48.9053	4.9685	16515.8
3400.	44.0500	5.0037	49.0537	4.9685	17012.6
3500.	44.1950	5.0027	49.1977	4.9685	17509.5
3600.	44.3359	5.0017	49.3377	4.9685	18006.3
3700.	44.4729	5.0009	49.4738	4.9685	18503.1
3800.	44.6063	5.0000	49.6063	4.9685	19000.0
3900.	44.7362	4.9992	49.7353	4.9685	19496.8
4000.	44.8627	4.9984	49.8611	4.9686	19993.7
4100.	44.9861	4.9977	49.9838	4.9686	20490.6
4200.	45.1065	4.9970	50.1036	4.9687	20987.4
4300.	45.2241	4.9964	50.2205	4.9688	21484.3
4400.	45.3390	4.9957	50.3347	4.9690	21981.2
4500.	45.4512	4.9951	50.4464	4.9691	22478.1
4600.	45.5610	4.9946	50.5556	4.9694	22975.0
4700.	45.6684	4.9940	50.6625	4.9696	23472.0
4800.	45.7736	4.9935	50.7671	4.9700	23969.0
4900.	45.8765	4.9931	50.8696	4.9704	24466.0
5000.	45.9774	4.9926	50.9700	4.9709	24963.0
5100.	46.0763	4.9922	51.0684	4.9715	25460.2
5200.	46.1732	4.9918	51.1650	4.9721	25957.3
5300.	46.2683	4.9914	51.2597	4.9729	26454.6
5400.	46.3616	4.9911	51.3527	4.9738	26951.9
5500.	46.4532	4.9908	51.4439	4.9748	27449.3
5600.	46.5431	4.9905	51.5336	4.9760	27946.9
5700.	46.6314	4.9903	51.6217	4.9773	28444.6
5800.	46.7182	4.9901	51.7083	4.9788	28942.4
5900.	46.8035	4.9899	51.7934	4.9805	29440.3
6000.	46.8874	4.9897	51.8771	4.9823	29938.5
6100.	46.9698	4.9896	51.9595	4.9844	30436.8
6200.	47.0510	4.9896	52.0405	4.9867	30935.4
6300.	47.1308	4.9895	52.1203	4.9891	31434.1

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 12.0105

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
6400.	47.2094	4.9896	52.1989	4.9918	31933.2
6500.	47.2867	4.9896	52.2764	4.9948	32432.5
6600.	47.3629	4.9897	52.3526	4.9980	32932.2
6700.	47.4380	4.9899	52.4278	5.0015	33432.1
6800.	47.5119	4.9901	52.5019	5.0052	33932.5
6900.	47.5847	4.9903	52.5750	5.0092	34433.2
7000.	47.6565	4.9906	52.6471	5.0135	34934.3
7100.	47.7273	4.9910	52.7183	5.0180	35435.9
7200.	47.7971	4.9914	52.7885	5.0229	35937.9
7300.	47.8660	4.9918	52.8578	5.0281	36440.5
7400.	47.9339	4.9924	52.9263	5.0336	36943.6
7500.	48.0009	4.9930	52.9939	5.0394	37447.2
7600.	48.0671	4.9936	53.0607	5.0455	37951.4
7700.	48.1323	4.9943	53.1267	5.0519	38456.3
7800.	48.1968	4.9951	53.1919	5.0586	38961.8
7900.	48.2604	4.9960	53.2564	5.0657	39468.0
8000.	48.3233	4.9969	53.3201	5.0731	39975.0
8100.	48.3854	4.9979	53.3832	5.0808	40482.7
8200.	48.4467	4.9989	53.4456	5.0889	40991.2
8300.	48.5073	5.0001	53.5073	5.0972	41500.5
8400.	48.5672	5.0013	53.5684	5.1059	42010.6
8500.	48.6264	5.0025	53.6289	5.1150	42521.7
8600.	48.6849	5.0039	53.6888	5.1243	43033.6
8700.	48.7427	5.0053	53.7481	5.1340	43546.5
8800.	48.8000	5.0069	53.8068	5.1440	44060.4
8900.	48.8565	5.0085	53.8650	5.1543	44575.3
9000.	48.9125	5.0101	53.9227	5.1649	45091.3
9100.	48.9679	5.0119	53.9798	5.1758	45608.3
9200.	49.0227	5.0137	54.0364	5.1870	46126.5
9300.	49.0769	5.0157	54.0926	5.1985	46645.7
9400.	49.1305	5.0177	54.1482	5.2103	47166.2
9500.	49.1836	5.0198	54.2034	5.2224	47687.8
9600.	49.2362	5.0219	54.2582	5.2347	48210.6
9700.	49.2883	5.0242	54.3125	5.2474	48734.7
9800.	49.3398	5.0265	54.3664	5.2603	49260.1
9900.	49.3909	5.0290	54.4198	5.2735	49786.8
10000.	49.4414	5.0315	54.4729	5.2869	50314.8
10100.	49.4915	5.0341	54.5256	5.3006	50844.2

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.083260
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.34836
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.083206

Table A-7-1 Thermodynamic Functions for N^+

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
273.15	31.9565	5.7640	37.7204	5.1113	1574.4
298.15	32.4588	5.7082	38.1670	5.0880	1701.9
1000.	39.0197	5.2135	44.2331	4.9784	5213.5
1100.	39.5155	5.1920	44.7075	4.9766	5711.2
1200.	39.9665	5.1740	45.1405	4.9752	6208.8
1300.	40.3800	5.1587	45.5387	4.9742	6706.3
1400.	40.7618	5.1454	45.9073	4.9734	7203.6
1500.	41.1164	5.1340	46.2504	4.9728	7700.9
1600.	41.4474	5.1239	46.5713	4.9723	8198.2
1700.	41.7578	5.1149	46.8727	4.9721	8695.4
1800.	42.0499	5.1070	47.1569	4.9721	9192.6
1900.	42.3258	5.0999	47.4258	4.9724	9689.8
2000.	42.5873	5.0935	47.6808	4.9730	10187.1
2100.	42.8356	5.0878	47.9235	4.9740	10684.4
2200.	43.0722	5.0827	48.1549	4.9754	11181.9
2300.	43.2980	5.0781	48.3761	4.9774	11679.5
2400.	43.5141	5.0739	48.5880	4.9799	12177.4
2500.	43.7211	5.0702	48.7913	4.9830	12675.5
2600.	43.9199	5.0669	48.9868	4.9868	13174.0
2700.	44.1111	5.0640	49.1751	4.9913	13672.9
2800.	44.2952	5.0615	49.3567	4.9964	14172.3
2900.	44.4728	5.0594	49.5322	5.0023	14672.2
3000.	44.6443	5.0576	49.7019	5.0089	15172.8
3100.	44.8101	5.0561	49.8662	5.0162	15674.0
3200.	44.9706	5.0550	50.0256	5.0241	16176.0
3300.	45.1261	5.0542	50.1803	5.0327	16678.9
3400.	45.2770	5.0537	50.3307	5.0418	17182.6
3500.	45.4235	5.0535	50.4770	5.0516	17687.3
3600.	45.5659	5.0536	50.6195	5.0618	18192.9
3700.	45.7043	5.0540	50.7583	5.0725	18699.6
3800.	45.8391	5.0546	50.8937	5.0836	19207.4
3900.	45.9704	5.0555	51.0259	5.0951	19716.4
4000.	46.0984	5.0566	51.1550	5.1069	20226.5
4100.	46.2233	5.0580	51.2813	5.1189	20737.8
4200.	46.3452	5.0596	51.4048	5.1312	21250.3
4300.	46.4643	5.0614	51.5257	5.1436	21764.0
4400.	46.5807	5.0634	51.6441	5.1562	22279.0
4500.	46.6945	5.0656	51.7601	5.1688	22795.2
4600.	46.8058	5.0680	51.8738	5.1815	23312.8
4700.	46.9149	5.0705	51.9854	5.1942	23831.5
4800.	47.0216	5.0732	52.0949	5.2068	24351.6
4900.	47.1263	5.0761	52.2024	5.2194	24872.9
5000.	47.2289	5.0791	52.3080	5.2319	25395.5
5100.	47.3295	5.0822	52.4117	5.2442	25919.3
5200.	47.4282	5.0854	52.5136	5.2564	26444.3
5300.	47.5251	5.0888	52.6139	5.2685	26970.5
5400.	47.6202	5.0922	52.7125	5.2803	27498.0
5500.	47.7137	5.0957	52.8095	5.2920	28026.6
5600.	47.8056	5.0994	52.9049	5.3034	28556.4
5700.	47.8959	5.1030	52.9989	5.3146	29087.3
5800.	47.9846	5.1068	53.0914	5.3256	29619.3
5900.	48.0720	5.1106	53.1825	5.3363	30152.4
6000.	48.1579	5.1144	53.2723	5.3468	30686.6
6100.	48.2425	5.1183	53.3608	5.3570	31221.7
6200.	48.3257	5.1223	53.4480	5.3670	31758.0
6300.	48.4077	5.1262	53.5339	5.3767	32295.1

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 14.0075

Table A-7-1 Thermodynamic Functions for N^+ - continued

T °K	$\frac{-(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	48.4885	5.1302	53.6187	5.3861	32833.3
6500.	48.5680	5.1342	53.7022	5.3953	33372.4
6600.	48.6465	5.1382	53.7847	5.4042	33912.3
6700.	48.7238	5.1423	53.8660	5.4129	34453.2
6800.	48.8000	5.1463	53.9463	5.4213	34994.9
6900.	48.8751	5.1504	54.0255	5.4294	35537.4
7000.	48.9493	5.1544	54.1037	5.4373	36080.8
7100.	49.0224	5.1584	54.1808	5.4449	36624.9
7200.	49.0946	5.1625	54.2570	5.4524	37169.7
7300.	49.1658	5.1665	54.3323	5.4595	37715.3
7400.	49.2361	5.1705	54.4066	5.4665	38261.6
7500.	49.3056	5.1745	54.4801	5.4732	38808.6
7600.	49.3741	5.1785	54.5526	5.4797	39356.3
7700.	49.4419	5.1824	54.6243	5.4860	39904.6
7800.	49.5087	5.1863	54.6951	5.4921	40453.5
7900.	49.5748	5.1903	54.7651	5.4980	41003.0
8000.	49.6402	5.1941	54.8343	5.5038	41553.1
8100.	49.7047	5.1980	54.9027	5.5093	42103.7
8200.	49.7685	5.2018	54.9703	5.5147	42654.9
8300.	49.8316	5.2056	55.0372	5.5198	43206.7
8400.	49.8939	5.2094	55.1033	5.5249	43758.9
8500.	49.9556	5.2131	55.1688	5.5297	44311.6
8600.	50.0166	5.2168	55.2335	5.5344	44864.8
8700.	50.0769	5.2205	55.2975	5.5390	45418.5
8800.	50.1366	5.2242	55.3608	5.5434	45972.6
8900.	50.1957	5.2278	55.4235	5.5477	46527.2
9000.	50.2541	5.2314	55.4855	5.5519	47082.2
9100.	50.3119	5.2349	55.5468	5.5560	47637.6
9200.	50.3692	5.2384	55.6076	5.5599	48193.4
9300.	50.4258	5.2419	55.6677	5.5637	48749.6
9400.	50.4819	5.2453	55.7272	5.5674	49306.1
9500.	50.5374	5.2487	55.7862	5.5710	49863.0
9600.	50.5924	5.2521	55.8445	5.5745	50420.3
9700.	50.6468	5.2555	55.9023	5.5779	50977.9
9800.	50.7008	5.2588	55.9595	5.5813	51535.9
9900.	50.7542	5.2620	56.0162	5.5845	52094.2
10000.	50.8071	5.2653	56.0724	5.5877	52652.8
10100.	50.8595	5.2685	56.1280	5.5908	53211.7

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.071390
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.29870
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.071343

Table A-8-1 Thermodynamic Functions for O^+

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
273.15	31.6076	4.9681	36.5758	4.9681	1357.1
298.15	32.0427	4.9681	37.0109	4.9681	1481.3
1000.	38.0549	4.9681	43.0231	4.9681	4968.1
1100.	38.5285	4.9681	43.4966	4.9681	5465.0
1200.	38.9608	4.9681	43.9289	4.9681	5961.8
1300.	39.3584	4.9681	44.3266	4.9681	6458.6
1400.	39.7266	4.9681	44.6947	4.9681	6955.4
1500.	40.0694	4.9681	45.0375	4.9681	7452.2
1600.	40.3900	4.9681	45.3581	4.9682	7949.0
1700.	40.6912	4.9681	45.6593	4.9682	8445.9
1800.	40.9752	4.9681	45.9433	4.9682	8942.7
1900.	41.2438	4.9682	46.2119	4.9682	9439.5
2000.	41.4986	4.9682	46.4668	4.9682	9936.3
2100.	41.7410	4.9682	46.7092	4.9682	10433.1
2200.	41.9721	4.9682	46.9403	4.9682	10929.9
2300.	42.1930	4.9682	47.1611	4.9682	11426.8
2400.	42.4044	4.9682	47.3726	4.9683	11923.6
2500.	42.6072	4.9682	47.5754	4.9684	12420.4
2600.	42.8021	4.9682	47.7703	4.9685	12917.3
2700.	42.9896	4.9682	47.9578	4.9688	13414.1
2800.	43.1703	4.9682	48.1385	4.9691	13911.0
2900.	43.3446	4.9683	48.3129	4.9696	14408.0
3000.	43.5130	4.9683	48.4813	4.9703	14904.9
3100.	43.6759	4.9684	48.6443	4.9712	15402.0
3200.	43.8337	4.9685	48.8022	4.9724	15899.2
3300.	43.9866	4.9686	48.9552	4.9738	16396.5
3400.	44.1349	4.9688	49.1037	4.9757	16894.0
3500.	44.2789	4.9690	49.2480	4.9780	17391.7
3600.	44.4189	4.9693	49.3883	4.9809	17889.6
3700.	44.5551	4.9697	49.5248	4.9842	18387.9
3800.	44.6876	4.9701	49.6578	4.9882	18886.5
3900.	44.8167	4.9706	49.7874	4.9929	19385.5
4000.	44.9426	4.9713	49.9139	4.9983	19885.1
4100.	45.0654	4.9720	50.0374	5.0046	20385.2
4200.	45.1852	4.9729	50.1580	5.0116	20886.0
4300.	45.3022	4.9739	50.2761	5.0196	21387.6
4400.	45.4166	4.9750	50.3916	5.0284	21890.0
4500.	45.5284	4.9763	50.5047	5.0383	22393.3
4600.	45.6378	4.9778	50.6155	5.0491	22897.7
4700.	45.7448	4.9794	50.7242	5.0610	23403.2
4800.	45.8497	4.9812	50.8309	5.0740	23909.9
4900.	45.9524	4.9833	50.9357	5.0880	24418.0
5000.	46.0531	4.9855	51.0386	5.1031	24927.5
5100.	46.1519	4.9880	51.1398	5.1193	25438.7
5200.	46.2487	4.9907	51.2394	5.1367	25951.4
5300.	46.3438	4.9936	51.3374	5.1551	26466.0
5400.	46.4372	4.9968	51.4340	5.1746	26982.5
5500.	46.5289	5.0002	51.5291	5.1951	27501.0
5600.	46.6191	5.0039	51.6229	5.2168	28021.6
5700.	46.7077	5.0078	51.7154	5.2395	28544.4
5800.	46.7948	5.0120	51.8068	5.2632	29069.5
5900.	46.8805	5.0164	51.8969	5.2879	29597.0
6000.	46.9649	5.0212	51.9860	5.3135	30127.1
6100.	47.0479	5.0262	52.0741	5.3401	30659.8
6200.	47.1297	5.0315	52.1611	5.3676	31195.1
6300.	47.2102	5.0370	52.2472	5.3959	31733.3

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 15.9995

Table A-8-1 Thermodynamic Functions for O^+. - continued

T °K	$\frac{-(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	47.2896	5.0429	52.3324	5.4250	32274.4
6500.	47.3678	5.0490	52.4168	5.4550	32818.3
6600.	47.4449	5.0554	52.5003	5.4856	33365.4
6700.	47.5210	5.0620	52.5830	5.5169	33915.5
6800.	47.5961	5.0689	52.6650	5.5489	34468.8
6900.	47.6701	5.0761	52.7462	5.5814	35025.3
7000.	47.7432	5.0836	52.8268	5.6145	35585.1
7100.	47.8154	5.0913	52.9067	5.6481	36148.2
7200.	47.8866	5.0993	52.9859	5.6821	36714.7
7300.	47.9570	5.1075	53.0645	5.7165	37284.6
7400.	48.0266	5.1159	53.1425	5.7513	37858.0
7500.	48.0953	5.1247	53.2200	5.7863	38434.9
7600.	48.1632	5.1336	53.2968	5.8216	39015.3
7700.	48.2304	5.1428	53.3732	5.8571	39599.2
7800.	48.2968	5.1521	53.4490	5.8928	40186.7
7900.	48.3625	5.1617	53.5243	5.9285	40777.8
8000.	48.4275	5.1716	53.5991	5.9644	41372.4
8100.	48.4918	5.1816	53.6734	6.0002	41970.7
8200.	48.5555	5.1918	53.7472	6.0360	42572.5
8300.	48.6184	5.2022	53.8206	6.0717	43177.9
8400.	48.6808	5.2127	53.8935	6.1074	43786.8
8500.	48.7426	5.2234	53.9660	6.1428	44399.3
8600.	48.8037	5.2343	54.0381	6.1781	45015.4
8700.	48.8643	5.2454	54.1097	6.2132	45634.9
8800.	48.9243	5.2566	54.1809	6.2480	46258.0
8900.	48.9838	5.2679	54.2517	6.2825	46884.5
9000.	49.0427	5.2794	54.3221	6.3166	47514.5
9100.	49.1011	5.2910	54.3921	6.3504	48147.8
9200.	49.1590	5.3027	54.4617	6.3838	48784.6
9300.	49.2164	5.3145	54.5308	6.4168	49424.6
9400.	49.2733	5.3264	54.5997	6.4494	50067.9
9500.	49.3297	5.3384	54.6681	6.4814	50714.4
9600.	49.3857	5.3504	54.7361	6.5130	51364.2
9700.	49.4412	5.3626	54.8038	6.5441	52017.0
9800.	49.4962	5.3748	54.8710	6.5746	52673.0
9900.	49.5509	5.3871	54.9379	6.6045	53331.9
10000.	49.6051	5.3994	55.0045	6.6339	53993.9
10100.	49.6589	5.4118	55.0706	6.6627	54658.7

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.062502
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.26151
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.062461

Table A-9-1 Thermodynamic Functions for F^+

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o-H^o_0}{T}$	S^o	C^o_p	$H^o-H^o_0$
273.15	32.7783	5.3560	38.1343	5.6453	1463.0
298.15	33.2484	5.3792	38.6275	5.6169	1603.8
1000.	39.7704	5.3073	45.0777	5.0973	5307.3
1100.	40.2753	5.2873	45.5625	5.0771	5816.0
1200.	40.7345	5.2691	46.0036	5.0613	6322.9
1300.	41.1556	5.2526	46.4082	5.0486	6828.3
1400.	41.5443	5.2376	46.7820	5.0383	7332.7
1500.	41.9052	5.2240	47.1293	5.0298	7836.1
1600.	42.2420	5.2117	47.4536	5.0228	8338.7
1700.	42.5576	5.2004	47.7580	5.0169	8840.7
1800.	42.8545	5.1900	48.0446	5.0119	9342.1
1900.	43.1349	5.1806	48.3154	5.0076	9843.1
2000.	43.4004	5.1718	48.5722	5.0040	10343.6
2100.	43.6525	5.1637	48.8163	5.0009	10843.9
2200.	43.8926	5.1563	49.0488	4.9982	11343.8
2300.	44.1216	5.1494	49.2710	4.9959	11843.5
2400.	44.3406	5.1429	49.4836	4.9940	12343.0
2500.	44.5505	5.1369	49.6874	4.9925	12842.3
2600.	44.7518	5.1314	49.8832	4.9912	13341.5
2700.	44.9454	5.1261	50.0715	4.9904	13840.6
2800.	45.1317	5.1213	50.2530	4.9898	14339.6
2900.	45.3113	5.1167	50.4281	4.9896	14838.6
3000.	45.4847	5.1125	50.5973	4.9898	15337.5
3100.	45.6523	5.1086	50.7609	4.9903	15836.5
3200.	45.8144	5.1049	50.9193	4.9912	16335.6
3300.	45.9715	5.1015	51.0729	4.9925	16834.8
3400.	46.1237	5.0983	51.2220	4.9942	17334.1
3500.	46.2715	5.0953	51.3668	4.9963	17833.6
3600.	46.4150	5.0926	51.5076	4.9988	18333.4
3700.	46.5545	5.0901	51.6446	5.0018	18833.4
3800.	46.6902	5.0878	51.7780	5.0051	19333.8
3900.	46.8223	5.0858	51.9081	5.0089	19834.5
4000.	46.9510	5.0839	52.0349	5.0131	20335.6
4100.	47.0766	5.0822	52.1588	5.0177	20837.1
4200.	47.1990	5.0807	52.2798	5.0227	21339.1
4300.	47.3186	5.0795	52.3980	5.0281	21841.6
4400.	47.4353	5.0783	52.5137	5.0338	22344.7
4500.	47.5494	5.0774	52.6269	5.0399	22848.4
4600.	47.6610	5.0767	52.7377	5.0464	23352.7
4700.	47.7702	5.0761	52.8463	5.0531	23857.7
4800.	47.8771	5.0757	52.9528	5.0602	24363.4
4900.	47.9817	5.0755	53.0572	5.0676	24869.7
5000.	48.0842	5.0754	53.1596	5.0752	25376.9
5100.	48.1847	5.0755	53.2602	5.0831	25884.8
5200.	48.2833	5.0757	53.3590	5.0911	26393.5
5300.	48.3800	5.0760	53.4560	5.0994	26903.0
5400.	48.4749	5.0766	53.5514	5.1079	27413.4
5500.	48.5680	5.0772	53.6452	5.1165	27924.6
5600.	48.6595	5.0780	53.7375	5.1253	28436.7
5700.	48.7494	5.0789	53.8283	5.1341	28949.7
5800.	48.8378	5.0799	53.9177	5.1431	29463.5
5900.	48.9246	5.0811	54.0057	5.1522	29978.3
6000.	49.0100	5.0823	54.0923	5.1613	30494.0
6100.	49.0940	5.0837	54.1777	5.1704	31010.6
6200.	49.1767	5.0852	54.2619	5.1796	31528.1
6300.	49.2581	5.0867	54.3448	5.1888	32046.5

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 19.00

Table A-9-1 Thermodynamic Functions for F^+ - continued

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
6400.	49.3382	5.0884	54.4266	5.1980	32565.8
6500.	49.4171	5.0902	54.5073	5.2072	33086.1
6600.	49.4948	5.0920	54.5868	5.2163	33607.3
6700.	49.5714	5.0939	54.6653	5.2254	34129.3
6800.	49.6469	5.0959	54.7428	5.2344	34652.3
6900.	49.7213	5.0980	54.8193	5.2434	35176.2
7000.	49.7947	5.1001	54.8948	5.2522	35701.0
7100.	49.8670	5.1023	54.9694	5.2610	36226.7
7200.	49.9384	5.1046	55.0430	5.2697	36753.2
7300.	50.0088	5.1069	55.1158	5.2783	37280.6
7400.	50.0783	5.1093	55.1876	5.2868	37808.8
7500.	50.1469	5.1117	55.2587	5.2951	38337.9
7600.	50.2147	5.1142	55.3289	5.3033	38867.9
7700.	50.2815	5.1167	55.3982	5.3114	39398.6
7800.	50.3476	5.1192	55.4668	5.3194	39930.1
7900.	50.4128	5.1218	55.5346	5.3272	40462.5
8000.	50.4772	5.1244	55.6017	5.3348	40995.6
8100.	50.5409	5.1271	55.6680	5.3423	41529.4
8200.	50.6038	5.1298	55.7336	5.3497	42064.0
8300.	50.6660	5.1325	55.7985	5.3569	42599.4
8400.	50.7275	5.1352	55.8627	5.3639	43135.4
8500.	50.7883	5.1379	55.9262	5.3708	43672.2
8600.	50.8484	5.1406	55.9891	5.3775	44209.6
8700.	50.9079	5.1434	56.0513	5.3841	44747.7
8800.	50.9667	5.1462	56.1128	5.3905	45286.4
8900.	51.0248	5.1490	56.1738	5.3967	45825.8
9000.	51.0824	5.1517	56.2341	5.4028	46365.7
9100.	51.1393	5.1545	56.2939	5.4087	46906.3
9200.	51.1957	5.1573	56.3530	5.4145	47447.5
9300.	51.2514	5.1601	56.4116	5.4200	47989.2
9400.	51.3066	5.1629	56.4696	5.4255	48531.5
9500.	51.3613	5.1657	56.5270	5.4307	49074.3
9600.	51.4154	5.1685	56.5839	5.4358	49617.6
9700.	51.4690	5.1713	56.6403	5.4408	50161.4
9800.	51.5220	5.1741	56.6961	5.4455	50705.8
9900.	51.5746	5.1768	56.7514	5.4502	51250.5
10000.	51.6266	5.1796	56.8062	5.4546	51795.8
10100.	51.6782	5.1323	56.8605	5.4590	52341.5

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.052632
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.22021
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.052598

Table A-10-1 Thermodynamic Functions for Ne^+

T °K	$\frac{-(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
273.15	32.3159	5.0342	37.3501	5.2379	1375.1
298.15	32.7576	5.0533	37.8109	5.2858	1506.6
1000.	39.0461	5.2804	44.3265	5.2704	5280.4
1100.	39.5493	5.2779	44.8272	5.2367	5805.7
1200.	40.0083	5.2732	45.2815	5.2074	6327.9
1300.	40.4302	5.2672	45.6973	5.1819	6847.3
1400.	40.8203	5.2603	46.0805	5.1600	7364.4
1500.	41.1829	5.2529	46.4359	5.1410	7879.4
1600.	41.5217	5.2454	46.7671	5.1244	8392.6
1700.	41.8395	5.2379	47.0773	5.1100	8904.3
1800.	42.1386	5.2304	47.3690	5.0975	9414.7
1900.	42.4212	5.2231	47.6443	5.0864	9923.9
2000.	42.6890	5.2160	47.9050	5.0767	10432.0
2100.	42.9433	5.2092	48.1525	5.0681	10939.3
2200.	43.1855	5.2026	48.3881	5.0604	11445.7
2300.	43.4166	5.1962	48.6128	5.0536	11951.4
2400.	43.6376	5.1902	48.8278	5.0474	12456.4
2500.	43.8494	5.1844	49.0337	5.0419	12960.9
2600.	44.0526	5.1788	49.2314	5.0370	13464.8
2700.	44.2479	5.1734	49.4214	5.0325	13968.3
2800.	44.4360	5.1683	49.6043	5.0284	14471.3
2900.	44.6173	5.1634	49.7807	5.0247	14974.0
3000.	44.7922	5.1588	49.9510	5.0214	15476.3
3100.	44.9613	5.1543	50.1156	5.0183	15978.3
3200.	45.1249	5.1500	50.2749	5.0154	16479.9
3300.	45.2833	5.1459	50.4292	5.0129	16981.4
3400.	45.4369	5.1419	50.5788	5.0105	17482.5
3500.	45.5859	5.1381	50.7240	5.0083	17983.5
3600.	45.7306	5.1345	50.8651	5.0062	18484.2
3700.	45.8712	5.1310	51.0022	5.0043	18984.7
3800.	46.0080	5.1276	51.1356	5.0026	19485.1
3900.	46.1411	5.1244	51.2656	5.0009	19985.2
4000.	46.2708	5.1213	51.3921	4.9994	20485.2
4100.	46.3973	5.1183	51.5156	4.9980	20985.1
4200.	46.5206	5.1154	51.6360	4.9967	21484.9
4300.	46.6409	5.1127	51.7536	4.9955	21984.5
4400.	46.7584	5.1100	51.8684	4.9943	22483.9
4500.	46.8732	5.1074	51.9806	4.9932	22983.3
4600.	46.9854	5.1049	52.0904	4.9922	23482.6
4700.	47.0952	5.1025	52.1977	4.9912	23981.8
4800.	47.2026	5.1002	52.3028	4.9903	24480.8
4900.	47.3077	5.0979	52.4057	4.9895	24979.8
5000.	47.4107	5.0957	52.5065	4.9887	25478.7
5100.	47.5116	5.0936	52.6052	4.9879	25977.6
5200.	47.6105	5.0916	52.7021	4.9872	26476.3
5300.	47.7075	5.0896	52.7971	4.9865	26975.0
5400.	47.8026	5.0877	52.8903	4.9859	27473.6
5500.	47.8959	5.0859	52.9818	4.9853	27972.2
5600.	47.9875	5.0840	53.0716	4.9847	28470.7
5700.	48.0775	5.0823	53.1598	4.9841	28969.1
5800.	48.1659	5.0806	53.2465	4.9836	29467.5
5900.	48.2527	5.0790	53.3317	4.9831	29965.8
6000.	48.3381	5.0774	53.4154	4.9826	30464.1
6100.	48.4220	5.0758	53.4978	4.9822	30962.4
6200.	48.5045	5.0743	53.5788	4.9817	31460.6
6300.	48.5857	5.0728	53.6585	4.9813	31958.7

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 20.1825

Table A-10-1 Thermodynamic Functions for Ne^+ - continued

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
6400.	48.6656	5.0714	53.7369	4.9809	32456.8
6500.	48.7442	5.0700	53.8142	4.9806	32954.9
6600.	48.8216	5.0686	53.8902	4.9802	33452.9
6700.	48.8978	5.0673	53.9651	4.9799	33950.9
6800.	48.9728	5.0660	54.0389	4.9795	34448.9
6900.	49.0468	5.0648	54.1115	4.9792	34946.8
7000.	49.1197	5.0635	54.1832	4.9789	35444.7
7100.	49.1915	5.0623	54.2538	4.9786	35942.6
7200.	49.2623	5.0612	54.3234	4.9783	36440.5
7300.	49.3321	5.0600	54.3921	4.9781	36938.3
7400.	49.4009	5.0589	54.4598	4.9778	37436.1
7500.	49.4688	5.0578	54.5267	4.9776	37933.9
7600.	49.5358	5.0568	54.5926	4.9773	38431.6
7700.	49.6019	5.0558	54.6576	4.9771	38929.3
7800.	49.6671	5.0547	54.7219	4.9769	39427.0
7900.	49.7315	5.0538	54.7853	4.9767	39924.7
8000.	49.7951	5.0528	54.8479	4.9764	40422.3
8100.	49.8578	5.0518	54.9097	4.9763	40920.0
8200.	49.9198	5.0509	54.9707	4.9761	41417.6
8300.	49.9810	5.0500	55.0311	4.9759	41915.2
8400.	50.0415	5.0491	55.0906	4.9757	42412.8
8500.	50.1013	5.0483	55.1495	4.9755	42910.3
8600.	50.1603	5.0474	55.2077	4.9754	43407.9
8700.	50.2186	5.0466	55.2652	4.9752	43905.4
8800.	50.2763	5.0458	55.3221	4.9750	44402.9
8900.	50.3333	5.0450	55.3783	4.9749	44900.4
9000.	50.3897	5.0442	55.4339	4.9747	45397.9
9100.	50.4454	5.0434	55.4889	4.9746	45895.4
9200.	50.5005	5.0427	55.5432	4.9745	46392.8
9300.	50.5550	5.0420	55.5970	4.9743	46890.3
9400.	50.6090	5.0412	55.6502	4.9742	47387.7
9500.	50.6623	5.0405	55.7029	4.9741	47885.1
9600.	50.7151	5.0398	55.7549	4.9740	48382.5
9700.	50.7673	5.0392	55.8065	4.9738	48879.9
9800.	50.8190	5.0385	55.8575	4.9737	49377.3
9900.	50.8701	5.0378	55.9080	4.9736	49874.6
10000.	50.9208	5.0372	55.9580	4.9735	50372.0
10100.	50.9709	5.0366	56.0075	4.9734	50869.3

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.049548
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.20731
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.049516

Table A-11-1 Thermodynamic Functions for Na^+

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
273.15	29.9332	4.9681	34.9014	4.9681	1357.1
298.15	30.3683	4.9681	35.3365	4.9681	1481.3
1000.	36.3806	4.9681	41.3487	4.9681	4968.1
1100.	36.8541	4.9681	41.8222	4.9681	5465.0
1200.	37.2864	4.9681	42.2545	4.9681	5961.8
1300.	37.6840	4.9681	42.6522	4.9681	6458.6
1400.	38.0522	4.9681	43.0204	4.9681	6955.4
1500.	38.3950	4.9681	43.3631	4.9681	7452.2
1600.	38.7156	4.9681	43.6838	4.9681	7949.0
1700.	39.0168	4.9681	43.9850	4.9681	8445.9
1800.	39.3008	4.9681	44.2689	4.9681	8942.7
1900.	39.5694	4.9681	44.5375	4.9681	9439.5
2000.	39.8242	4.9681	44.7924	4.9681	9936.3
2100.	40.0666	4.9681	45.0348	4.9681	10433.1
2200.	40.2977	4.9681	45.2659	4.9681	10929.9
2300.	40.5186	4.9681	45.4867	4.9681	11426.7
2400.	40.7300	4.9681	45.6982	4.9681	11923.6
2500.	40.9328	4.9681	45.9010	4.9681	12420.4
2600.	41.1277	4.9681	46.0958	4.9681	12917.2
2700.	41.3152	4.9681	46.2833	4.9681	13414.0
2800.	41.4959	4.9681	46.4640	4.9681	13910.8
2900.	41.6702	4.9681	46.6384	4.9681	14407.6
3000.	41.8386	4.9681	46.8068	4.9681	14904.4
3100.	42.0015	4.9681	46.9697	4.9681	15401.3
3200.	42.1593	4.9681	47.1274	4.9681	15898.1
3300.	42.3122	4.9681	47.2803	4.9681	16394.9
3400.	42.4605	4.9681	47.4286	4.9681	16891.7
3500.	42.6045	4.9681	47.5726	4.9681	17388.5
3600.	42.7444	4.9681	47.7126	4.9681	17885.3
3700.	42.8806	4.9681	47.8487	4.9681	18382.2
3800.	43.0131	4.9681	47.9812	4.9681	18879.0
3900.	43.1421	4.9681	48.1103	4.9681	19375.8
4000.	43.2679	4.9681	48.2360	4.9681	19872.6
4100.	43.3906	4.9681	48.3587	4.9681	20369.4
4200.	43.5103	4.9681	48.4784	4.9681	20866.2
4300.	43.6272	4.9681	48.5953	4.9681	21363.0
4400.	43.7414	4.9681	48.7096	4.9681	21859.9
4500.	43.8531	4.9681	48.8212	4.9681	22356.7
4600.	43.9622	4.9681	48.9304	4.9681	22853.5
4700.	44.0691	4.9681	49.0372	4.9681	23350.3
4800.	44.1737	4.9681	49.1418	4.9681	23847.1
4900.	44.2761	4.9681	49.2443	4.9681	24343.9
5000.	44.3765	4.9681	49.3447	4.9681	24840.7
5100.	44.4749	4.9681	49.4430	4.9681	25337.6
5200.	44.5714	4.9681	49.5395	4.9681	25834.4
5300.	44.6660	4.9681	49.6341	4.9681	26331.2
5400.	44.7589	4.9681	49.7270	4.9681	26828.0
5500.	44.8500	4.9681	49.8182	4.9681	27324.8
5600.	44.9395	4.9681	49.9077	4.9681	27821.6
5700.	45.0275	4.9681	49.9956	4.9681	28318.5
5800.	45.1139	4.9681	50.0820	4.9681	28815.3
5900.	45.1988	4.9681	50.1670	4.9681	29312.1
6000.	45.2823	4.9681	50.2505	4.9681	29808.9
6100.	45.3644	4.9681	50.3326	4.9681	30305.7
6200.	45.4452	4.9681	50.4134	4.9681	30802.5
6300.	45.5247	4.9681	50.4928	4.9681	31299.3

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 22.9905

Table A-11-1 Thermodynamic Functions for Na^+ - continued

T °K	$-(F^o-H_0^o)/T$	$(H^o - H_0^o)/T$	S^o	C_p^o	$H^o - H_0^o$
6400.	45.6029	4.9681	50.5711	4.9681	31796.2
6500.	45.6800	4.9681	50.6481	4.9681	32293.0
6600.	45.7558	4.9681	50.7240	4.9681	32789.8
6700.	45.8305	4.9681	50.7987	4.9681	33286.6
6800.	45.9041	4.9681	50.8723	4.9681	33783.4
6900.	45.9767	4.9681	50.9448	4.9681	34280.2
7000.	46.0481	4.9681	51.0163	4.9681	34777.0
7100.	46.1186	4.9681	51.0868	4.9681	35273.9
7200.	46.1881	4.9681	51.1563	4.9681	35770.7
7300.	46.2566	4.9681	51.2248	4.9681	36267.5
7400.	46.3242	4.9681	51.2924	4.9681	36764.3
7500.	46.3909	4.9681	51.3591	4.9681	37261.1
7600.	46.4567	4.9681	51.4249	4.9681	37757.9
7700.	46.5217	4.9681	51.4898	4.9681	38254.8
7800.	46.5858	4.9681	51.5539	4.9681	38751.6
7900.	46.6491	4.9681	51.6172	4.9681	39248.4
8000.	46.7115	4.9681	51.6797	4.9681	39745.2
8100.	46.7733	4.9681	51.7414	4.9681	40242.0
8200.	46.8342	4.9681	51.8024	4.9681	40738.8
8300.	46.8944	4.9681	51.8626	4.9681	41235.6
8400.	46.9539	4.9681	51.9221	4.9681	41732.5
8500.	47.0127	4.9681	51.9809	4.9681	42229.3
8600.	47.0708	4.9681	52.0390	4.9681	42726.1
8700.	47.1283	4.9681	52.0964	4.9681	43222.9
8800.	47.1851	4.9681	52.1532	4.9681	43719.7
8900.	47.2412	4.9681	52.2094	4.9681	44216.5
9000.	47.2967	4.9681	52.2649	4.9681	44713.3
9100.	47.3516	4.9681	52.3198	4.9681	45210.2
9200.	47.4059	4.9681	52.3741	4.9681	45707.0
9300.	47.4596	4.9681	52.4278	4.9681	46203.8
9400.	47.5128	4.9681	52.4809	4.9681	46700.6
9500.	47.5653	4.9681	52.5335	4.9681	47197.4
9600.	47.6174	4.9681	52.5855	4.9681	47694.2
9700.	47.6688	4.9681	52.6370	4.9681	48191.1
9800.	47.7198	4.9681	52.6879	4.9681	48687.9
9900.	47.7702	4.9681	52.7384	4.9681	49184.7
10000.	47.8202	4.9681	52.7883	4.9681	49681.5
10100.	47.8696	4.9681	52.8377	4.9681	50178.3

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.043496
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.18199
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.043468

Table A-12-1 Thermodynamic Functions for Mg^+

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
273.15	31.4783	4.9681	36.4464	4.9681	1357.1
298.15	31.9134	4.9681	36.8815	4.9681	1481.3
1000.	37.9256	4.9681	42.8938	4.9681	4968.1
1100.	38.3991	4.9681	43.3673	4.9681	5465.0
1200.	38.8314	4.9681	43.7996	4.9681	5961.8
1300.	39.2291	4.9681	44.1972	4.9681	6458.6
1400.	39.5973	4.9681	44.5654	4.9681	6955.4
1500.	39.9400	4.9681	44.9082	4.9681	7452.2
1600.	40.2607	4.9681	45.2288	4.9681	7949.0
1700.	40.5619	4.9681	45.5300	4.9681	8445.9
1800.	40.8458	4.9681	45.8140	4.9681	8942.7
1900.	41.1144	4.9681	46.0826	4.9681	9439.5
2000.	41.3693	4.9681	46.3374	4.9681	9936.3
2100.	41.6117	4.9681	46.5798	4.9682	10433.1
2200.	41.8428	4.9681	46.8109	4.9682	10929.9
2300.	42.0636	4.9681	47.0318	4.9682	11426.7
2400.	42.2751	4.9682	47.2432	4.9682	11923.6
2500.	42.4779	4.9682	47.4460	4.9682	12420.4
2600.	42.6727	4.9682	47.6409	4.9682	12917.2
2700.	42.8602	4.9682	47.8284	4.9682	13414.0
2800.	43.0409	4.9682	48.0091	4.9682	13910.8
2900.	43.2153	4.9682	48.1834	4.9682	14407.6
3000.	43.3837	4.9682	48.3518	4.9682	14904.5
3100.	43.5466	4.9682	48.5147	4.9683	15401.3
3200.	43.7043	4.9682	48.6725	4.9683	15898.1
3300.	43.8572	4.9682	48.8254	4.9684	16394.9
3400.	44.0055	4.9682	48.9737	4.9685	16891.8
3500.	44.1495	4.9682	49.1177	4.9687	17388.7
3600.	44.2895	4.9682	49.2577	4.9689	17885.5
3700.	44.4256	4.9682	49.3938	4.9692	18382.4
3800.	44.5581	4.9683	49.5264	4.9696	18879.4
3900.	44.6872	4.9683	49.6555	4.9701	19376.4
4000.	44.8129	4.9684	49.7813	4.9707	19873.4
4100.	44.9356	4.9684	49.9041	4.9715	20370.5
4200.	45.0554	4.9685	50.0239	4.9725	20867.7
4300.	45.1723	4.9686	50.1409	4.9736	21365.0
4400.	45.2865	4.9687	50.2552	4.9750	21862.4
4500.	45.3982	4.9689	50.3671	4.9767	22360.0
4600.	45.5074	4.9691	50.4765	4.9786	22857.8
4700.	45.6142	4.9693	50.5836	4.9808	23355.8
4800.	45.7189	4.9696	50.6884	4.9834	23854.0
4900.	45.8213	4.9699	50.7912	4.9864	24352.4
5000.	45.9217	4.9703	50.8920	4.9897	24851.3
5100.	46.0202	4.9707	50.9908	4.9935	25350.4
5200.	46.1167	4.9711	51.0879	4.9978	25850.0
5300.	46.2114	4.9717	51.1831	5.0025	26350.0
5400.	46.3043	4.9723	51.2767	5.0078	26850.5
5500.	46.3956	4.9730	51.3686	5.0136	27351.6
5600.	46.4852	4.9738	51.4590	5.0200	27853.2
5700.	46.5732	4.9747	51.5479	5.0269	28355.6
5800.	46.6598	4.9756	51.6354	5.0344	28858.6
5900.	46.7448	4.9767	51.7215	5.0426	29362.5
6000.	46.8285	4.9779	51.8063	5.0514	29867.2
6100.	46.9108	4.9791	51.8899	5.0608	30372.8
6200.	46.9917	4.9805	51.9723	5.0710	30879.4
6300.	47.0714	4.9821	52.0535	5.0817	31387.0

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 24.32

Table A-12-1 Thermodynamic Functions for Mg^+ - continued

T °K	$\frac{-(F^o-H_0^o)}{T}$	$\frac{H^o - H_0^o}{T}$	S^o	C_p^o	$H^o - H_0^o$
6400.	47.1499	4.9837	52.1336	5.0932	31895.7
6500.	47.2272	4.9855	52.2127	5.1054	32405.7
6600.	47.3033	4.9874	52.2907	5.1182	32916.8
6700.	47.3783	4.9895	52.3678	5.1317	33429.3
6800.	47.4522	4.9916	52.4439	5.1460	33943.2
6900.	47.5252	4.9940	52.5192	5.1609	34458.5
7000.	47.5970	4.9965	52.5935	5.1765	34975.4
7100.	47.6679	4.9991	52.6671	5.1928	35493.9
7200.	47.7379	5.0019	52.7398	5.2098	36014.0
7300.	47.8069	5.0049	52.8118	5.2275	36535.9
7400.	47.8750	5.0080	52.8830	5.2458	37059.5
7500.	47.9422	5.0113	52.9536	5.2648	37585.0
7600.	48.0086	5.0148	53.0235	5.2845	38112.5
7700.	48.0742	5.0184	53.0927	5.3048	38642.0
7800.	48.1390	5.0222	53.1612	5.3257	39173.5
7900.	48.2030	5.0262	53.2292	5.3473	39707.1
8000.	48.2662	5.0304	53.2966	5.3694	40243.0
8100.	48.3288	5.0347	53.3635	5.3922	40781.0
8200.	48.3906	5.0392	53.4298	5.4156	41321.4
8300.	48.4517	5.0439	53.4956	5.4395	41864.2
8400.	48.5121	5.0487	53.5609	5.4640	42409.3
8500.	48.5719	5.0538	53.6257	5.4890	42957.0
8600.	48.6310	5.0590	53.6900	5.5146	43507.2
8700.	48.6896	5.0644	53.7539	5.5407	44059.9
8800.	48.7475	5.0699	53.8174	5.5673	44615.3
8900.	48.8048	5.0757	53.8805	5.5944	45173.4
9000.	48.8615	5.0816	53.9431	5.6220	45734.2
9100.	48.9177	5.0877	54.0054	5.6501	46297.8
9200.	48.9734	5.0939	54.0673	5.6787	46864.2
9300.	49.0285	5.1004	54.1288	5.7077	47433.6
9400.	49.0830	5.1070	54.1900	5.7372	48005.8
9500.	49.1371	5.1138	54.2509	5.7672	48581.0
9600.	49.1907	5.1208	54.3115	5.7975	49159.3
9700.	49.2438	5.1279	54.3717	5.8284	49740.5
9800.	49.2964	5.1352	54.4316	5.8597	50324.9
9900.	49.3486	5.1427	54.4913	5.8914	50912.5
10000.	49.4003	5.1503	54.5507	5.9235	51503.2
10100.	49.4516	5.1581	54.6098	5.9561	52097.2

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.041118
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.17204
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.041091

Table A-13-1 Thermodynamic Functions for Al^+

T °K	$-(F^o-H^o_0)/T$	$(H^o-H^o_0)/T$	S^o	C^o_p	$H^o-H^o_0$
273.15	30.4102	4.9681	35.3784	4.9681	1357.1
298.15	30.8453	4.9681	35.8135	4.9681	1481.3
1000.	36.8576	4.9681	41.8257	4.9681	4968.1
1100.	37.3311	4.9681	42.2992	4.9681	5465.0
1200.	37.7634	4.9681	42.7315	4.9681	5961.8
1300.	38.1610	4.9681	43.1292	4.9681	6458.6
1400.	38.5292	4.9681	43.4974	4.9681	6955.4
1500.	38.8720	4.9681	43.8401	4.9681	7452.2
1600.	39.1926	4.9681	44.1608	4.9681	7949.0
1700.	39.4938	4.9681	44.4619	4.9681	8445.9
1800.	39.7778	4.9681	44.7459	4.9681	8942.7
1900.	40.0464	4.9681	45.0145	4.9681	9439.5
2000.	40.3012	4.9681	45.2694	4.9681	9936.3
2100.	40.5436	4.9681	45.5118	4.9681	10433.1
2200.	40.7747	4.9681	45.7429	4.9682	10929.9
2300.	40.9956	4.9681	45.9637	4.9682	11426.7
2400.	41.2070	4.9682	46.1752	4.9682	11923.6
2500.	41.4098	4.9682	46.3780	4.9682	12420.4
2600.	41.6047	4.9682	46.5728	4.9682	12917.2
2700.	41.7922	4.9682	46.7603	4.9682	13414.0
2800.	41.9729	4.9682	46.9410	4.9682	13910.8
2900.	42.1472	4.9682	47.1154	4.9682	14407.6
3000.	42.3156	4.9682	47.2838	4.9682	14904.5
3100.	42.4785	4.9682	47.4467	4.9683	15401.3
3200.	42.6363	4.9682	47.6044	4.9684	15898.1
3300.	42.7891	4.9682	47.7573	4.9685	16395.0
3400.	42.9375	4.9682	47.9056	4.9687	16891.8
3500.	43.0815	4.9682	48.0497	4.9690	17388.7
3600.	43.2214	4.9682	48.1897	4.9694	17885.6
3700.	43.3576	4.9683	48.3258	4.9699	18382.6
3800.	43.4901	4.9683	48.4584	4.9706	18879.6
3900.	43.6191	4.9684	48.5875	4.9715	19376.7
4000.	43.7449	4.9685	48.7134	4.9726	19873.9
4100.	43.8676	4.9686	48.8362	4.9741	20371.3
4200.	43.9873	4.9688	48.9561	4.9759	20868.8
4300.	44.1042	4.9689	49.0732	4.9781	21366.5
4400.	44.2185	4.9692	49.1877	4.9808	21864.4
4500.	44.3302	4.9695	49.2996	4.9840	22362.6
4600.	44.4394	4.9698	49.4092	4.9879	22861.2
4700.	44.5463	4.9703	49.5165	4.9924	23360.2
4800.	44.6509	4.9708	49.6217	4.9977	23859.7
4900.	44.7534	4.9714	49.7248	5.0039	24359.8
5000.	44.8539	4.9721	49.8260	5.0109	24860.5
5100.	44.9523	4.9729	49.9253	5.0189	25362.0
5200.	45.0489	4.9739	50.0228	5.0280	25864.4
5300.	45.1437	4.9750	50.1187	5.0383	26367.7
5400.	45.2367	4.9763	50.2130	5.0497	26872.1
5500.	45.3280	4.9778	50.3057	5.0625	27377.7
5600.	45.4177	4.9794	50.3971	5.0766	27884.6
5700.	45.5058	4.9812	50.4871	5.0921	28393.0
5800.	45.5925	4.9833	50.5758	5.1091	28903.1
5900.	45.6777	4.9856	50.6633	5.1276	29414.9
6000.	45.7615	4.9881	50.7496	5.1478	29928.6
6100.	45.8440	4.9909	50.8349	5.1695	30444.5
6200.	45.9252	4.9940	50.9191	5.1930	30962.6
6300.	46.0051	4.9973	51.0024	5.2182	31483.2

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 26.98

Table A-13-1 Thermodynamic Functions for Al^+ - continued

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
6400.	46.0838	5.0010	51.0848	5.2451	32006.3
6500.	46.1614	5.0050	51.1663	5.2739	32532.2
6600.	46.2378	5.0093	51.2471	5.3044	33061.1
6700.	46.3132	5.0139	51.3271	5.3367	33593.2
6800.	46.3875	5.0189	51.4064	5.3709	34128.6
6900.	46.4608	5.0243	51.4851	5.4069	34667.4
7000.	46.5332	5.0300	51.5632	5.4448	35210.0
7100.	46.6045	5.0361	51.6407	5.4844	35756.4
7200.	46.6750	5.0426	51.7177	5.5259	36306.9
7300.	46.7446	5.0495	51.7942	5.5692	36861.7
7400.	46.8134	5.0569	51.8702	5.6142	37420.8
7500.	46.8813	5.0646	51.9459	5.6610	37984.6
7600.	46.9484	5.0728	52.0212	5.7095	38553.1
7700.	47.0148	5.0814	52.0962	5.7596	39126.5
7800.	47.0804	5.0904	52.1708	5.8114	39705.1
7900.	47.1453	5.0999	52.2452	5.8648	40288.9
8000.	47.2096	5.1098	52.3193	5.9196	40878.1
8100.	47.2731	5.1201	52.3932	5.9760	41472.9
8200.	47.3360	5.1309	52.4669	6.0338	42073.3
8300.	47.3982	5.1421	52.5404	6.0930	42679.7
8400.	47.4599	5.1538	52.6137	6.1534	43292.0
8500.	47.5210	5.1659	52.6869	6.2151	43910.4
8600.	47.5815	5.1785	52.7599	6.2779	44535.0
8700.	47.6414	5.1915	52.8329	6.3419	45166.0
8800.	47.7008	5.2049	52.9057	6.4068	45803.4
8900.	47.7597	5.2188	52.9785	6.4727	46447.4
9000.	47.8181	5.2331	53.0512	6.5395	47098.0
9100.	47.8760	5.2478	53.1238	6.6071	47755.3
9200.	47.9334	5.2630	53.1964	6.6755	48419.5
9300.	47.9904	5.2785	53.2690	6.7445	49090.4
9400.	48.0469	5.2945	53.3415	6.8140	49768.4
9500.	48.1031	5.3109	53.4139	6.8841	50453.3
9600.	48.1588	5.3276	53.4864	6.9546	51145.2
9700.	48.2141	5.3448	53.5588	7.0255	51844.2
9800.	48.2690	5.3623	53.6312	7.0967	52550.3
9900.	48.3235	5.3802	53.7037	7.1681	53263.6
10000.	48.3777	5.3984	53.7761	7.2396	53983.9
10100.	48.4315	5.4170	53.8484	7.3112	54711.5

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.037064
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.15508
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.037040

Table A-14-1 Thermodynamic Functions for Si^+

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
273.15	32.6325	5.8876	38.5201	5.9349	1608.2
298.15	33.1481	5.8865	39.0346	5.8177	1755.1
1000.	40.0298	5.4362	45.4660	5.0515	5436.2
1100.	40.5462	5.4005	45.9467	5.0366	5940.5
1200.	41.0148	5.3697	46.3844	5.0254	6443.6
1300.	41.4435	5.3429	46.7863	5.0167	6945.7
1400.	41.8385	5.3193	47.1579	5.0098	7447.0
1500.	42.2048	5.2985	47.5033	5.0043	7947.7
1600.	42.5462	5.2799	47.8261	4.9998	8447.9
1700.	42.8658	5.2634	48.1291	4.9961	8947.7
1800.	43.1662	5.2484	48.4146	4.9930	9447.2
1900.	43.4496	5.2349	48.6845	4.9904	9946.3
2000.	43.7178	5.2226	48.9404	4.9882	10445.3
2100.	43.9723	5.2114	49.1837	4.9863	10944.0
2200.	44.2145	5.2011	49.4157	4.9846	11442.5
2300.	44.4455	5.1917	49.6372	4.9832	11940.9
2400.	44.6663	5.1830	49.8493	4.9819	12439.2
2500.	44.8777	5.1749	50.0526	4.9808	12937.3
2600.	45.0805	5.1674	50.2479	4.9799	13435.3
2700.	45.2754	5.1605	50.4359	4.9790	13933.3
2800.	45.4629	5.1540	50.6169	4.9782	14431.1
2900.	45.6437	5.1479	50.7916	4.9775	14928.9
3000.	45.8181	5.1422	50.9603	4.9769	15426.7
3100.	45.9866	5.1369	51.1235	4.9763	15924.3
3200.	46.1497	5.1319	51.2815	4.9758	16421.9
3300.	46.3075	5.1271	51.4346	4.9754	16919.5
3400.	46.4605	5.1226	51.5831	4.9750	17417.0
3500.	46.6089	5.1184	51.7273	4.9746	17914.5
3600.	46.7531	5.1144	51.8675	4.9742	18411.9
3700.	46.8931	5.1106	52.0038	4.9739	18909.3
3800.	47.0294	5.1070	52.1364	4.9737	19406.7
3900.	47.1620	5.1036	52.2656	4.9734	19904.1
4000.	47.2912	5.1003	52.3915	4.9732	20401.4
4100.	47.4171	5.0972	52.5143	4.9731	20898.7
4200.	47.5399	5.0943	52.6341	4.9729	21396.0
4300.	47.6597	5.0915	52.7512	4.9729	21893.3
4400.	47.7767	5.0888	52.8655	4.9728	22390.6
4500.	47.8910	5.0862	52.9772	4.9729	22887.9
4600.	48.0028	5.0837	53.0865	4.9729	23385.1
4700.	48.1121	5.0814	53.1935	4.9731	23882.4
4800.	48.2191	5.0791	53.2982	4.9733	24379.8
4900.	48.3238	5.0770	53.4007	4.9736	24877.1
5000.	48.4263	5.0749	53.5012	4.9741	25374.5
5100.	48.5268	5.0729	53.5997	4.9746	25871.9
5200.	48.6253	5.0710	53.6963	4.9752	26369.4
5300.	48.7219	5.0692	53.7911	4.9760	26867.0
5400.	48.8166	5.0675	53.8841	4.9769	27364.6
5500.	48.9096	5.0659	53.9755	4.9779	27862.4
5600.	49.0008	5.0643	54.0652	4.9791	28360.2
5700.	49.0905	5.0628	54.1533	4.9805	28858.2
5800.	49.1785	5.0614	54.2399	4.9821	29356.3
5900.	49.2650	5.0601	54.3251	4.9839	29854.6
6000.	49.3500	5.0589	54.4089	4.9860	30353.1
6100.	49.4337	5.0577	54.4913	4.9882	30851.8
6200.	49.5159	5.0566	54.5725	4.9907	31350.8
6300.	49.5968	5.0556	54.6523	4.9935	31850.0

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 28.09

Table A-14-1 Thermodynamic Functions for Si^+ - continued

T °K	$-(F^\circ - H^\circ_0)/T$	$(H^\circ - H^\circ_0)/T$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	49.6764	5.0546	54.7310	4.9966	32349.5
6500.	49.7548	5.0537	54.8085	4.9999	32849.3
6600.	49.8319	5.0529	54.8849	5.0036	33349.5
6700.	49.9079	5.0522	54.9601	5.0076	33850.0
6800.	49.9827	5.0516	55.0343	5.0119	34351.0
6900.	50.0565	5.0511	55.1075	5.0165	34852.4
7000.	50.1291	5.0506	55.1798	5.0215	35354.3
7100.	50.2008	5.0502	55.2510	5.0269	35856.7
7200.	50.2714	5.0500	55.3214	5.0327	36359.7
7300.	50.3411	5.0498	55.3908	5.0388	36863.3
7400.	50.4098	5.0497	55.4594	5.0454	37367.5
7500.	50.4776	5.0496	55.5272	5.0524	37872.4
7600.	50.5444	5.0497	55.5942	5.0597	38378.0
7700.	50.6105	5.0499	55.6604	5.0676	38884.3
7800.	50.6756	5.0502	55.7258	5.0758	39391.5
7900.	50.7400	5.0506	55.7905	5.0845	39899.5
8000.	50.8035	5.0511	55.8545	5.0936	40408.4
8100.	50.8662	5.0516	55.9179	5.1032	40918.2
8200.	50.9282	5.0523	55.9806	5.1133	41429.1
8300.	50.9895	5.0531	56.0426	5.1238	41940.9
8400.	51.0500	5.0540	56.1040	5.1348	42453.8
8500.	51.1098	5.0550	56.1649	5.1462	42967.9
8600.	51.1689	5.0562	56.2251	5.1581	43483.1
8700.	51.2274	5.0574	56.2848	5.1705	43999.5
8800.	51.2852	5.0588	56.3440	5.1834	44517.2
8900.	51.3424	5.0603	56.4026	5.1968	45036.2
9000.	51.3989	5.0618	56.4608	5.2106	45556.6
9100.	51.4549	5.0636	56.5184	5.2249	46078.4
9200.	51.5102	5.0654	56.5756	5.2397	46601.6
9300.	51.5650	5.0673	56.6323	5.2550	47126.3
9400.	51.6192	5.0694	56.6886	5.2707	47652.6
9500.	51.6729	5.0716	56.7445	5.2869	48180.5
9600.	51.7260	5.0740	56.7999	5.3036	48710.0
9700.	51.7786	5.0764	56.8550	5.3208	49241.2
9800.	51.8306	5.0790	56.9096	5.3384	49774.2
9900.	51.8822	5.0817	56.9639	5.3565	50308.9
10000.	51.9333	5.0845	57.0179	5.3750	50845.5
10100.	51.9839	5.0875	57.0714	5.3940	51383.9

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.035600
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.14895
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.035577

Table A-15-1 Thermodynamic Functions for P^+

T °K	$-\frac{(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
273.15	32.7714	6.5587	39.3301	6.3306	1791.5
298.15	33.3447	6.5335	39.8782	6.1883	1948.0
1000.	40.7971	5.7378	46.5349	5.1084	5737.8
1100.	41.3412	5.6794	47.0206	5.0851	6247.4
1200.	41.8332	5.6292	47.4624	5.0687	6755.0
1300.	42.2820	5.5856	47.8676	5.0577	7261.3
1400.	42.6945	5.5477	48.2422	5.0515	7766.7
1500.	43.0761	5.5145	48.5906	5.0495	8271.8
1600.	43.4310	5.4855	48.9165	5.0514	8776.8
1700.	43.7628	5.4601	49.2229	5.0567	9282.1
1800.	44.0743	5.4379	49.5122	5.0652	9788.2
1900.	44.3678	5.4186	49.7863	5.0765	10295.3
2000.	44.6452	5.4018	50.0471	5.0902	10803.6
2100.	44.9084	5.3873	50.2958	5.1060	11313.4
2200.	45.1588	5.3749	50.5337	5.1234	11824.9
2300.	45.3975	5.3644	50.7619	5.1422	12338.1
2400.	45.6256	5.3556	50.9811	5.1618	12853.3
2500.	45.8440	5.3482	51.1922	5.1822	13370.5
2600.	46.0537	5.3422	51.3959	5.2029	13889.8
2700.	46.2552	5.3374	51.5926	5.2237	14411.1
2800.	46.4492	5.3337	51.7830	5.2444	14934.5
2900.	46.6364	5.3310	51.9674	5.2647	15460.0
3000.	46.8171	5.3291	52.1462	5.2846	15987.4
3100.	46.9918	5.3280	52.3198	5.3040	16516.9
3200.	47.1609	5.3276	52.4885	5.3226	17048.2
3300.	47.3249	5.3277	52.6526	5.3404	17581.4
3400.	47.4839	5.3283	52.8122	5.3574	18116.2
3500.	47.6384	5.3294	52.9678	5.3735	18652.8
3600.	47.7885	5.3308	53.1194	5.3886	19190.9
3700.	47.9346	5.3326	53.2672	5.4029	19730.5
3800.	48.0769	5.3346	53.4115	5.4162	20271.5
3900.	48.2155	5.3368	53.5523	5.4286	20813.7
4000.	48.3506	5.3393	53.6899	5.4401	21357.1
4100.	48.4825	5.3419	53.8244	5.4507	21901.7
4200.	48.6112	5.3446	53.9558	5.4604	22447.2
4300.	48.7370	5.3474	54.0844	5.4692	22993.7
4400.	48.8600	5.3502	54.2102	5.4773	23541.1
4500.	48.9803	5.3531	54.3334	5.4846	24089.2
4600.	49.0980	5.3561	54.4540	5.4912	24638.0
4700.	49.2132	5.3590	54.5722	5.4970	25187.4
4800.	49.3260	5.3619	54.6880	5.5022	25737.3
4900.	49.4366	5.3649	54.8015	5.5068	26287.8
5000.	49.5450	5.3677	54.9128	5.5108	26838.7
5100.	49.6514	5.3706	55.0219	5.5142	27389.9
5200.	49.7557	5.3734	55.1290	5.5171	27941.5
5300.	49.8581	5.3761	55.2342	5.5195	28493.3
5400.	49.9586	5.3788	55.3373	5.5215	29045.4
5500.	50.0573	5.3814	55.4387	5.5230	29597.6
5600.	50.1543	5.3839	55.5382	5.5242	30150.0
5700.	50.2496	5.3864	55.6360	5.5250	30702.4
5800.	50.3433	5.3888	55.7321	5.5255	31255.0
5900.	50.4354	5.3911	55.8265	5.5257	31807.5
6000.	50.5261	5.3933	55.9194	5.5256	32360.1
6100.	50.6152	5.3955	56.0107	5.5252	32912.6
6200.	50.7030	5.3976	56.1006	5.5246	33465.1
6300.	50.7894	5.3996	56.1890	5.5239	34017.6

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 30.9745

Table A-15-1 Thermodynamic Functions for P^+ - continued

T °K	$-(F^\circ-H^\circ_0)/T$	$(H^\circ - H^\circ_0)/T$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	50.8744	5.4015	56.2759	5.5229	34569.9
6500.	50.9582	5.4034	56.3616	5.5218	35122.1
6600.	51.0407	5.4052	56.4459	5.5205	35674.2
6700.	51.1220	5.4069	56.5289	5.5191	36226.2
6800.	51.2021	5.4085	56.6106	5.5176	36778.1
6900.	51.2811	5.4101	56.6912	5.5161	37329.7
7000.	51.3589	5.4116	56.7705	5.5144	37881.3
7100.	51.4357	5.4130	56.8487	5.5127	38432.6
7200.	51.5114	5.4144	56.9258	5.5110	38983.8
7300.	51.5861	5.4157	57.0018	5.5092	39534.8
7400.	51.6598	5.4170	57.0768	5.5074	40085.7
7500.	51.7325	5.4182	57.1507	5.5056	40636.3
7600.	51.8043	5.4193	57.2236	5.5039	41186.8
7700.	51.8751	5.4204	57.2955	5.5021	41737.1
7800.	51.9451	5.4214	57.3665	5.5004	42287.2
7900.	52.0141	5.4224	57.4366	5.4987	42837.2
8000.	52.0824	5.4234	57.5057	5.4971	43386.9
8100.	52.1497	5.4243	57.5740	5.4955	43936.6
8200.	52.2163	5.4251	57.6414	5.4940	44486.0
8300.	52.2821	5.4259	57.7080	5.4926	45035.4
8400.	52.3470	5.4267	57.7738	5.4912	45584.6
8500.	52.4113	5.4275	57.8388	5.4900	46133.6
8600.	52.4748	5.4282	57.9030	5.4889	46682.6
8700.	52.5375	5.4289	57.9664	5.4878	47231.4
8800.	52.5996	5.4296	58.0291	5.4869	47780.1
8900.	52.6609	5.4302	58.0911	5.4861	48328.8
9000.	52.7216	5.4308	58.1524	5.4854	48877.4
9100.	52.7816	5.4314	58.2130	5.4849	49425.9
9200.	52.8410	5.4320	58.2730	5.4845	49974.3
9300.	52.8997	5.4326	58.3323	5.4843	50522.8
9400.	52.9578	5.4331	58.3909	5.4842	51071.2
9500.	53.0153	5.4336	58.4489	5.4842	51619.6
9600.	53.0722	5.4342	58.5064	5.4844	52168.0
9700.	53.1285	5.4347	58.5632	5.4848	52716.5
9800.	53.1843	5.4352	58.6195	5.4853	53265.0
9900.	53.2394	5.4357	58.6752	5.4861	53813.6
10000.	53.2941	5.4362	58.7303	5.4869	54362.2
10100.	53.3482	5.4367	58.7849	5.4880	54911.0

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} °K^{-1} (or °C^{-1})	0.032285
joules g^{-1} °K^{-1} (or °C^{-1})	0.13508
Btu lb^{-1} °R^{-1} (or °F^{-1})	0.032264

Table A-16-1 Thermodynamic Functions for S^+

T °K	$\frac{-(F^o - H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
273.15	33.6799	4.9681	38.6481	4.9681	1357.1
298.15	34.1150	4.9681	39.0831	4.9681	1481.3
1000.	40.1272	4.9681	45.0954	4.9682	4968.1
1100.	40.6008	4.9682	45.5689	4.9682	5465.0
1200.	41.0330	4.9682	46.0012	4.9682	5961.8
1300.	41.4307	4.9682	46.3989	4.9682	6458.6
1400.	41.7989	4.9682	46.7671	4.9684	6955.4
1500.	42.1417	4.9682	47.1099	4.9688	7452.3
1600.	42.4623	4.9683	47.4306	4.9695	7949.2
1700.	42.7635	4.9684	47.7319	4.9708	8446.2
1800.	43.0475	4.9686	48.0160	4.9730	8943.4
1900.	43.3161	4.9689	48.2850	4.9763	9440.9
2000.	43.5710	4.9694	48.5404	4.9810	9938.7
2100.	43.8135	4.9701	48.7835	4.9876	10437.1
2200.	44.0447	4.9710	49.0158	4.9963	10936.3
2300.	44.2657	4.9724	49.2381	5.0075	11436.5
2400.	44.4774	4.9741	49.4515	5.0214	11937.9
2500.	44.6805	4.9763	49.6568	5.0384	12440.8
2600.	44.8757	4.9791	49.8548	5.0585	12945.7
2700.	45.0637	4.9825	50.0461	5.0819	13452.7
2800.	45.2449	4.9865	50.2314	5.1087	13962.2
2900.	45.4200	4.9912	50.4112	5.1389	14474.5
3000.	45.5893	4.9967	50.5860	5.1725	14990.1
3100.	45.7532	5.0029	50.7562	5.2094	15509.1
3200.	45.9122	5.0100	50.9222	5.2494	16032.0
3300.	46.0665	5.0179	51.0844	5.2925	16559.1
3400.	46.2164	5.0267	51.2431	5.3385	17090.6
3500.	46.3622	5.0363	51.3985	5.3870	17626.9
3600.	46.5043	5.0467	51.5510	5.4380	18168.1
3700.	46.6427	5.0580	51.7007	5.4912	18714.6
3800.	46.7777	5.0701	51.8478	5.5462	19266.4
3900.	46.9096	5.0830	51.9926	5.6029	19823.9
4000.	47.0385	5.0968	52.1352	5.6610	20387.0
4100.	47.1645	5.1112	52.2757	5.7201	20956.1
4200.	47.2878	5.1265	52.4143	5.7801	21531.1
4300.	47.4087	5.1424	52.5510	5.8407	22112.1
4400.	47.5271	5.1589	52.6860	5.9017	22699.3
4500.	47.6432	5.1761	52.8193	5.9627	23292.5
4600.	47.7572	5.1939	52.9510	6.0236	23891.8
4700.	47.8690	5.2122	53.0812	6.0842	24497.2
4800.	47.9790	5.2310	53.2099	6.1442	25108.6
4900.	48.0870	5.2502	53.3372	6.2034	25726.0
5000.	48.1933	5.2699	53.4632	6.2617	26349.3
5100.	48.2979	5.2899	53.5877	6.3189	26978.3
5200.	48.4008	5.3102	53.7110	6.3749	27613.0
5300.	48.5021	5.3308	53.8329	6.4295	28253.2
5400.	48.6020	5.3516	53.9536	6.4826	28898.9
5500.	48.7003	5.3727	54.0730	6.5341	29549.7
5600.	48.7973	5.3939	54.1912	6.5839	30205.6
5700.	48.8930	5.4152	54.3082	6.6320	30866.4
5800.	48.9874	5.4365	54.4239	6.6782	31532.0
5900.	49.0805	5.4580	54.5384	6.7224	32202.0
6000.	49.1724	5.4794	54.6518	6.7648	32876.4
6100.	49.2631	5.5008	54.7639	6.8051	33554.9
6200.	49.3528	5.5222	54.8749	6.8435	34237.3
6300.	49.4413	5.5434	54.9847	6.8798	34923.5

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 32.0655

Table A-16-1 Thermodynamic Functions for S^+ - continued

T °K	$\frac{-(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	49.5287	5.5646	55.0933	6.9141	35613.2
6500.	49.6152	5.5856	55.2008	6.9464	36306.3
6600.	49.7006	5.6064	55.3071	6.9766	37002.5
6700.	49.7851	5.6271	55.4122	7.0049	37701.5
6800.	49.8686	5.6476	55.5162	7.0312	38403.4
6900.	49.9512	5.6678	55.6190	7.0555	39107.7
7000.	50.0329	5.6878	55.7207	7.0779	39814.4
7100.	50.1137	5.7075	55.8212	7.0984	40523.2
7200.	50.1937	5.7269	55.9206	7.1171	41234.0
7300.	50.2728	5.7461	56.0189	7.1340	41946.6
7400.	50.3511	5.7650	56.1161	7.1492	42660.8
7500.	50.4286	5.7835	56.2121	7.1626	43376.4
7600.	50.5053	5.8017	56.3071	7.1744	44093.2
7700.	50.5813	5.8196	56.4009	7.1846	44811.2
7800.	50.6565	5.8372	56.4937	7.1933	45530.1
7900.	50.7310	5.8544	56.5854	7.2005	46249.8
8000.	50.8047	5.8713	56.6760	7.2062	46970.2
8100.	50.8778	5.8878	56.7655	7.2106	47691.0
8200.	50.9501	5.9039	56.8540	7.2137	48412.2
8300.	51.0218	5.9197	56.9415	7.2155	49133.7
8400.	51.0928	5.9352	57.0279	7.2161	49855.3
8500.	51.1631	5.9502	57.1133	7.2155	50576.9
8600.	51.2328	5.9649	57.1977	7.2139	51298.4
8700.	51.3018	5.9793	57.2811	7.2112	52019.6
8800.	51.3702	5.9932	57.3635	7.2076	52740.6
8900.	51.4380	6.0069	57.4449	7.2030	53461.1
9000.	51.5052	6.0201	57.5253	7.1975	54181.1
9100.	51.5718	6.0330	57.6048	7.1912	54900.6
9200.	51.6378	6.0456	57.6834	7.1841	55619.3
9300.	51.7032	6.0578	57.7610	7.1763	56337.4
9400.	51.7681	6.0696	57.8377	7.1678	57054.6
9500.	51.8324	6.0811	57.9135	7.1586	57770.9
9600.	51.8961	6.0923	57.9884	7.1489	58486.3
9700.	51.9593	6.1032	58.0625	7.1386	59200.7
9800.	52.0220	6.1137	58.1356	7.1278	59914.0
9900.	52.0841	6.1239	58.2079	7.1165	60626.2
10000.	52.1457	6.1337	58.2794	7.1047	61337.3
10100.	52.2067	6.1433	58.3500	7.0926	62047.1

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.031186
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.13048
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.031166

Table A-17-1 Thermodynamic Functions for Cl^+

T °K	$-\frac{(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
273.15	34.4552	5.0885	39.5437	5.4199	1389.9
298.15	34.9021	5.1192	40.0213	5.4868	1526.3
1000.	41.3419	5.4213	46.7632	5.3654	5421.3
1100.	41.8583	5.4140	47.2723	5.3171	5955.4
1200.	42.3290	5.4042	47.7331	5.2761	6485.0
1300.	42.7611	5.3929	48.1540	5.2414	7010.8
1400.	43.1603	5.3810	48.5414	5.2123	7533.5
1500.	43.5312	5.3690	48.9001	5.1879	8053.4
1600.	43.8773	5.3570	49.2343	5.1678	8571.2
1700.	44.2017	5.3454	49.5471	5.1515	9087.1
1800.	44.5069	5.3342	49.8411	5.1386	9601.6
1900.	44.7950	5.3237	50.1187	5.1290	10114.9
2000.	45.0678	5.3137	50.3816	5.1224	10627.5
2100.	45.3269	5.3045	50.6314	5.1185	11139.5
2200.	45.5734	5.2960	50.8695	5.1171	11651.3
2300.	45.8087	5.2883	51.0970	5.1181	12163.0
2400.	46.0336	5.2812	51.3148	5.1212	12675.0
2500.	46.2491	5.2749	51.5240	5.1263	13187.3
2600.	46.4558	5.2693	51.7252	5.1331	13700.3
2700.	46.6546	5.2644	51.9191	5.1414	14214.0
2800.	46.8460	5.2602	52.1062	5.1511	14728.6
2900.	47.0305	5.2566	52.2871	5.1619	15244.2
3000.	47.2087	5.2537	52.4623	5.1737	15761.0
3100.	47.3809	5.2513	52.6322	5.1862	16279.0
3200.	47.5476	5.2495	52.7970	5.1995	16798.3
3300.	47.7091	5.2482	52.9573	5.2132	17318.9
3400.	47.8658	5.2473	53.1131	5.2272	17840.9
3500.	48.0179	5.2470	53.2648	5.2415	18364.4
3600.	48.1657	5.2470	53.4127	5.2559	18889.2
3700.	48.3094	5.2474	53.5569	5.2703	19415.5
3800.	48.4494	5.2482	53.6976	5.2846	19943.3
3900.	48.5857	5.2493	53.8351	5.2987	20472.4
4000.	48.7186	5.2507	53.9694	5.3126	21003.0
4100.	48.8483	5.2524	54.1007	5.3262	21534.9
4200.	48.9749	5.2543	54.2293	5.3395	22068.2
4300.	49.0986	5.2565	54.3551	5.3524	22602.8
4400.	49.2194	5.2588	54.4782	5.3649	23138.7
4500.	49.3377	5.2613	54.5989	5.3769	23675.8
4600.	49.4533	5.2639	54.7172	5.3885	24214.1
4700.	49.5666	5.2667	54.8333	5.3996	24753.5
4800.	49.6775	5.2696	54.9470	5.4102	25294.0
4900.	49.7862	5.2725	55.0587	5.4203	25835.5
5000.	49.8927	5.2756	55.1683	5.4299	26378.0
5100.	49.9972	5.2787	55.2759	5.4390	26921.4
5200.	50.0997	5.2819	55.3816	5.4475	27465.8
5300.	50.2004	5.2851	55.4855	5.4556	28010.9
5400.	50.2992	5.2883	55.5875	5.4632	28556.9
5500.	50.3963	5.2916	55.6878	5.4704	29103.6
5600.	50.4916	5.2948	55.7865	5.4770	29650.9
5700.	50.5854	5.2981	55.8834	5.4832	30199.0
5800.	50.6776	5.3013	55.9789	5.4890	30747.6
5900.	50.7682	5.3045	56.0727	5.4943	31296.7
6000.	50.8574	5.3077	56.1651	5.4992	31846.4
6100.	50.9451	5.3109	56.2561	5.5037	32396.6
6200.	51.0315	5.3141	56.3456	5.5079	32947.2
6300.	51.1166	5.3172	56.4337	5.5116	33498.1

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 35.4565

Table A-17-1 Thermodynamic Functions for Cl^+ - continued

T °K	$-(F^\circ - H^\circ_0)/T$	$(H^\circ - H^\circ_0)/T$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	51.2003	5.3202	56.5206	5.5150	34049.5
6500.	51.2829	5.3232	56.6061	5.5180	34601.1
6600.	51.3641	5.3262	56.6904	5.5207	35153.1
6700.	51.4443	5.3291	56.7734	5.5231	35705.3
6800.	51.5232	5.3320	56.8552	5.5252	36257.7
6900.	51.6011	5.3348	56.9359	5.5270	36810.3
7000.	51.6779	5.3376	57.0155	5.5285	37363.1
7100.	51.7536	5.3403	57.0939	5.5297	37916.0
7200.	51.8283	5.3429	57.1712	5.5307	38469.0
7300.	51.9020	5.3455	57.2475	5.5315	39022.1
7400.	51.9748	5.3480	57.3228	5.5320	39575.3
7500.	52.0466	5.3505	57.3971	5.5323	40128.5
7600.	52.1175	5.3529	57.4703	5.5324	40681.7
7700.	52.1875	5.3552	57.5426	5.5323	41235.0
7800.	52.2566	5.3575	57.6140	5.5321	41788.2
7900.	52.3248	5.3597	57.6845	5.5316	42341.4
8000.	52.3923	5.3618	57.7541	5.5310	42894.5
8100.	52.4589	5.3639	57.8228	5.5303	43447.6
8200.	52.5247	5.3659	57.8906	5.5294	44000.6
8300.	52.5898	5.3679	57.9577	5.5283	44553.5
8400.	52.6541	5.3698	58.0239	5.5271	45106.2
8500.	52.7176	5.3716	58.0893	5.5258	45658.9
8600.	52.7805	5.3734	58.1539	5.5244	46211.4
8700.	52.8426	5.3751	58.2177	5.5229	46763.8
8800.	52.9040	5.3768	58.2809	5.5213	47316.0
8900.	52.9648	5.3784	58.3432	5.5196	47868.0
9000.	53.0249	5.3800	58.4049	5.5178	48419.9
9100.	53.0844	5.3815	58.4659	5.5159	48971.6
9200.	53.1432	5.3829	58.5261	5.5139	49523.1
9300.	53.2014	5.3843	58.5857	5.5119	50074.3
9400.	53.2590	5.3857	58.6447	5.5098	50625.4
9500.	53.3160	5.3870	58.7030	5.5077	51176.3
9600.	53.3724	5.3882	58.7606	5.5055	51727.0
9700.	53.4282	5.3894	58.8177	5.5032	52277.4
9800.	53.4835	5.3906	58.8741	5.5009	52827.6
9900.	53.5383	5.3917	58.9299	5.4986	53377.6
10000.	53.5924	5.3927	58.9852	5.4962	53927.3
10100.	53.6461	5.3937	59.0399	5.4938	54476.8

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} °K^{-1} (or °C^{-1})	0.028204
joules g^{-1} °K^{-1} (or °C^{-1})	0.11800
Btu lb^{-1} °R^{-1} (or °F^{-1})	0.028186

Table A-18-1 Thermodynamic Functions for Ar^+

T °K	$-(F^\circ - H^\circ_0)/T$	$(H^\circ - H^\circ_0)/T$	S°	C°_p	$H^\circ - H^\circ_0$
273.15	34.3353	4.9721	39.3074	4.9981	1358.1
298.15	34.7708	4.9750	39.7458	5.0154	1483.3
1000.	40.9048	5.2134	46.1182	5.4431	5213.4
1100.	41.4027	5.2337	46.6364	5.4301	5757.1
1200.	41.8588	5.2493	47.1081	5.4111	6299.2
1300.	42.2795	5.2609	47.5404	5.3890	6839.2
1400.	42.6697	5.2692	47.9389	5.3657	7376.9
1500.	43.0334	5.2749	48.3083	5.3421	7912.3
1600.	43.3740	5.2784	48.6523	5.3192	8445.4
1700.	43.6940	5.2801	48.9741	5.2973	8976.2
1800.	43.9958	5.2805	49.2763	5.2766	9504.9
1900.	44.2813	5.2798	49.5611	5.2572	10031.6
2000.	44.5521	5.2782	49.8303	5.2392	10556.4
2100.	44.8096	5.2759	50.0855	5.2225	11079.5
2200.	45.0549	5.2731	50.3281	5.2070	11600.9
2300.	45.2893	5.2699	50.5592	5.1927	12120.9
2400.	45.5135	5.2665	50.7799	5.1795	12639.5
2500.	45.7284	5.2627	50.9911	5.1673	13156.8
2600.	45.9347	5.2588	51.1936	5.1560	13673.0
2700.	46.1331	5.2548	51.3880	5.1456	14188.0
2800.	46.3242	5.2508	51.5749	5.1359	14702.1
2900.	46.5083	5.2466	51.7550	5.1270	15215.2
3000.	46.6861	5.2425	51.9287	5.1187	15727.5
3100.	46.8580	5.2384	52.0964	5.1110	16239.0
3200.	47.0242	5.2343	52.2585	5.1039	16749.7
3300.	47.1852	5.2302	52.4155	5.0972	17259.8
3400.	47.3413	5.2262	52.5675	5.0910	17769.2
3500.	47.4928	5.2223	52.7150	5.0853	18278.0
3600.	47.6398	5.2184	52.8582	5.0799	18786.3
3700.	47.7827	5.2146	52.9973	5.0748	19294.0
3800.	47.9218	5.2109	53.1326	5.0701	19801.2
3900.	48.0571	5.2072	53.2642	5.0657	20308.0
4000.	48.1888	5.2036	53.3924	5.0615	20814.4
4100.	48.3173	5.2001	53.5174	5.0576	21320.3
4200.	48.4426	5.1966	53.6392	5.0540	21825.9
4300.	48.5648	5.1933	53.7581	5.0505	22331.1
4400.	48.6842	5.1900	53.8742	5.0473	22836.0
4500.	48.8008	5.1868	53.9876	5.0442	23340.6
4600.	48.9147	5.1837	54.0984	5.0413	23844.9
4700.	49.0262	5.1806	54.2068	5.0386	24348.9
4800.	49.1352	5.1776	54.3128	5.0360	24852.6
4900.	49.2419	5.1747	54.4166	5.0335	25356.1
5000.	49.3465	5.1719	54.5183	5.0312	25859.3
5100.	49.4488	5.1691	54.6179	5.0290	26362.3
5200.	49.5492	5.1664	54.7156	5.0269	26865.1
5300.	49.6476	5.1637	54.8113	5.0249	27367.7
5400.	49.7441	5.1611	54.9052	5.0230	27870.1
5500.	49.8387	5.1586	54.9974	5.0212	28372.3
5600.	49.9317	5.1561	55.0878	5.0195	28874.4
5700.	50.0229	5.1537	55.1766	5.0179	29376.2
5800.	50.1125	5.1514	55.2639	5.0163	29877.9
5900.	50.2006	5.1491	55.3496	5.0149	30379.5
6000.	50.2871	5.1468	55.4339	5.0134	30880.9
6100.	50.3721	5.1446	55.5168	5.0121	31382.2
6200.	50.4558	5.1425	55.5983	5.0108	31883.3
6300.	50.5380	5.1404	55.6784	5.0095	32384.3

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 39.9435

T °K	$-\frac{(F^o - H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
6400.	50.6190	5.1383	55.7573	5.0084	32885.2
6500.	50.6986	5.1363	55.8349	5.0072	33386.0
6600.	50.7770	5.1343	55.9114	5.0061	33886.7
6700.	50.8542	5.1324	55.9867	5.0051	34387.2
6800.	50.9303	5.1305	56.0608	5.0041	34887.7
6900.	51.0051	5.1287	56.1338	5.0031	35388.1
7000.	51.0789	5.1269	56.2058	5.0022	35888.3
7100.	51.1516	5.1251	56.2768	5.0013	36388.5
7200.	51.2233	5.1234	56.3467	5.0005	36888.6
7300.	51.2940	5.1217	56.4157	4.9996	37388.6
7400.	51.3636	5.1201	56.4837	4.9988	37888.5
7500.	51.4323	5.1184	56.5508	4.9981	38388.4
7600.	51.5001	5.1169	56.6170	4.9973	38888.1
7700.	51.5670	5.1153	56.6823	4.9966	39387.8
7800.	51.6330	5.1138	56.7468	4.9959	39887.5
7900.	51.6981	5.1123	56.8104	4.9953	40387.0
8000.	51.7624	5.1108	56.8733	4.9947	40886.5
8100.	51.8259	5.1094	56.9353	4.9940	41386.0
8200.	51.8886	5.1080	56.9966	4.9934	41885.3
8300.	51.9505	5.1066	57.0571	4.9929	42384.6
8400.	52.0117	5.1052	57.1169	4.9923	42883.9
8500.	52.0721	5.1039	57.1760	4.9918	43383.1
8600.	52.1318	5.1026	57.2343	4.9913	43882.3
8700.	52.1907	5.1013	57.2920	4.9908	44381.4
8800.	52.2490	5.1000	57.3491	4.9903	44880.4
8900.	52.3067	5.0988	57.4055	4.9898	45379.4
9000.	52.3636	5.0976	57.4612	4.9894	45878.4
9100.	52.4199	5.0964	57.5163	4.9889	46377.3
9200.	52.4756	5.0952	57.5709	4.9885	46876.2
9300.	52.5307	5.0941	57.6248	4.9881	47375.0
9400.	52.5852	5.0930	57.6781	4.9877	47873.8
9500.	52.6391	5.0918	57.7309	4.9873	48372.5
9600.	52.6924	5.0908	57.7831	4.9869	48871.2
9700.	52.7451	5.0897	57.8348	4.9866	49369.9
9800.	52.7973	5.0886	57.8860	4.9862	49868.6
9900.	52.8490	5.0876	57.9366	4.9859	50367.2
10000.	52.9001	5.0866	57.9867	4.9856	50865.7
10100.	52.9507	5.0856	58.0363	4.9852	51364.3

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.025035
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.10475
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.025019

Table A-70 Thermodynamic Functions for NF_2

T °K	$-(F^o-H^o_0)/T$	$(H^o-H^o_0)/T$	S^o	$H^o-H^o_0$	C^o_p
50.	36.887	7.943	44.830	397.1	7.949
75.	40.108	7.946	48.054	595.9	7.960
100.	42.395	7.955	50.350	795.5	8.019
125.	44.172	7.980	52.153	997.5	8.149
150.	45.631	8.023	53.654	1203.5	8.338
175.	46.872	8.084	54.956	1414.8	8.568
200.	47.956	8.161	56.117	1632.1	8.825
225.	48.923	8.250	57.172	1856.1	9.100
250.	49.797	8.349	58.146	2087.2	9.383
275.	50.598	8.456	59.053	2325.3	9.668
300.	51.338	8.568	59.906	2570.5	9.947
325.	52.028	8.685	60.713	2822.6	10.216
350.	52.676	8.803	61.480	3081.2	10.473
375.	53.288	8.923	62.211	3346.1	10.714
400.	53.868	9.042	62.909	3616.8	10.938
425.	54.419	9.160	63.579	3892.8	11.146
450.	54.946	9.275	64.222	4173.9	11.339
475.	55.451	9.389	64.839	4459.6	11.516
500.	55.935	9.499	65.434	4749.6	11.678
550.	56.850	9.711	66.561	5340.8	11.963
600.	57.704	9.909	67.613	5945.2	12.204
650.	58.504	10.093	68.598	6560.6	12.406
700.	59.259	10.265	69.523	7185.2	12.577
750.	59.972	10.424	70.396	7817.8	12.722
800.	60.650	10.571	71.221	8457.1	12.846
850.	61.295	10.708	72.003	9102.1	12.953
900.	61.911	10.836	72.746	9752.1	13.044
950.	62.500	10.954	73.454	10406.4	13.124
1000.	63.065	11.064	74.129	11064.4	13.194
1050.	63.607	11.167	74.774	11725.6	13.255
1100.	64.129	11.263	75.392	12389.7	13.309
1150.	64.631	11.353	75.985	13056.4	13.356
1200.	65.116	11.438	76.554	13725.3	13.399
1250.	65.585	11.517	77.102	14396.2	13.436
1300.	66.038	11.591	77.629	15068.9	13.470
1350.	66.477	11.662	78.138	15743.2	13.501
1400.	66.902	11.728	78.630	16418.9	13.528
1450.	67.315	11.790	79.105	17095.9	13.553
1500.	67.715	11.849	79.565	17774.1	13.575
1550.	68.105	11.905	80.010	18453.4	13.596
1600.	68.484	11.959	80.442	19133.7	13.614
1650.	68.852	12.009	80.861	19814.8	13.631
1700.	69.212	12.057	81.269	20496.8	13.647
1750.	69.562	12.103	81.664	21179.5	13.661
1800.	69.903	12.146	82.049	21862.9	13.675
1850.	70.237	12.188	82.424	22546.9	13.687
1900.	70.562	12.227	82.789	23231.6	13.698
1950.	70.880	12.265	83.145	23916.8	13.709
2000.	71.191	12.301	83.493	24602.4	13.718
2050.	71.496	12.336	83.832	25288.6	13.728

MW 52.0 ELECTRONIC MULTIPLICITY 2. ROTATIONAL SYMMETRY 2.
MOMENTS OF INERTIA (GM CM**2*EXP-39)
IA 1.203700 IB 7.374800 IC 8.570200
CENTRIFUGAL STRETCHING CONSTANT 0.

NO OF FREQUENCIES 3 FREQUENCIES IN CM-1
1075.00000 510.00000 940.00000

DEGENERACIES
1.0 1.0 1.0

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units.

Table A-70 Thermodynamic Functions for NF_2 - continued

T °K	$\frac{-(F^o-H_0^o)}{T}$	$\frac{H^o-H_0^o}{T}$	S^o	$H^o-H_0^o$	C_p^o
2100.	71.793	12.369	84.162	25975.2	13.736
2150.	72.085	12.401	84.486	26662.2	13.744
2200.	72.370	12.432	84.802	27349.6	13.751
2250.	72.650	12.461	85.111	28037.3	13.758
2300.	72.924	12.489	85.413	28725.4	13.765
2350.	73.193	12.516	85.709	29413.7	13.771
2400.	73.457	12.543	85.999	30102.4	13.776
2450.	73.716	12.568	86.284	30791.4	13.782
2500.	73.970	12.592	86.562	31480.6	13.787
2600.	74.465	12.638	87.103	32859.7	13.796
2700.	74.942	12.681	87.624	34239.7	13.804
2800.	75.404	12.722	88.126	35620.5	13.812
2900.	75.851	12.759	88.611	37002.0	13.818
3000.	76.285	12.795	89.079	38384.1	13.824
3100.	76.705	12.828	89.533	39766.8	13.830
3200.	77.112	12.859	89.972	41150.0	13.835
3300.	77.509	12.889	90.398	42533.7	13.839
3400.	77.894	12.917	90.811	43917.8	13.843
3500.	78.269	12.944	91.212	45302.3	13.847
3600.	78.634	12.969	91.602	46687.2	13.850
3700.	78.989	12.993	91.982	48072.4	13.854
3800.	79.336	13.015	92.351	49457.9	13.857
3900.	79.674	13.037	92.711	50843.7	13.859
4000.	80.005	13.057	93.062	52229.8	13.862
4100.	80.327	13.077	93.404	53616.1	13.864
4200.	80.643	13.096	93.739	55002.6	13.866
4300.	80.951	13.114	94.065	56389.4	13.868
4400.	81.253	13.131	94.384	57776.3	13.870
4500.	81.548	13.147	94.695	59163.4	13.872
4600.	81.837	13.163	95.000	60550.7	13.874
4700.	82.120	13.178	95.299	61938.2	13.875
4800.	82.398	13.193	95.591	63325.8	13.877
4900.	82.670	13.207	95.877	64713.5	13.878
5000.	82.937	13.220	96.157	66101.4	13.879
5100.	83.199	13.233	96.432	67489.4	13.881
5200.	83.456	13.246	96.702	68877.5	13.882
5300.	83.709	13.258	96.966	70265.8	13.883
5400.	83.956	13.269	97.226	71654.1	13.884
5500.	84.200	13.280	97.481	73042.5	13.885
5600.	84.439	13.291	97.731	74431.1	13.886
5700.	84.675	13.302	97.976	75819.7	13.887
5800.	84.906	13.312	98.218	77208.4	13.887
5900.	85.134	13.322	98.455	78597.2	13.888
6000.	85.358	13.331	98.689	79986.0	13.889
273.15	50.540	8.448	58.988	2307.4	9.647
298.15	51.285	8.560	59.845	2552.1	9.927

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	.0192308
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	.0804617
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	.0192182

Table A-71 Thermodynamic Functions for N_2F_4

T °K	$-(F^o-H^o_0)/T$	$(H^o-H^o_0)/T$	S^o	$H^o-H^o_0$	C^o_p
50.	42.698	8.293	50.991	414.7	9.029
75.	46.130	8.662	54.792	649.6	9.773
100.	48.674	9.046	57.720	904.6	10.661
125.	50.737	9.476	60.214	1184.5	11.767
150.	52.507	9.961	62.469	1494.2	13.025
175.	54.082	10.494	64.576	1836.4	14.354
200.	55.520	11.060	66.580	2212.0	15.690
225.	56.857	11.647	68.503	2620.5	16.988
250.	58.114	12.243	70.358	3060.8	18.220
275.	59.309	12.839	72.149	3530.9	19.370
300.	60.452	13.428	73.880	4028.5	20.429
325.	61.550	14.005	75.554	4551.5	21.396
350.	62.608	14.564	77.173	5097.6	22.274
375.	63.631	15.105	78.737	5664.5	23.067
400.	64.623	15.626	80.249	6250.3	23.782
425.	65.585	16.125	81.710	6853.0	24.426
450.	66.521	16.602	83.123	7471.0	25.005
475.	67.431	17.058	84.489	8102.8	25.526
500.	68.317	17.494	85.811	8746.9	25.996
550.	70.023	18.305	88.327	10067.6	26.803
600.	71.648	19.041	90.689	11424.8	27.464
650.	73.199	19.711	92.909	12812.0	28.009
700.	74.682	20.320	95.002	14224.1	28.462
750.	76.103	20.876	96.979	15657.0	28.842
800.	77.467	21.384	98.851	17107.3	29.163
850.	78.777	21.850	100.627	18572.5	29.435
900.	80.039	22.278	102.317	20050.2	29.669
950.	81.254	22.672	103.926	21538.8	29.871
1000.	82.426	23.037	105.463	23036.9	30.046
1050.	83.558	23.374	106.933	24543.0	30.198
1100.	84.653	23.688	108.341	26056.4	30.332
1150.	85.713	23.979	109.692	27576.0	30.450
1200.	86.739	24.251	110.990	29101.2	30.555
1250.	87.734	24.505	112.239	30631.3	30.648
1300.	88.700	24.743	113.443	32165.8	30.731
1350.	89.638	24.966	114.604	33704.2	30.805
1400.	90.550	25.176	115.726	35246.2	30.872
1450.	91.437	25.373	116.810	36791.3	30.933
1500.	92.300	25.560	117.860	38339.4	30.988
1550.	93.141	25.735	118.877	39890.0	31.037
1600.	93.961	25.902	119.863	41443.0	31.083
1650.	94.760	26.060	120.820	42998.2	31.124
1700.	95.540	26.209	121.750	44555.4	31.162
1750.	96.302	26.351	122.653	46114.4	31.197
1800.	97.047	26.486	123.533	47675.1	31.229
1850.	97.774	26.615	124.389	49237.3	31.259
1900.	98.485	26.737	125.223	50800.9	31.286
1950.	99.181	26.854	126.036	52365.9	31.312
2000.	99.863	26.966	126.829	53932.0	31.335
2050.	100.530	27.073	127.603	55499.4	31.357

MW 104.0 ELECTRONIC MULTIPLICITY 1. ROTATIONAL SYMMETRY 2.
MOMENTS OF INERTIA (GM CM**2*EXP-39)
IA 15.051700 IB 26.248400 IC 29.837800
CENTRIFUGAL STRETCHING CONSTANT 0.

NO OF FREQUENCIES 12 FREQUENCIES IN CM-1

1011.00000	962.00000	933.00000	850.00000	589.00000
537.00000	517.00000	390.00000	500.00000	736.00000
285.00000	100.00000			

DEGENERACIES

1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0
1.0	1.0			

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units.

Table A-71 Thermodynamic Functions for N_2F_4 - continued

T °K	$-(F^o-H^o_0)/T$	$(H^o-H^o_0)/T$	S^o	$H^o-H^o_0$	C^o_p
2100.	101.184	27.175	128.359	57067.7	31.377
2150.	101.824	27.273	129.097	58637.0	31.396
2200.	102.452	27.367	129.819	60207.3	31.414
2250.	103.068	27.457	130.525	61778.4	31.430
2300.	103.673	27.544	131.216	63350.3	31.446
2350.	104.266	27.627	131.893	64923.0	31.461
2400.	104.848	27.707	132.555	66496.4	31.474
2450.	105.421	27.784	133.204	68070.4	31.487
2500.	105.983	27.858	133.841	69645.1	31.499
2600.	107.078	27.998	135.076	72796.1	31.521
2700.	108.137	28.129	136.266	75949.2	31.541
2800.	109.162	28.252	137.414	79104.2	31.559
2900.	110.156	28.366	138.522	82260.9	31.575
3000.	111.119	28.473	139.592	85419.1	31.589
3100.	112.054	28.574	140.628	88578.7	31.602
3200.	112.963	28.669	141.632	91739.5	31.614
3300.	113.847	28.758	142.605	94901.5	31.625
3400.	114.707	28.842	143.549	98064.5	31.635
3500.	115.544	28.922	144.466	101228.4	31.644
3600.	116.360	28.998	145.358	104393.2	31.652
3700.	117.155	29.070	146.225	107558.8	31.660
3800.	117.931	29.138	147.069	110725.1	31.667
3900.	118.689	29.203	147.892	113892.1	31.673
4000.	119.429	29.265	148.694	117059.8	31.679
4100.	120.152	29.324	149.476	120228.0	31.685
4200.	120.860	29.380	150.240	123396.7	31.690
4300.	121.552	29.434	150.986	126566.0	31.695
4400.	122.229	29.485	151.714	129735.7	31.700
4500.	122.892	29.535	152.427	132905.9	31.704
4600.	123.542	29.582	153.124	136076.5	31.708
4700.	124.179	29.627	153.806	139247.4	31.711
4800.	124.803	29.671	154.473	142418.7	31.715
4900.	125.415	29.712	155.127	145590.4	31.718
5000.	126.016	29.752	155.768	148762.4	31.721
5100.	126.605	29.791	156.396	151934.6	31.724
5200.	127.184	29.828	157.012	155107.2	31.727
5300.	127.753	29.864	157.617	158280.0	31.729
5400.	128.311	29.899	158.210	161453.1	31.732
5500.	128.860	29.932	158.792	164626.4	31.734
5600.	129.400	29.964	159.364	167799.9	31.736
5700.	129.930	29.995	159.926	170973.7	31.738
5800.	130.452	30.025	160.478	174147.6	31.740
5900.	130.966	30.055	161.020	177321.8	31.742
6000.	131.471	30.083	161.554	180496.1	31.744
273.15	59.223	12.796	72.018	3495.1	19.287
298.15	60.369	13.385	73.754	3990.8	20.353

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	.0096154
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	.0402308
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	.00960911

Table A-72-1 Thermodynamic Functions for Ti^+

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
273.15	36.9693	6.3385	43.3078	6.2670	1731.4
298.15	37.5241	6.3321	43.8562	6.2577	1887.9
1000.	45.0941	6.0885	51.1826	5.6337	6088.5
1100.	45.6723	6.0443	51.7166	5.5734	6648.7
1200.	46.1964	6.0031	52.1996	5.5296	7203.8
1300.	46.6754	5.9655	52.6409	5.4998	7755.1
1400.	47.1162	5.9315	53.0478	5.4820	8304.1
1500.	47.5244	5.9012	53.4257	5.4744	8851.9
1600.	47.9044	5.8746	53.7790	5.4756	9399.3
1700.	48.2598	5.8513	54.1111	5.4844	9947.2
1800.	48.5937	5.8313	54.4250	5.5000	10496.4
1900.	48.9085	5.8144	54.7230	5.5214	11047.4
2000.	49.2064	5.8004	55.0068	5.5479	11600.9
2100.	49.4891	5.7891	55.2782	5.5787	12157.2
2200.	49.7582	5.7803	55.5385	5.6132	12716.7
2300.	50.0150	5.7739	55.7889	5.6505	13279.9
2400.	50.2606	5.7695	56.0302	5.6902	13846.9
2500.	50.4961	5.7672	56.2633	5.7317	14418.0
2600.	50.7223	5.7666	56.4889	5.7743	14993.3
2700.	50.9399	5.7677	56.7077	5.8177	15572.9
2800.	51.1497	5.7703	56.9200	5.8612	16156.8
2900.	51.3523	5.7742	57.1265	5.9047	16745.1
3000.	51.5481	5.7792	57.3274	5.9476	17337.7
3100.	51.7377	5.7854	57.5231	5.9897	17934.6
3200.	51.9215	5.7924	57.7139	6.0308	18535.7
3300.	52.0999	5.8002	57.9001	6.0706	19140.7
3400.	52.2732	5.8087	58.0819	6.1089	19749.7
3500.	52.4417	5.8178	58.2595	6.1457	20362.5
3600.	52.6057	5.8274	58.4331	6.1807	20978.8
3700.	52.7655	5.8374	58.6029	6.2140	21598.6
3800.	52.9213	5.8478	58.7691	6.2456	22221.6
3900.	53.0733	5.8584	58.9317	6.2753	22847.6
4000.	53.2218	5.8691	59.0909	6.3032	23476.5
4100.	53.3669	5.8800	59.2469	6.3293	24108.2
4200.	53.5087	5.8910	59.3997	6.3537	24742.3
4300.	53.6474	5.9021	59.5495	6.3764	25378.9
4400.	53.7832	5.9131	59.6963	6.3975	26017.6
4500.	53.9162	5.9241	59.8403	6.4170	26658.3
4600.	54.0466	5.9350	59.9816	6.4351	27300.9
4700.	54.1743	5.9458	60.1201	6.4517	27945.3
4800.	54.2996	5.9565	60.2561	6.4671	28591.2
4900.	54.4225	5.9671	60.3896	6.4812	29238.6
5000.	54.5432	5.9775	60.5207	6.4942	29887.4
5100.	54.6617	5.9877	60.6494	6.5062	30537.5
5200.	54.7780	5.9978	60.7759	6.5171	31188.6
5300.	54.8924	6.0077	60.9001	6.5272	31840.9
5400.	55.0048	6.0174	61.0222	6.5365	32494.1
5500.	55.1153	6.0269	61.1422	6.5451	33148.1
5600.	55.2240	6.0363	61.2602	6.5530	33803.0
5700.	55.3309	6.0454	61.3763	6.5603	34458.7
5800.	55.4361	6.0543	61.4904	6.5671	35115.1
5900.	55.5397	6.0631	61.6027	6.5734	35772.1
6000.	55.6416	6.0716	61.7133	6.5793	36429.7
6100.	55.7421	6.0800	61.8221	6.5848	37087.9
6200.	55.8410	6.0882	61.9292	6.5900	37746.7
6300.	55.9385	6.0962	62.0347	6.5950	38405.9

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 47.90

Table A-72-1 Thermodynamic Functions for Ti^{+} - continued

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
6400.	56.0345	6.1040	62.1385	6.5997	39065.7
6500.	56.1292	6.1117	62.2409	6.6043	39725.9
6600.	56.2226	6.1192	62.3418	6.6087	40386.5
6700.	56.3147	6.1265	62.4412	6.6129	41047.6
6800.	56.4055	6.1337	62.5392	6.6171	41709.1
6900.	56.4951	6.1407	62.6358	6.6212	42371.0
7000.	56.5835	6.1476	62.7311	6.6253	43033.4
7100.	56.6707	6.1544	62.8251	6.6294	43696.1
7200.	56.7569	6.1610	62.9179	6.6334	44359.2
7300.	56.8419	6.1675	63.0094	6.6375	45022.8
7400.	56.9259	6.1739	63.0997	6.6415	45686.7
7500.	57.0088	6.1801	63.1889	6.6457	46351.1
7600.	57.0907	6.1863	63.2770	6.6498	47015.9
7700.	57.1716	6.1923	63.3639	6.6540	47681.1
7800.	57.2515	6.1983	63.4498	6.6583	48346.7
7900.	57.3305	6.2041	63.5346	6.6626	49012.7
8000.	57.4086	6.2099	63.6185	6.6670	49679.2
8100.	57.4858	6.2156	63.7013	6.6715	50346.1
8200.	57.5621	6.2212	63.7832	6.6760	51013.5
8300.	57.6375	6.2267	63.8642	6.6807	51681.3
8400.	57.7121	6.2321	63.9442	6.6854	52349.6
8500.	57.7859	6.2375	64.0234	6.6901	53018.4
8600.	57.8589	6.2428	64.1016	6.6950	53687.7
8700.	57.9311	6.2480	64.1791	6.6999	54357.4
8800.	58.0025	6.2531	64.2557	6.7049	55027.6
8900.	58.0732	6.2582	64.3314	6.7100	55698.4
9000.	58.1432	6.2633	64.4065	6.7151	56369.6
9100.	58.2124	6.2683	64.4807	6.7203	57041.4
9200.	58.2809	6.2732	64.5542	6.7256	57713.7
9300.	58.3488	6.2781	64.6269	6.7309	58386.5
9400.	58.4159	6.2830	64.6989	6.7362	59059.9
9500.	58.4825	6.2878	64.7702	6.7416	59733.8
9600.	58.5483	6.2925	64.8408	6.7471	60408.2
9700.	58.6136	6.2972	64.9108	6.7526	61083.2
9800.	58.6782	6.3019	64.9801	6.7581	61758.7
9900.	58.7422	6.3065	65.0487	6.7637	62434.8
10000.	58.8056	6.3111	65.1167	6.7692	63111.5
10100.	58.8684	6.3157	65.1841	6.7748	63788.7

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.020877
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.087349
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.020863

Table A-73-1 Thermodynamic Functions for Br^+

T °K	$-(F^o-H^o_0)/T$	$(H^o-H^o_0)/T$	S^o	C^o_p	$H^o-H^o_0$
273.15	36.8455	4.9682	41.8136	4.9682	1357.1
298.15	37.2806	4.9682	42.2487	4.9682	1481.3
1000.	43.3074	5.0353	48.3426	5.2778	5035.3
1100.	43.7885	5.0609	48.8494	5.3568	5567.0
1200.	44.2300	5.0887	49.3187	5.4300	6106.4
1300.	44.6384	5.1175	49.7559	5.4948	6652.7
1400.	45.0187	5.1465	50.1652	5.5502	7205.1
1500.	45.3748	5.1750	50.5498	5.5962	7762.5
1600.	45.7097	5.2025	50.9122	5.6334	8324.0
1700.	46.0259	5.2288	51.2546	5.6628	8888.9
1800.	46.3254	5.2535	51.5790	5.6856	9456.4
1900.	46.6101	5.2768	51.8869	5.7030	10025.8
2000.	46.8813	5.2984	52.1797	5.7162	10596.8
2100.	47.1403	5.3186	52.4589	5.7260	11169.0
2200.	47.3882	5.3373	52.7254	5.7334	11742.0
2300.	47.6258	5.3546	52.9804	5.7391	12315.6
2400.	47.8541	5.3707	53.2248	5.7436	12889.7
2500.	48.0736	5.3857	53.4593	5.7473	13464.3
2600.	48.2851	5.3997	53.6848	5.7506	14039.2
2700.	48.4892	5.4127	53.9019	5.7536	14614.4
2800.	48.6862	5.4250	54.1112	5.7565	15189.9
2900.	48.8768	5.4364	54.3132	5.7594	15765.7
3000.	49.0613	5.4473	54.5086	5.7624	16341.8
3100.	49.2401	5.4575	54.6975	5.7654	16918.2
3200.	49.4135	5.4671	54.8806	5.7684	17494.9
3300.	49.5819	5.4763	55.0582	5.7714	18071.9
3400.	49.7455	5.4850	55.2305	5.7743	18649.1
3500.	49.9046	5.4933	55.3979	5.7772	19226.7
3600.	50.0595	5.5013	55.5607	5.7799	19804.6
3700.	50.2103	5.5088	55.7191	5.7825	20382.7
3800.	50.3573	5.5161	55.8734	5.7848	20961.1
3900.	50.5007	5.5230	56.0237	5.7869	21539.7
4000.	50.6406	5.5296	56.1702	5.7887	22118.5
4100.	50.7772	5.5360	56.3132	5.7902	22697.4
4200.	50.9107	5.5420	56.4527	5.7914	23276.5
4300.	51.0412	5.5478	56.5890	5.7922	23855.7
4400.	51.1688	5.5534	56.7222	5.7926	24434.9
4500.	51.2936	5.5587	56.8523	5.7926	25014.2
4600.	51.4159	5.5638	56.9796	5.7923	25593.4
4700.	51.5356	5.5686	57.1042	5.7916	26172.6
4800.	51.6529	5.5733	57.2261	5.7905	26751.7
4900.	51.7678	5.5777	57.3455	5.7890	27330.7
5000.	51.8805	5.5819	57.4625	5.7872	27909.5
5100.	51.9911	5.5859	57.5770	5.7850	28488.1
5200.	52.0996	5.5897	57.6893	5.7825	29066.5
5300.	52.2061	5.5933	57.7995	5.7796	29644.6
5400.	52.3107	5.5967	57.9075	5.7764	30222.4
5500.	52.4134	5.6000	58.0134	5.7729	30799.9
5600.	52.5144	5.6030	58.1174	5.7691	31377.0
5700.	52.6136	5.6059	58.2195	5.7651	31953.7
5800.	52.7111	5.6086	58.3197	5.7607	32530.0
5900.	52.8070	5.6112	58.4182	5.7562	33105.9
6000.	52.9013	5.6135	58.5149	5.7514	33681.2
6100.	52.9941	5.6158	58.6099	5.7464	34256.1
6200.	53.0855	5.6178	58.7033	5.7412	34830.5
6300.	53.1754	5.6197	58.7951	5.7358	35404.3

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 79.9155

Table A-73-1 Thermodynamic Functions for Br^+ - continued

T °K	$\frac{-(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	53.2639	5.6215	58.8854	5.7302	35977.6
6500.	53.3510	5.6231	58.9742	5.7245	36550.4
6600.	53.4369	5.6246	59.0615	5.7187	37122.5
6700.	53.5215	5.6260	59.1475	5.7127	37694.1
6800.	53.6049	5.6272	59.2321	5.7066	38265.1
6900.	53.6870	5.6283	59.3153	5.7004	38835.4
7000.	53.7680	5.6293	59.3973	5.6941	39405.2
7100.	53.8479	5.6302	59.4780	5.6878	39974.2
7200.	53.9266	5.6309	59.5575	5.6813	40542.7
7300.	54.0043	5.6316	59.6359	5.6748	41110.5
7400.	54.0809	5.6321	59.7130	5.6683	41677.7
7500.	54.1565	5.6326	59.7891	5.6617	42244.2
7600.	54.2311	5.6329	59.8640	5.6551	42810.0
7700.	54.3048	5.6331	59.9379	5.6485	43375.2
7800.	54.3774	5.6333	60.0107	5.6418	43939.7
7900.	54.4492	5.6334	60.0826	5.6352	44503.6
8000.	54.5201	5.6333	60.1534	5.6285	45066.7
8100.	54.5901	5.6332	60.2233	5.6219	45629.3
8200.	54.6592	5.6331	60.2922	5.6152	46191.1
8300.	54.7274	5.6328	60.3603	5.6086	46752.3
8400.	54.7949	5.6325	60.4274	5.6020	47312.8
8500.	54.8616	5.6321	60.4936	5.5954	47872.7
8600.	54.9274	5.6316	60.5590	5.5888	48431.9
8700.	54.9925	5.6311	60.6236	5.5823	48990.5
8800.	55.0569	5.6305	60.6874	5.5758	49548.4
8900.	55.1205	5.6298	60.7504	5.5694	50105.6
9000.	55.1834	5.6291	60.8125	5.5630	50662.2
9100.	55.2456	5.6284	60.8740	5.5566	51218.2
9200.	55.3071	5.6276	60.9347	5.5503	51773.6
9300.	55.3679	5.6267	60.9946	5.5441	52328.3
9400.	55.4281	5.6258	61.0539	5.5379	52882.4
9500.	55.4876	5.6248	61.1125	5.5318	53435.9
9600.	55.5465	5.6238	61.1704	5.5257	53988.7
9700.	55.6048	5.6228	61.2276	5.5197	54541.0
9800.	55.6625	5.6217	61.2842	5.5138	55092.7
9900.	55.7195	5.6206	61.3401	5.5079	55643.8
10000.	55.7760	5.6194	61.3955	5.5021	56194.3
10100.	55.8319	5.6182	61.4502	5.4964	56744.2

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.012513
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.052354
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.012505

Table A-74-1 Thermodynamic Functions for W^{+}

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
273.15	37.5096	4.9788	42.4884	5.0534	1360.0
298.15	37.9459	4.9873	42.9332	5.1082	1487.0
1000.	44.4172	6.0268	50.4439	7.5535	6026.8
1100.	44.9986	6.1739	51.1725	7.7314	6791.3
1200.	45.5417	6.3100	51.8517	7.8769	7572.0
1300.	46.0518	6.4352	52.4869	7.9929	8365.7
1400.	46.5329	6.5498	53.0827	8.0818	9169.7
1500.	46.9884	6.6542	53.6426	8.1462	9981.3
1600.	47.4209	6.7489	54.1698	8.1888	10798.2
1700.	47.8327	6.8344	54.6671	8.2131	11618.4
1800.	48.2256	6.9113	55.1368	8.2224	12440.3
1900.	48.6011	6.9803	55.5814	8.2203	13262.5
2000.	48.9608	7.0420	56.0028	8.2103	14084.1
2100.	49.3057	7.0973	56.4030	8.1954	14904.4
2200.	49.6370	7.1469	56.7839	8.1785	15723.1
2300.	49.9557	7.1913	57.1471	8.1618	16540.1
2400.	50.2627	7.2315	57.4941	8.1472	17355.5
2500.	50.5586	7.2679	57.8265	8.1362	18169.7
2600.	50.8443	7.3011	58.1454	8.1297	18982.9
2700.	51.1204	7.3318	58.4522	8.1283	19795.8
2800.	51.3876	7.3603	58.7479	8.1326	20608.8
2900.	51.6464	7.3871	59.0334	8.1424	21422.5
3000.	51.8972	7.4125	59.3097	8.1576	22237.4
3100.	52.1407	7.4368	59.5775	8.1780	23054.2
3200.	52.3772	7.4604	59.8375	8.2030	23873.2
3300.	52.6071	7.4833	60.0904	8.2320	24694.9
3400.	52.8308	7.5058	60.3366	8.2645	25519.7
3500.	53.0487	7.5280	60.5767	8.2998	26347.9
3600.	53.2611	7.5499	60.8110	8.3372	27179.7
3700.	53.4682	7.5717	61.0400	8.3759	28015.4
3800.	53.6705	7.5934	61.2639	8.4154	28854.9
3900.	53.8680	7.6150	61.4830	8.4550	29698.5
4000.	54.0610	7.6365	61.6975	8.4941	30545.9
4100.	54.2499	7.6579	61.9077	8.5322	31397.2
4200.	54.4347	7.6791	62.1138	8.5687	32252.3
4300.	54.6156	7.7002	62.3158	8.6034	33110.9
4400.	54.7929	7.7211	62.5140	8.6357	33972.9
4500.	54.9666	7.7418	62.7084	8.6654	34838.0
4600.	55.1370	7.7621	62.8991	8.6923	35705.9
4700.	55.3041	7.7822	63.0863	8.7161	36576.3
4800.	55.4682	7.8019	63.2701	8.7367	37449.0
4900.	55.6293	7.8211	63.4504	8.7540	38323.6
5000.	55.7875	7.8399	63.6274	8.7680	39199.7
5100.	55.9429	7.8582	63.8011	8.7786	40077.1
5200.	56.0957	7.8760	63.9717	8.7859	40955.3
5300.	56.2458	7.8932	64.1391	8.7899	41834.1
5400.	56.3935	7.9098	64.3034	8.7907	42713.2
5500.	56.5388	7.9258	64.4647	8.7885	43592.2
5600.	56.6818	7.9412	64.6230	8.7833	44470.8
5700.	56.8225	7.9559	64.7784	8.7753	45348.7
5800.	56.9610	7.9700	64.9309	8.7646	46225.8
5900.	57.0973	7.9833	65.0806	8.7515	47101.6
6000.	57.2316	7.9960	65.2276	8.7360	47976.0
6100.	57.3639	8.0080	65.3718	8.7184	48848.7
6200.	57.4942	8.0193	65.5135	8.6989	49719.6
6300.	57.6226	8.0299	65.6525	8.6776	50588.4

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 183.86

Table A-74-1 Thermodynamic Functions for W^+ - continued

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
6400.	57.7491	8.0399	65.7890	8.6547	51455.1
6500.	57.8738	8.0491	65.9230	8.6303	52319.3
6600.	57.9968	8.0577	66.0545	8.6047	53181.1
6700.	58.1180	8.0657	66.1837	8.5780	54040.2
6800.	58.2376	8.0730	66.3106	8.5504	54896.7
6900.	58.3555	8.0798	66.4352	8.5220	55750.3
7000.	58.4718	8.0859	66.5576	8.4929	56601.0
7100.	58.5865	8.0914	66.6779	8.4633	57448.8
7200.	58.6997	8.0963	66.7961	8.4333	58293.7
7300.	58.8114	8.1008	66.9122	8.4031	59135.5
7400.	58.9217	8.1046	67.0263	8.3727	59974.3
7500.	59.0305	8.1080	67.1385	8.3423	60810.0
7600.	59.1379	8.1109	67.2488	8.3119	61642.7
7700.	59.2439	8.1133	67.3572	8.2816	62472.4
7800.	59.3486	8.1153	67.4639	8.2515	63299.1
7900.	59.4520	8.1168	67.5688	8.2217	64122.7
8000.	59.5541	8.1179	67.6721	8.1923	64943.4
8100.	59.6550	8.1187	67.7736	8.1632	65761.2
8200.	59.7546	8.1190	67.8736	8.1346	66576.1
8300.	59.8530	8.1191	67.9721	8.1065	67388.1
8400.	59.9502	8.1187	68.0690	8.0789	68197.4
8500.	60.0463	8.1181	68.1644	8.0519	69003.9
8600.	60.1413	8.1172	68.2584	8.0254	69807.8
8700.	60.2351	8.1160	68.3511	7.9996	70609.0
8800.	60.3278	8.1145	68.4424	7.9745	71407.7
8900.	60.4195	8.1128	68.5323	7.9500	72204.0
9000.	60.5102	8.1109	68.6210	7.9262	72997.8
9100.	60.5998	8.1087	68.7085	7.9030	73789.2
9200.	60.6884	8.1063	68.7947	7.8805	74578.4
9300.	60.7760	8.1038	68.8798	7.8588	75365.3
9400.	60.8627	8.1011	68.9637	7.8377	76150.2
9500.	60.9484	8.0982	69.0466	7.8173	76932.9
9600.	61.0332	8.0952	69.1283	7.7975	77713.6
9700.	61.1170	8.0920	69.2090	7.7785	78492.4
9800.	61.2000	8.0887	69.2887	7.7601	79269.3
9900.	61.2821	8.0853	69.3674	7.7423	80044.5
10000.	61.3634	8.0818	69.4451	7.7253	80817.8
10100.	61.4438	8.0782	69.5219	7.7088	81589.5

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} °K^{-1} (or °C^{-1})	.0054389
joules g^{-1} °K^{-1} (or °C^{-1})	.022756
Btu lb^{-1} °R^{-1} (or °F^{-1})	.0054354

Table A-75-1 Thermodynamic Functions for Zr^+

T °K	$\frac{-(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
273.15	37.3543	5.9205	43.2748	6.7330	1617.2
298.15	37.8759	5.9898	43.8657	6.7598	1785.9
1000.	45.4762	6.4167	51.8929	6.5387	6416.7
1100.	46.0884	6.4295	52.5179	6.5767	7072.5
1200.	46.6484	6.4435	53.0919	6.6171	7732.2
1300.	47.1647	6.4583	53.6231	6.6561	8395.8
1400.	47.6439	6.4738	54.1177	6.6918	9063.3
1500.	48.0911	6.4894	54.5805	6.7231	9734.0
1600.	48.5104	6.5048	55.0152	6.7501	10407.7
1700.	48.9052	6.5200	55.4252	6.7726	11083.9
1800.	49.2783	6.5345	55.8128	6.7912	11762.1
1900.	49.6320	6.5484	56.1804	6.8061	12442.0
2000.	49.9682	6.5616	56.5298	6.8177	13123.2
2100.	50.2887	6.5740	56.8627	6.8265	13805.5
2200.	50.5947	6.5857	57.1804	6.8328	14488.5
2300.	50.8877	6.5965	57.4842	6.8369	15172.0
2400.	51.1687	6.6066	57.7753	6.8392	15855.8
2500.	51.4386	6.6159	58.0545	6.8397	16539.7
2600.	51.6982	6.6245	58.3227	6.8389	17223.7
2700.	51.9484	6.6324	58.5808	6.8367	17907.5
2800.	52.1897	6.6396	58.8294	6.8334	18591.0
2900.	52.4228	6.6462	59.0691	6.8291	19274.1
3000.	52.6483	6.6523	59.3005	6.8239	19956.8
3100.	52.8665	6.6577	59.5242	6.8180	20638.9
3200.	53.0779	6.6626	59.7405	6.8113	21320.3
3300.	53.2830	6.6670	59.9500	6.8040	22001.1
3400.	53.4821	6.6709	60.1530	6.7961	22681.1
3500.	53.6755	6.6744	60.3499	6.7878	23360.3
3600.	53.8636	6.6774	60.5410	6.7790	24038.7
3700.	54.0466	6.6800	60.7266	6.7699	24716.1
3800.	54.2248	6.6823	60.9070	6.7606	25392.7
3900.	54.3984	6.6842	61.0825	6.7510	26068.2
4000.	54.5676	6.6857	61.2533	6.7412	26742.8
4100.	54.7327	6.6869	61.4197	6.7314	27416.5
4200.	54.8939	6.6879	61.5818	6.7215	28089.1
4300.	55.0512	6.6886	61.7398	6.7116	28760.8
4400.	55.2050	6.6890	61.8940	6.7018	29431.4
4500.	55.3553	6.6891	62.0445	6.6922	30101.1
4600.	55.5024	6.6891	62.1915	6.6827	30769.9
4700.	55.6462	6.6889	62.3351	6.6734	31437.7
4800.	55.7870	6.6885	62.4755	6.6645	32104.6
4900.	55.9249	6.6879	62.6128	6.6558	32770.6
5000.	56.0600	6.6871	62.7472	6.6475	33435.7
5100.	56.1925	6.6863	62.8788	6.6396	34100.1
5200.	56.3223	6.6853	63.0076	6.6321	34763.7
5300.	56.4496	6.6843	63.1339	6.6251	35426.5
5400.	56.5746	6.6831	63.2576	6.6185	36088.7
5500.	56.6972	6.6819	63.3790	6.6124	36750.2
5600.	56.8176	6.6806	63.4981	6.6068	37411.2
5700.	56.9358	6.6792	63.6150	6.6017	38071.6
5800.	57.0519	6.6779	63.7298	6.5972	38731.6
5900.	57.1661	6.6765	63.8425	6.5932	39391.1
6000.	57.2783	6.6750	63.9533	6.5898	40050.2
6100.	57.3886	6.6736	64.0622	6.5869	40709.1
6200.	57.4971	6.6722	64.1693	6.5845	41367.6
6300.	57.6039	6.6708	64.2746	6.5827	42026.0

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 91.22

Table A-75-1 Thermodynamic Functions for Zr^+ - continued

T °K	$\frac{-(F^o-H^o_0)}{T}$	$\frac{H^o - H^o_0}{T}$	S^o	C^o_p	$H^o - H^o_0$
6400.	57.7089	6.6694	64.3783	6.5814	42684.2
6500.	57.8123	6.6680	64.4803	6.5806	43342.3
6600.	57.9141	6.6667	64.5808	6.5803	44000.3
6700.	58.0143	6.6654	64.6798	6.5806	44658.4
6800.	58.1131	6.6642	64.7772	6.5813	45316.5
6900.	58.2103	6.6630	64.8733	6.5825	45974.6
7000.	58.3062	6.6619	64.9681	6.5842	46633.0
7100.	58.4007	6.6608	65.0615	6.5863	47291.5
7200.	58.4939	6.6598	65.1536	6.5888	47950.2
7300.	58.5857	6.6588	65.2445	6.5918	48609.3
7400.	58.6763	6.6579	65.3342	6.5951	49268.6
7500.	58.7657	6.6571	65.4228	6.5988	49928.3
7600.	58.8538	6.6564	65.5102	6.6028	50588.4
7700.	58.9408	6.6557	65.5965	6.6072	51248.9
7800.	59.0267	6.6551	65.6818	6.6118	51909.8
7900.	59.1115	6.6546	65.7661	6.6168	52571.2
8000.	59.1952	6.6541	65.8493	6.6220	53233.2
8100.	59.2779	6.6538	65.9316	6.6275	53895.7
8200.	59.3595	6.6535	66.0130	6.6332	54558.7
8300.	59.4401	6.6533	66.0934	6.6391	55222.3
8400.	59.5198	6.6532	66.1730	6.6452	55886.5
8500.	59.5986	6.6531	66.2517	6.6515	56551.4
8600.	59.6764	6.6531	66.3295	6.6579	57216.8
8700.	59.7533	6.6532	66.4065	6.6645	57882.9
8800.	59.8293	6.6534	66.4827	6.6712	58549.7
8900.	59.9045	6.6536	66.5581	6.6780	59217.2
9000.	59.9789	6.6539	66.6328	6.6848	59885.3
9100.	60.0524	6.6543	66.7067	6.6918	60554.1
9200.	60.1251	6.6547	66.7799	6.6988	61223.7
9300.	60.1971	6.6553	66.8523	6.7058	61893.9
9400.	60.2682	6.6558	66.9241	6.7129	62564.8
9500.	60.3387	6.6565	66.9951	6.7200	63236.5
9600.	60.4084	6.6572	67.0655	6.7270	63908.8
9700.	60.4774	6.6579	67.1353	6.7341	64581.9
9800.	60.5457	6.6587	67.2044	6.7411	65255.7
9900.	60.6133	6.6596	67.2729	6.7482	65930.1
10000.	60.6802	6.6605	67.3407	6.7551	66605.3
10100.	60.7465	6.6615	67.4080	6.7620	67281.1

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.010962
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.045865
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.010955

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Table A-76-1 Thermodynamic Functions for Mo^+

T °K	$\frac{-(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
273.15	37.7529	4.9681	42.7210	4.9681	1357.1
298.15	38.1880	4.9681	43.1561	4.9681	1481.3
1000.	44.2002	4.9682	49.1684	4.9682	4968.2
1100.	44.6737	4.9682	49.6419	4.9683	5465.0
1200.	45.1060	4.9682	50.0742	4.9688	5961.8
1300.	45.5037	4.9683	50.4720	4.9700	6458.8
1400.	45.8719	4.9685	50.8403	4.9725	6955.9
1500.	46.2147	4.9689	51.1836	4.9773	7453.3
1600.	46.5354	4.9697	51.5050	4.9857	7951.4
1700.	46.8367	4.9710	51.8077	4.9994	8450.7
1800.	47.1209	4.9731	52.0940	5.0201	8951.6
1900.	47.3898	4.9763	52.3662	5.0500	9455.0
2000.	47.6452	4.9810	52.6262	5.0909	9961.9
2100.	47.8884	4.9874	52.8758	5.1451	10473.6
2200.	48.1206	4.9961	53.1167	5.2144	10991.4
2300.	48.3429	5.0074	53.3503	5.3005	11517.0
2400.	48.5563	5.0217	53.5780	5.4048	12052.2
2500.	48.7617	5.0395	53.8011	5.5286	12598.7
2600.	48.9597	5.0610	54.0207	5.6726	13158.5
2700.	49.1512	5.0866	54.2378	5.8371	13733.9
2800.	49.3367	5.1167	54.4534	6.0223	14326.7
2900.	49.5168	5.1514	54.6682	6.2277	14939.0
3000.	49.6921	5.1910	54.8831	6.4527	15572.9
3100.	49.8631	5.2355	55.0986	6.6963	16230.2
3200.	50.0301	5.2852	55.3153	6.9569	16912.7
3300.	50.1935	5.3400	55.5335	7.2330	17622.1
3400.	50.3538	5.3999	55.7537	7.5225	18359.7
3500.	50.5113	5.4648	55.9761	7.8235	19126.9
3600.	50.6662	5.5346	56.2008	8.1334	19924.7
3700.	50.8188	5.6091	56.4280	8.4499	20753.8
3800.	50.9695	5.6881	56.6576	8.7704	21614.8
3900.	51.1183	5.7713	56.8895	9.0922	22508.0
4000.	51.2655	5.8583	57.1238	9.4129	23433.2
4100.	51.4112	5.9489	57.3601	9.7298	24390.4
4200.	51.5557	6.0426	57.5983	10.0405	25379.0
4300.	51.6990	6.1391	57.8381	10.3428	26398.2
4400.	51.8413	6.2380	58.0793	10.6345	27447.2
4500.	51.9826	6.3388	58.3214	10.9136	28524.7
4600.	52.1230	6.4412	58.5642	11.1785	29629.4
4700.	52.2627	6.5447	58.8073	11.4277	30759.9
4800.	52.4015	6.6488	59.0504	11.6599	31914.4
4900.	52.5397	6.7533	59.2930	11.8742	33091.3
5000.	52.6772	6.8577	59.5349	12.0698	34288.6
5100.	52.8140	6.9617	59.7757	12.2464	35504.6
5200.	52.9502	7.0649	60.0151	12.4036	36737.3
5300.	53.0858	7.1669	60.2527	12.5414	37984.7
5400.	53.2207	7.2676	60.4882	12.6601	39244.9
5500.	53.3549	7.3666	60.7215	12.7599	40516.1
5600.	53.4885	7.4636	60.9522	12.8413	41796.3
5700.	53.6215	7.5585	61.1800	12.9051	43083.7
5800.	53.7537	7.6512	61.4049	12.9519	44376.7
5900.	53.8853	7.7413	61.6266	12.9826	45673.6
6000.	54.0161	7.8288	61.8449	12.9982	46972.7
6100.	54.1463	7.9136	62.0598	12.9996	48272.7
6200.	54.2756	7.9955	62.2711	12.9877	49572.2
6300.	54.4042	8.0746	62.4788	12.9638	50869.9

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 95.95

Table A-76-1 Thermodynamic Functions for Mo^+ - continued

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
6400.	54.5319	8.1507	62.6826	12.9286	52164.6
6500.	54.6589	8.2239	62.8828	12.8833	53455.3
6600.	54.7850	8.2941	63.0791	12.8288	54740.9
6700.	54.9102	8.3613	63.2715	12.7662	56020.8
6800.	55.0346	8.4256	63.4601	12.6962	57293.9
6900.	55.1580	8.4869	63.6449	12.6199	58559.8
7000.	55.2805	8.5454	63.8259	12.5379	59817.7
7100.	55.4022	8.6010	64.0032	12.4512	61067.2
7200.	55.5228	8.6539	64.1767	12.3605	62307.8
7300.	55.6425	8.7040	64.3465	12.2663	63539.2
7400.	55.7613	8.7515	64.5128	12.1695	64761.0
7500.	55.8791	8.7964	64.6755	12.0705	65973.0
7600.	55.9959	8.8388	64.8347	11.9698	67175.0
7700.	56.1117	8.8788	64.9905	11.8681	68366.9
7800.	56.2265	8.9165	65.1430	11.7656	69548.6
7900.	56.3403	8.9519	65.2922	11.6629	70720.1
8000.	56.4531	8.9852	65.4383	11.5602	71881.2
8100.	56.5649	9.0163	65.5812	11.4579	73032.1
8200.	56.6757	9.0455	65.7212	11.3563	74172.8
8300.	56.7855	9.0727	65.8582	11.2556	75303.4
8400.	56.8943	9.0981	65.9924	11.1560	76424.0
8500.	57.0022	9.1217	66.1239	11.0578	77534.6
8600.	57.1090	9.1437	66.2526	10.9610	78635.6
8700.	57.2148	9.1640	66.3788	10.8659	79726.9
8800.	57.3196	9.1828	66.5025	10.7725	80808.8
8900.	57.4235	9.2002	66.6237	10.6809	81881.4
9000.	57.5264	9.2161	66.7425	10.5912	82945.0
9100.	57.6283	9.2307	66.8591	10.5036	83999.8
9200.	57.7293	9.2441	66.9734	10.4179	85045.8
9300.	57.8293	9.2563	67.0856	10.3344	86083.4
9400.	57.9283	9.2673	67.1956	10.2529	87112.8
9500.	58.0265	9.2773	67.3037	10.1735	88134.1
9600.	58.1236	9.2862	67.4098	10.0962	89147.5
9700.	58.2199	9.2942	67.5141	10.0211	90153.4
9800.	58.3153	9.3012	67.6165	9.9480	91151.8
9900.	58.4097	9.3074	67.7171	9.8770	92143.1
10000.	58.5033	9.3127	67.8160	9.8080	93127.3
10100.	58.5960	9.3173	67.9133	9.7411	94104.7

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.010422
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.043606
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.010415

Table A-77-1 Thermodynamic Functions for I^+

T °K	$-(F^\circ - H^\circ_0)/T$	$(H^\circ - H^\circ_0)/T$	S°	C°_p	$H^\circ - H^\circ_0$
273.15	38.2242	4.9681	43.1923	4.9681	1357.1
298.15	38.6592	4.9681	43.6274	4.9681	1481.3
1000.	44.6716	4.9689	49.6405	4.9759	4968.9
1100.	45.1452	4.9699	50.1151	4.9839	5466.9
1200.	45.5777	4.9716	50.5493	4.9961	5965.9
1300.	45.9757	4.9741	50.9498	5.0130	6466.3
1400.	46.3445	4.9776	51.3221	5.0348	6968.6
1500.	46.6880	4.9823	51.6703	5.0612	7473.4
1600.	47.0098	4.9881	51.9979	5.0920	7981.0
1700.	47.3124	4.9952	52.3076	5.1266	8491.9
1800.	47.5981	5.0036	52.6017	5.1643	9006.4
1900.	47.8689	5.0131	52.8820	5.2045	9524.9
2000.	48.1263	5.0237	53.1500	5.2466	10047.4
2100.	48.3717	5.0353	53.4070	5.2900	10574.2
2200.	48.6062	5.0479	53.6542	5.3343	11105.4
2300.	48.8309	5.0613	53.8923	5.3790	11641.1
2400.	49.0466	5.0755	54.1221	5.4236	12181.2
2500.	49.2541	5.0903	54.3444	5.4680	12725.8
2600.	49.4541	5.1057	54.5598	5.5117	13274.8
2700.	49.6470	5.1215	54.7686	5.5546	13828.1
2800.	49.8336	5.1377	54.9713	5.5965	14385.7
2900.	50.0142	5.1543	55.1684	5.6372	14947.4
3000.	50.1892	5.1710	55.3602	5.6766	15513.1
3100.	50.3590	5.1880	55.5470	5.7145	16082.7
3200.	50.5240	5.2050	55.7290	5.7509	16655.9
3300.	50.6844	5.2221	55.9065	5.7857	17232.8
3400.	50.8406	5.2391	56.0797	5.8189	17813.0
3500.	50.9927	5.2561	56.2488	5.8504	18396.5
3600.	51.1410	5.2731	56.4141	5.8802	18983.1
3700.	51.2857	5.2899	56.5756	5.9083	19572.5
3800.	51.4270	5.3065	56.7335	5.9347	20164.7
3900.	51.5651	5.3229	56.8880	5.9593	20759.4
4000.	51.7000	5.3391	57.0391	5.9823	21356.5
4100.	51.8321	5.3551	57.1871	6.0036	21955.8
4200.	51.9613	5.3707	57.3320	6.0232	22557.1
4300.	52.0878	5.3861	57.4740	6.0413	23160.4
4400.	52.2118	5.4012	57.6131	6.0578	23765.4
4500.	52.3334	5.4160	57.7494	6.0728	24371.9
4600.	52.4526	5.4304	57.8830	6.0863	24979.9
4700.	52.5695	5.4445	58.0140	6.0983	25589.1
4800.	52.6843	5.4582	58.1425	6.1091	26199.5
4900.	52.7970	5.4716	58.2686	6.1185	26810.9
5000.	52.9076	5.4846	58.3923	6.1266	27423.1
5100.	53.0164	5.4973	58.5137	6.1336	28036.1
5200.	53.1233	5.5096	58.6328	6.1394	28649.8
5300.	53.2283	5.5215	58.7498	6.1441	29264.0
5400.	53.3316	5.5331	58.8647	6.1478	29878.6
5500.	53.4333	5.5443	58.9775	6.1505	30493.5
5600.	53.5333	5.5551	59.0884	6.1522	31108.6
5700.	53.6317	5.5656	59.1973	6.1532	31723.9
5800.	53.7286	5.5757	59.3043	6.1533	32339.2
5900.	53.8240	5.5855	59.4095	6.1526	32954.5
6000.	53.9179	5.5950	59.5129	6.1512	33569.7
6100.	54.0105	5.6041	59.6145	6.1491	34184.8
6200.	54.1017	5.6128	59.7145	6.1464	34799.5
6300.	54.1915	5.6213	59.8128	6.1431	35414.0

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 126.91

Table A-77-1 Thermodynamic Functions for I^+ - continued

T °K	$-(F^o-H^o_0)/T$	$(H^o-H^o_0)/T$	S^o	C^o_p	$H^o-H^o_0$
6400.	54.2801	5.6294	59.9095	6.1393	36028.2
6500.	54.3675	5.6372	60.0047	6.1350	36641.9
6600.	54.4536	5.6447	60.0983	6.1302	37255.1
6700.	54.5385	5.6519	60.1905	6.1250	37867.9
6800.	54.6223	5.6588	60.2812	6.1193	38480.1
6900.	54.7050	5.6655	60.3704	6.1134	39091.8
7000.	54.7865	5.6718	60.4584	6.1071	39702.8
7100.	54.8670	5.6779	60.5449	6.1004	40313.2
7200.	54.9465	5.6837	60.6302	6.0936	40922.9
7300.	55.0249	5.6893	60.7142	6.0864	41531.9
7400.	55.1024	5.6946	60.7970	6.0791	42140.1
7500.	55.1788	5.6997	60.8785	6.0716	42747.7
7600.	55.2544	5.7045	60.9589	6.0638	43354.4
7700.	55.3290	5.7091	61.0381	6.0560	43960.4
7800.	55.4027	5.7135	61.1162	6.0480	44565.6
7900.	55.4755	5.7177	61.1932	6.0399	45170.0
8000.	55.5474	5.7217	61.2691	6.0317	45773.6
8100.	55.6185	5.7255	61.3440	6.0234	46376.4
8200.	55.6888	5.7291	61.4179	6.0151	46978.3
8300.	55.7583	5.7325	61.4907	6.0068	47579.4
8400.	55.8269	5.7357	61.5626	5.9984	48179.7
8500.	55.8948	5.7387	61.6335	5.9900	48779.1
8600.	55.9620	5.7416	61.7036	5.9816	49377.7
8700.	56.0284	5.7443	61.7727	5.9733	49975.4
8800.	56.0940	5.7469	61.8409	5.9650	50572.3
8900.	56.1590	5.7493	61.9082	5.9567	51168.4
9000.	56.2232	5.7515	61.9747	5.9485	51763.7
9100.	56.2868	5.7536	62.0404	5.9404	52358.1
9200.	56.3497	5.7556	62.1053	5.9323	52951.7
9300.	56.4119	5.7575	62.1694	5.9244	53544.6
9400.	56.4735	5.7592	62.2327	5.9165	54136.6
9500.	56.5345	5.7608	62.2953	5.9088	54727.9
9600.	56.5948	5.7623	62.3571	5.9012	55318.4
9700.	56.6545	5.7637	62.4182	5.8937	55908.1
9800.	56.7136	5.7650	62.4786	5.8864	56497.1
9900.	56.7722	5.7662	62.5384	5.8793	57085.4
10000.	56.8301	5.7673	62.5974	5.8723	57673.0
10100.	56.8875	5.7683	62.6558	5.8656	58259.9

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.0078796
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.032968
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.0078744

Table A-78-1 Thermodynamic Functions for K^+

T °K	$-(F^o-H^o_0)/T$	$(H^o-H^o_0)/T$	S^o	C^o_p	$H^o-H^o_0$
273.15	31.5162	4.9681	36.4843	4.9681	1357.1
298.15	31.9513	4.9681	36.9194	4.9681	1481.3
1000.	37.9635	4.9681	42.9317	4.9681	4968.1
1100.	38.4370	4.9681	43.4052	4.9681	5465.0
1200.	38.8693	4.9681	43.8375	4.9681	5961.8
1300.	39.2670	4.9681	44.2351	4.9681	6458.6
1400.	39.6352	4.9681	44.6033	4.9681	6955.4
1500.	39.9779	4.9681	44.9461	4.9681	7452.2
1600.	40.2986	4.9681	45.2667	4.9681	7949.0
1700.	40.5998	4.9681	45.5679	4.9681	8445.9
1800.	40.8837	4.9681	45.8519	4.9681	8942.7
1900.	41.1523	4.9681	46.1205	4.9681	9439.5
2000.	41.4072	4.9681	46.3753	4.9681	9936.3
2100.	41.6496	4.9681	46.6177	4.9681	10433.1
2200.	41.8807	4.9681	46.8488	4.9681	10929.9
2300.	42.1015	4.9681	47.0697	4.9681	11426.7
2400.	42.3130	4.9681	47.2811	4.9681	11923.6
2500.	42.5158	4.9681	47.4839	4.9681	12420.4
2600.	42.7106	4.9681	47.6788	4.9681	12917.2
2700.	42.8981	4.9681	47.8663	4.9681	13414.0
2800.	43.0788	4.9681	48.0470	4.9681	13910.8
2900.	43.2532	4.9681	48.2213	4.9681	14407.6
3000.	43.4216	4.9681	48.3897	4.9681	14904.4
3100.	43.5845	4.9681	48.5526	4.9681	15401.3
3200.	43.7422	4.9681	48.7104	4.9681	15898.1
3300.	43.8951	4.9681	48.8632	4.9681	16394.9
3400.	44.0434	4.9681	49.0116	4.9681	16891.7
3500.	44.1874	4.9681	49.1556	4.9681	17388.5
3600.	44.3274	4.9681	49.2955	4.9681	17885.3
3700.	44.4635	4.9681	49.4317	4.9681	18382.2
3800.	44.5960	4.9681	49.5641	4.9681	18879.0
3900.	44.7250	4.9681	49.6932	4.9681	19375.8
4000.	44.8508	4.9681	49.8190	4.9681	19872.6
4100.	44.9735	4.9681	49.9417	4.9681	20369.4
4200.	45.0932	4.9681	50.0614	4.9681	20866.2
4300.	45.2101	4.9681	50.1783	4.9681	21363.0
4400.	45.3243	4.9681	50.2925	4.9681	21859.9
4500.	45.4360	4.9681	50.4041	4.9681	22356.7
4600.	45.5452	4.9681	50.5133	4.9681	22853.5
4700.	45.6520	4.9681	50.6202	4.9681	23350.3
4800.	45.7566	4.9681	50.7248	4.9681	23847.1
4900.	45.8591	4.9681	50.8272	4.9681	24343.9
5000.	45.9594	4.9681	50.9276	4.9681	24840.7
5100.	46.0578	4.9681	51.0260	4.9681	25337.6
5200.	46.1543	4.9681	51.1224	4.9681	25834.4
5300.	46.2489	4.9681	51.2171	4.9681	26331.2
5400.	46.3418	4.9681	51.3099	4.9681	26828.0
5500.	46.4330	4.9681	51.4011	4.9681	27324.8
5600.	46.5225	4.9681	51.4906	4.9681	27821.6
5700.	46.6104	4.9681	51.5786	4.9681	28318.5
5800.	46.6968	4.9681	51.6650	4.9681	28815.3
5900.	46.7817	4.9681	51.7499	4.9681	29312.1
6000.	46.8652	4.9681	51.8334	4.9681	29808.9
6100.	46.9474	4.9681	51.9155	4.9681	30305.7
6200.	47.0281	4.9681	51.9963	4.9681	30802.5
6300.	47.1076	4.9681	52.0758	4.9681	31299.3

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 39.0995

Table A-78-1 Thermodynamic Functions for K^+ - continued

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
6400.	47.1859	4.9681	52.1540	4.9681	31796.2
6500.	47.2629	4.9681	52.2311	4.9681	32293.0
6600.	47.3388	4.9681	52.3069	4.9681	32789.8
6700.	47.4135	4.9681	52.3816	4.9681	33286.6
6800.	47.4871	4.9681	52.4552	4.9681	33783.4
6900.	47.5596	4.9681	52.5277	4.9681	34280.2
7000.	47.6311	4.9681	52.5992	4.9681	34777.0
7100.	47.7016	4.9681	52.6697	4.9681	35273.9
7200.	47.7710	4.9681	52.7392	4.9681	35770.7
7300.	47.8396	4.9681	52.8077	4.9681	36267.5
7400.	47.9072	4.9681	52.8753	4.9681	36764.3
7500.	47.9739	4.9681	52.9420	4.9681	37261.1
7600.	48.0397	4.9681	53.0078	4.9681	37757.9
7700.	48.1046	4.9681	53.0727	4.9681	38254.8
7800.	48.1687	4.9681	53.1369	4.9681	38751.6
7900.	48.2320	4.9681	53.2001	4.9681	39248.4
8000.	48.2945	4.9681	53.2626	4.9681	39745.2
8100.	48.3562	4.9681	53.3244	4.9681	40242.0
8200.	48.4172	4.9681	53.3853	4.9681	40738.8
8300.	48.4774	4.9681	53.4455	4.9681	41235.6
8400.	48.5369	4.9681	53.5050	4.9681	41732.5
8500.	48.5957	4.9681	53.5638	4.9681	42229.3
8600.	48.6538	4.9681	53.6219	4.9681	42726.1
8700.	48.7112	4.9681	53.6794	4.9681	43222.9
8800.	48.7680	4.9681	53.7362	4.9681	43719.7
8900.	48.8241	4.9681	53.7923	4.9681	44216.5
9000.	48.8797	4.9681	53.8478	4.9681	44713.3
9100.	48.9345	4.9681	53.9027	4.9681	45210.2
9200.	48.9888	4.9681	53.9570	4.9681	45707.0
9300.	49.0426	4.9681	54.0107	4.9681	46203.8
9400.	49.0957	4.9681	54.0638	4.9682	46700.6
9500.	49.1483	4.9681	54.1164	4.9682	47197.4
9600.	49.2003	4.9681	54.1684	4.9682	47694.2
9700.	49.2518	4.9681	54.2199	4.9682	48191.1
9800.	49.3027	4.9681	54.2709	4.9682	48687.9
9900.	49.3532	4.9682	54.3213	4.9682	49184.7
10000.	49.4031	4.9682	54.3712	4.9682	49681.5
10100.	49.4525	4.9682	54.4207	4.9682	50178.3

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.025576
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.10701
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.025559

Table A-79-1 Thermodynamic Functions for Pb^{+}

T °K	$-(F^o-H^o_0)/T$	$(H^o - H^o_0)/T$	S^o	C^o_p	$H^o - H^o_0$
273.15	37.8646	4.9681	42.8328	4.9681	1357.1
298.15	38.2997	4.9681	43.2679	4.9681	1481.3
1000.	44.3120	4.9682	49.2801	4.9682	4968.2
1100.	44.7855	4.9682	49.7536	4.9682	5465.0
1200.	45.2178	4.9682	50.1859	4.9682	5961.8
1300.	45.6154	4.9682	50.5836	4.9683	6458.6
1400.	45.9836	4.9682	50.9518	4.9686	6955.5
1500.	46.3264	4.9682	51.2946	4.9691	7452.3
1600.	46.6470	4.9683	51.6153	4.9702	7949.3
1700.	46.9482	4.9685	51.9167	4.9719	8446.4
1800.	47.2322	4.9687	52.2010	4.9747	8943.7
1900.	47.5009	4.9691	52.4700	4.9787	9441.4
2000.	47.7558	4.9698	52.7255	4.9844	9939.5
2100.	47.9983	4.9706	52.9689	4.9920	10438.3
2200.	48.2295	4.9718	53.2014	5.0019	10938.0
2300.	48.4506	4.9734	53.4240	5.0142	11438.8
2400.	48.6623	4.9754	53.6377	5.0292	11940.9
2500.	48.8654	4.9779	53.8433	5.0470	12444.7
2600.	49.0607	4.9809	54.0417	5.0676	12950.4
2700.	49.2488	4.9846	54.2334	5.0912	13458.3
2800.	49.4301	4.9888	54.4190	5.1176	13968.7
2900.	49.6053	4.9938	54.5991	5.1468	14482.0
3000.	49.7747	4.9994	54.7741	5.1787	14998.2
3100.	49.9387	5.0057	54.9444	5.2131	15517.8
3200.	50.0977	5.0128	55.1105	5.2497	16040.9
3300.	50.2521	5.0205	55.2727	5.2884	16567.8
3400.	50.4021	5.0290	55.4311	5.3290	17098.6
3500.	50.5480	5.0382	55.5862	5.3711	17633.6
3600.	50.6901	5.0480	55.7381	5.4145	18172.9
3700.	50.8285	5.0585	55.8871	5.4589	18716.6
3800.	50.9636	5.0697	56.0333	5.5042	19264.7
3900.	51.0954	5.0814	56.1768	5.5499	19817.4
4000.	51.2242	5.0937	56.3179	5.5960	20374.7
4100.	51.3502	5.1065	56.4567	5.6421	20936.6
4200.	51.4734	5.1198	56.5932	5.6881	21503.1
4300.	51.5940	5.1335	56.7275	5.7336	22074.2
4400.	51.7122	5.1477	56.8599	5.7786	22649.8
4500.	51.8280	5.1622	56.9902	5.8229	23229.9
4600.	51.9417	5.1770	57.1187	5.8662	23814.4
4700.	52.0532	5.1922	57.2453	5.9085	24403.1
4800.	52.1626	5.2075	57.3701	5.9496	24996.0
4900.	52.2702	5.2231	57.4932	5.9895	25593.0
5000.	52.3758	5.2388	57.6146	6.0279	26193.9
5100.	52.4797	5.2546	57.7344	6.0649	26798.5
5200.	52.5819	5.2705	57.8525	6.1004	27406.8
5300.	52.6825	5.2865	57.9690	6.1343	28018.6
5400.	52.7814	5.3025	58.0840	6.1666	28633.6
5500.	52.8789	5.3185	58.1974	6.1972	29251.8
5600.	52.9749	5.3345	58.3093	6.2262	29873.0
5700.	53.0694	5.3503	58.4198	6.2535	30497.0
5800.	53.1626	5.3661	58.5287	6.2791	31123.6
5900.	53.2545	5.3818	58.6363	6.3031	31752.8
6000.	53.3451	5.3974	58.7424	6.3255	32384.2
6100.	53.4344	5.4128	58.8471	6.3462	33017.8
6200.	53.5225	5.4280	58.9505	6.3654	33653.4
6300.	53.6095	5.4430	59.0525	6.3830	34290.8

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 207.21

Table A-79-1 Thermodynamic Functions for Pb^+ - continued

T °K	$-(F^\circ - H^\circ_0)/T$	$(H^\circ - H^\circ_0)/T$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	53.6953	5.4578	59.1531	6.3991	34929.9
6500.	53.7801	5.4724	59.2525	6.4138	35570.6
6600.	53.8637	5.4868	59.3505	6.4271	36212.7
6700.	53.9463	5.5009	59.4472	6.4390	36856.0
6800.	54.0279	5.5148	59.5427	6.4496	37500.4
6900.	54.1085	5.5284	59.6369	6.4590	38145.8
7000.	54.1882	5.5417	59.7299	6.4671	38792.2
7100.	54.2669	5.5548	59.8217	6.4742	39439.2
7200.	54.3447	5.5676	59.9123	6.4802	40087.0
7300.	54.4216	5.5802	60.0017	6.4852	40735.2
7400.	54.4976	5.5924	60.0900	6.4892	41384.0
7500.	54.5727	5.6044	60.1771	6.4924	42033.1
7600.	54.6470	5.6161	60.2631	6.4947	42682.4
7700.	54.7205	5.6275	60.3480	6.4963	43332.0
7800.	54.7932	5.6387	60.4319	6.4972	43981.7
7900.	54.8651	5.6495	60.5146	6.4974	44631.4
8000.	54.9362	5.6601	60.5964	6.4971	45281.1
8100.	55.0066	5.6705	60.6771	6.4962	45930.8
8200.	55.0762	5.6805	60.7568	6.4949	46580.4
8300.	55.1452	5.6903	60.8355	6.4932	47229.8
8400.	55.2134	5.6999	60.9132	6.4911	47879.0
8500.	55.2809	5.7092	60.9900	6.4887	48528.0
8600.	55.3477	5.7182	61.0659	6.4861	49176.7
8700.	55.4139	5.7270	61.1409	6.4833	49825.2
8800.	55.4794	5.7356	61.2150	6.4803	50473.4
8900.	55.5442	5.7440	61.2882	6.4773	51121.2
9000.	55.6084	5.7521	61.3605	6.4742	51768.8
9100.	55.6720	5.7600	61.4321	6.4712	52416.1
9200.	55.7350	5.7677	61.5028	6.4682	53063.1
9300.	55.7974	5.7752	61.5727	6.4653	53709.7
9400.	55.8592	5.7826	61.6418	6.4625	54356.1
9500.	55.9205	5.7897	61.7102	6.4600	55002.2
9600.	55.9811	5.7967	61.7778	6.4577	55648.1
9700.	56.0412	5.8035	61.8447	6.4557	56293.8
9800.	56.1008	5.8101	61.9109	6.4540	56939.3
9900.	56.1598	5.8166	61.9764	6.4527	57584.6
10000.	56.2183	5.8230	62.0413	6.4518	58229.8
10100.	56.2763	5.8292	62.1055	6.4514	58875.0

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	.0048260
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	.020192
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	.0048229

Table A-80-1 Thermodynamic Functions for Hg^+

T °K	$-(F^\circ-H^\circ_0)/T$	$(H^\circ - H^\circ_0)/T$	S°	C°_p	$H^\circ - H^\circ_0$
273.15	37.7681	4.9681	42.7363	4.9681	1357.1
298.15	38.2032	4.9681	43.1714	4.9681	1481.3
1000.	44.2155	4.9681	49.1836	4.9681	4968.1
1100.	44.6890	4.9681	49.6571	4.9681	5465.0
1200.	45.1213	4.9681	50.0894	4.9681	5961.8
1300.	45.5189	4.9681	50.4871	4.9681	6458.6
1400.	45.8871	4.9681	50.8553	4.9681	6955.4
1500.	46.2299	4.9681	51.1980	4.9681	7452.2
1600.	46.5505	4.9681	51.5187	4.9681	7949.0
1700.	46.8517	4.9681	51.8199	4.9681	8445.9
1800.	47.1357	4.9681	52.1038	4.9681	8942.7
1900.	47.4043	4.9681	52.3725	4.9681	9439.5
2000.	47.6591	4.9681	52.6273	4.9681	9936.3
2100.	47.9015	4.9681	52.8697	4.9682	10433.1
2200.	48.1327	4.9681	53.1008	4.9682	10929.9
2300.	48.3535	4.9681	53.3217	4.9682	11426.7
2400.	48.5649	4.9682	53.5331	4.9682	11923.6
2500.	48.7678	4.9682	53.7359	4.9682	12420.4
2600.	48.9626	4.9682	53.9308	4.9682	12917.2
2700.	49.1501	4.9682	54.1183	4.9682	13414.0
2800.	49.3308	4.9682	54.2989	4.9682	13910.8
2900.	49.5051	4.9682	54.4733	4.9682	14407.6
3000.	49.6736	4.9682	54.6417	4.9682	14904.5
3100.	49.8365	4.9682	54.8046	4.9683	15401.3
3200.	49.9942	4.9682	54.9624	4.9683	15898.1
3300.	50.1471	4.9682	55.1152	4.9684	16395.0
3400.	50.2954	4.9682	55.2636	4.9686	16891.8
3500.	50.4394	4.9682	55.4076	4.9687	17388.7
3600.	50.5794	4.9682	55.5476	4.9690	17885.5
3700.	50.7155	4.9682	55.6837	4.9693	18382.5
3800.	50.8480	4.9683	55.8162	4.9697	18879.4
3900.	50.9770	4.9683	55.9453	4.9703	19376.4
4000.	51.1028	4.9684	56.0712	4.9709	19873.5
4100.	51.2255	4.9684	56.1939	4.9718	20370.6
4200.	51.3452	4.9685	56.3138	4.9728	20867.8
4300.	51.4621	4.9686	56.4308	4.9740	21365.2
4400.	51.5764	4.9688	56.5452	4.9755	21862.6
4500.	51.6880	4.9690	56.6570	4.9773	22360.3
4600.	51.7972	4.9692	56.7664	4.9794	22858.1
4700.	51.9041	4.9694	56.8735	4.9818	23356.2
4800.	52.0087	4.9697	56.9784	4.9846	23854.5
4900.	52.1112	4.9700	57.0812	4.9878	24353.1
5000.	52.2116	4.9704	57.1820	4.9914	24852.1
5100.	52.3101	4.9709	57.2809	4.9956	25351.4
5200.	52.4066	4.9714	57.3780	5.0002	25851.2
5300.	52.5013	4.9720	57.4733	5.0054	26351.5
5400.	52.5942	4.9726	57.5669	5.0111	26852.3
5500.	52.6855	4.9734	57.6589	5.0175	27353.7
5600.	52.7751	4.9743	57.7494	5.0245	27855.8
5700.	52.8632	4.9752	57.8384	5.0322	28358.6
5800.	52.9497	4.9763	57.9259	5.0406	28862.3
5900.	53.0348	4.9774	58.0122	5.0497	29366.8
6000.	53.1184	4.9787	58.0971	5.0595	29872.2
6100.	53.2007	4.9801	58.1809	5.0701	30378.7
6200.	53.2817	4.9817	58.2634	5.0815	30886.3
6300.	53.3615	4.9833	58.3448	5.0938	31395.0

The tables are in units of calories, moles and °K. See reverse side for conversion factors to other units. The atomic weight = 200.61

Table A-80-1 Thermodynamic Functions for Hg^{+} - continued

T °K	$\frac{-(F^\circ - H^\circ_0)}{T}$	$\frac{H^\circ - H^\circ_0}{T}$	S°	C°_p	$H^\circ - H^\circ_0$
6400.	53.4400	4.9852	58.4251	5.1068	31905.1
6500.	53.5173	4.9871	58.5044	5.1207	32416.4
6600.	53.5934	4.9893	58.5827	5.1355	32929.2
6700.	53.6685	4.9916	58.6600	5.1511	33443.6
6800.	53.7424	4.9940	58.7365	5.1677	33959.5
6900.	53.8154	4.9967	58.8120	5.1851	34477.1
7000.	53.8873	4.9995	58.8868	5.2034	34996.5
7100.	53.9582	5.0025	58.9607	5.2226	35517.8
7200.	54.0282	5.0057	59.0339	5.2428	36041.1
7300.	54.0973	5.0091	59.1064	5.2638	36566.4
7400.	54.1654	5.0127	59.1781	5.2858	37093.9
7500.	54.2327	5.0165	59.2492	5.3087	37623.6
7600.	54.2992	5.0205	59.3197	5.3324	38155.6
7700.	54.3649	5.0247	59.3896	5.3572	38690.1
7800.	54.4297	5.0291	59.4589	5.3828	39227.1
7900.	54.4938	5.0338	59.5276	5.4093	39766.7
8000.	54.5572	5.0386	59.5958	5.4367	40309.0
8100.	54.6198	5.0437	59.6635	5.4650	40854.1
8200.	54.6817	5.0490	59.7308	5.4941	41402.0
8300.	54.7430	5.0546	59.7975	5.5242	41952.9
8400.	54.8035	5.0603	59.8639	5.5550	42506.9
8500.	54.8635	5.0663	59.9298	5.5868	43064.0
8600.	54.9227	5.0726	59.9953	5.6193	43624.3
8700.	54.9814	5.0791	60.0605	5.6527	44187.9
8800.	55.0395	5.0858	60.1253	5.6869	44754.8
8900.	55.0970	5.0927	60.1897	5.7219	45325.3
9000.	55.1540	5.0999	60.2539	5.7577	45899.2
9100.	55.2104	5.1073	60.3177	5.7943	46476.8
9200.	55.2662	5.1150	60.3812	5.8316	47058.1
9300.	55.3216	5.1229	60.4445	5.8696	47643.2
9400.	55.3764	5.1311	60.5075	5.9084	48232.1
9500.	55.4307	5.1395	60.5702	5.9479	48824.9
9600.	55.4846	5.1481	60.6327	5.9881	49421.7
9700.	55.5380	5.1570	60.6949	6.0290	50022.5
9800.	55.5909	5.1661	60.7570	6.0706	50627.5
9900.	55.6434	5.1754	60.8188	6.1128	51236.7
10000.	55.6955	5.1850	60.8805	6.1557	51850.1
10100.	55.7471	5.1948	60.9420	6.1992	52467.8

CONVERSION FACTORS

To Convert Tabulated Values to Quantities Having the Dimensions Indicated Below	Multiply By
cal g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.0049848
joules g^{-1} $°K^{-1}$ (or $°C^{-1}$)	0.020856
Btu lb^{-1} $°R^{-1}$ (or $°F^{-1}$)	0.0049815

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APPENDIX B

THERMODYNAMIC FUNCTIONS OF THE HYDRATES OF SODIUM, POTASSIUM, AND AMMONIUM PENTABORATES

by George T. Furukawa and Martin L. Reilly

As a part of an earlier program on experimental thermodynamic investigations of boron compounds, heat-capacity measurements were obtained on sodium pentaborate pentahydrate ($NaB_5O_8 \cdot 5H_2O$), potassium pentaborate tetrahydrate ($KB_5O_8 \cdot 4H_2O$), and ammonium pentaborate tetrahydrate ($NH_4B_5O_8 \cdot 4H_2O$). These measurements have not as yet been published. Considering that these compounds should be of interest to the light-elements program, their thermodynamic functions from 0° to 370°K are herewith given. The gram-formula masses used for these compounds are one-half of those often used. The values for $NaB_5O_8 \cdot 5H_2O$ are given only to 345°K because of a possible dehydration that was observed above this temperature.

The numbering of these tables is continuous with the tables given in the earlier NBS Reports 6928 and 7093. No table of this report replaces or duplicates a table of any previous report.

TABLE B-55

THERMODYNAMIC FUNCTIONS FOR SODIUM PENTABORATE PENTAHYDRATE (NA $B_5O_8 \cdot 5H_2O$)

SOLID PHASE

GRAM MOLECULAR WT.=295.171 GRAMS 1 CAL=4.1840 ABS J

T DEG K = 273.15 + T DEG C

T	$-(F_T^0-H_0^0)/T$	$(H_T^0-H_0^0)/T$	$(S_T^0-S_0^0)$	$(H_T^0-H_0^0)$	C_P^0	$-(F_T^0-H_0^0)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.0000	0.0000	0.000	0.000	0.000	0.000
5.00	0.0061	0.0181	0.024	0.090	0.072	0.030
10.00	0.0482	0.1445	0.193	1.445	0.577	0.482
15.00	0.1615	0.4761	0.638	7.141	1.831	2.423
20.00	0.3703	1.0339	1.404	20.678	3.610	7.405
25.00	0.6749	1.7441	2.419	43.602	5.600	16.873
30.00	1.0642	2.5674	3.632	77.024	7.782	31.926
35.00	1.5271	3.4737	5.001	121.58	10.060	53.449
40.00	2.0535	4.4383	6.492	177.53	12.317	82.139
45.00	2.6336	5.4381	8.072	244.72	14.548	118.52
50.00	3.2593	6.4598	9.719	322.99	16.755	162.97
55.00	3.9238	7.4926	11.416	412.09	18.873	215.80
60.00	4.6200	8.5277	13.148	511.66	20.951	277.20
65.00	5.3435	9.5621	14.906	621.53	22.983	347.32
70.00	6.0899	10.588	16.678	741.20	24.859	426.29
75.00	6.8549	11.601	18.456	870.08	26.687	514.13
80.00	7.6355	12.601	20.236	1008.1	28.504	610.85
85.00	8.4293	13.590	22.019	1155.2	30.327	716.49
90.00	9.2337	14.567	23.801	1311.0	32.008	831.05
95.00	10.047	15.526	25.574	1475.0	33.566	954.47
100.00	10.868	16.467	27.335	1646.7	35.112	1086.8
105.00	11.693	17.391	29.085	1826.1	36.644	1227.8
110.00	12.523	18.301	30.825	2013.1	38.162	1377.6
115.00	13.357	19.197	32.555	2207.7	39.668	1536.0
120.00	14.193	20.081	34.273	2409.7	41.142	1703.1
125.00	15.030	20.953	35.982	2619.0	42.605	1878.8
130.00	15.869	21.814	37.682	2835.8	44.056	2062.9
135.00	16.708	22.664	39.371	3059.8	45.490	2255.6
140.00	17.547	23.505	41.052	3290.6	46.910	2456.7
145.00	18.387	24.336	42.722	3528.7	48.315	2666.1
150.00	19.226	25.158	44.383	3773.9	49.711	2883.8
155.00	20.064	25.973	46.037	4025.8	51.099	3109.9
160.00	20.901	26.781	47.682	4284.7	52.474	3344.2
165.00	21.738	27.579	49.316	4550.4	53.829	3586.8
170.00	22.573	28.370	50.944	4823.1	55.179	3837.2
175.00	23.406	29.156	52.562	5102.3	56.532	4096.1
180.00	24.238	29.935	54.173	5388.4	57.880	4363.0
185.00	25.069	30.710	55.779	5681.2	59.221	4637.9
190.00	25.899	31.477	57.376	5980.6	60.614	4920.7
195.00	26.726	32.244	58.970	6287.5	62.101	5211.5
200.00	27.553	33.009	60.562	6601.6	63.602	5510.5
205.00	28.377	33.774	62.149	6923.5	65.100	5817.2
210.00	29.199	34.536	63.736	7252.4	66.491	6131.9
215.00	30.022	35.294	65.315	7588.4	67.844	6454.6
220.00	30.841	36.049	66.891	7930.9	69.180	6785.1
225.00	31.659	36.800	68.461	8280.1	70.516	7123.3
230.00	32.476	37.548	70.024	8636.0	71.843	7469.6
235.00	33.291	38.291	71.585	8998.6	73.164	7823.6
240.00	34.106	39.032	73.138	9367.6	74.479	8185.5
245.00	34.919	39.768	74.687	9743.3	75.786	8555.0
250.00	35.729	40.502	76.231	10125.	77.089	8932.4
255.00	36.539	41.233	77.770	10514.	78.384	9317.4
260.00	37.347	41.960	79.304	10909.	79.675	9710.1
265.00	38.152	42.682	80.834	11311.	80.958	10110.
270.00	38.958	43.403	82.361	11719.	82.235	10518.
273.15	39.462	43.855	83.320	11979.	83.035	10779.
275.00	39.761	44.120	83.881	12133.	83.506	10934.
280.00	40.562	44.835	85.397	12554.	84.771	11357.
285.00	41.362	45.547	86.910	12981.	86.028	11788.
290.00	42.161	46.257	88.415	13414.	87.287	12226.
295.00	42.957	46.962	89.919	13854.	88.516	12672.
298.15	43.458	47.404	90.863	14134.	89.295	12957.
300.00	43.752	47.665	91.417	14299.	89.756	13125.

H_0^0 AND S_0^0 APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-55 (CONT.)

THERMODYNAMIC FUNCTIONS FOR SODIUM PENTABORATE PENTAHYDRATE ($NA\ B_5O_8.5H_2O$)

SOLID PHASE

GRAM MOLECULAR WT.=295.171 GRAMS　　　　1 CAL=4.1840 ABS J

T DEG K = 273.15 + T DEG C

T	$-(F^0_T-H^0_0)/T$	$(H^0_T-H^0_0)/T$	$(S^0_T-S^0_0)$	$(H^0_T-H^0_0)$	C^0_P	$-(F^0_T-H^0_0)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
300.00	43.752	47.665	91.417	14299.	89.756	13125.
305.00	44.546	48.365	92.911	14751.	91.001	13586.
310.00	45.337	49.063	94.400	15209.	92.251	14054.
315.00	46.128	49.759	95.887	15674.	93.509	14530.
320.00	46.917	50.452	97.369	16145.	94.783	15013.
325.00	47.706	51.145	98.848	16622.	96.087	15504.
330.00	48.489	51.836	100.33	17105.	97.419	16002.
335.00	49.276	52.526	101.80	17596.	98.786	16507.
340.00	50.057	53.217	103.27	18093.	100.17	17020.
345.00	50.841	53.905	104.75	18598.	101.54	17540.

H^0_0 AND S^0_0 APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-56

THERMODYNAMIC FUNCTIONS FOR POTASSIUM PENTABORATE TETRAHYDRATE ($K\,B_5O_8 \cdot 4H_2O$)

SOLID PHASE

GRAM MOLECULAR WT.=293.264 GRAMS — 1 CAL=4.1840 ABS J

T DEG K = 273.15 + T DEG C

T	$-(F_T^0-H_0^0)/T$	$(H_T^0-H_0^0)/T$	$(S_T^0-S_0^0)$	$(H_T^0-H_0^0)$	C_P^0	$-(F_T^0-H_0^0)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.0000	0.0000	0.000	0.000	0.000	0.000
5.00	0.0062	0.0184	0.025	0.092	0.074	0.031
10.00	0.0492	0.1473	0.196	1.473	0.588	0.492
15.00	0.1648	0.4870	0.652	7.304	1.881	2.473
20.00	0.3793	1.0689	1.448	21.378	3.815	7.585
25.00	0.6973	1.8355	2.533	45.887	6.033	17.432
30.00	1.1097	2.7342	3.844	82.027	8.435	33.291
35.00	1.6047	3.7263	5.331	130.42	10.931	56.164
40.00	2.1706	4.7804	6.951	191.22	13.373	86.824
45.00	2.7961	5.8681	8.664	264.05	15.751	125.83
50.00	3.4716	6.9716	10.443	348.57	18.033	173.57
55.00	4.1879	8.0758	12.264	444.17	20.181	230.33
60.00	4.9376	9.1683	14.106	550.10	22.172	296.25
65.00	5.7139	10.243	15.957	665.77	24.075	371.41
70.00	6.5117	11.293	17.804	790.46	25.782	455.81
75.00	7.3258	12.313	19.639	923.49	27.419	549.43
80.00	8.1522	13.307	21.460	1064.6	29.013	652.17
85.00	8.9683	14.278	23.266	1213.6	30.576	764.01
90.00	9.8313	15.223	25.055	1370.1	31.981	884.82
95.00	10.679	16.140	26.819	1533.3	33.322	1014.5
100.00	11.530	17.032	28.561	1703.2	34.634	1153.0
105.00	12.382	17.901	30.282	1879.6	35.923	1300.1
110.00	13.234	18.749	31.984	2062.4	37.187	1455.8
115.00	14.086	19.578	33.664	2251.5	38.425	1619.9
120.00	14.936	20.389	35.325	2446.7	39.641	1792.4
125.00	15.785	21.183	36.967	2647.9	40.848	1973.1
130.00	16.631	21.962	38.592	2855.2	42.046	2162.0
135.00	17.474	22.728	40.203	3068.4	43.239	2359.0
140.00	18.315	23.482	41.797	3287.5	44.424	2564.1
145.00	19.152	24.226	43.375	3512.7	45.607	2777.0
150.00	19.985	24.957	44.943	3743.5	46.778	2997.8
155.00	20.815	25.679	46.494	3980.4	47.942	3226.3
160.00	21.642	26.393	48.035	4223.0	49.097	3462.7
165.00	22.465	27.098	49.563	4471.3	50.246	3706.7
170.00	23.284	27.796	51.080	4725.4	51.384	3958.4
175.00	24.099	28.487	52.586	4985.2	52.517	4217.5
180.00	24.912	29.171	54.082	5250.5	53.638	4484.2
185.00	25.719	29.847	55.566	5521.5	54.754	4758.4
190.00	26.525	30.516	57.041	5798.0	55.860	5039.7
195.00	27.326	31.181	58.506	6080.1	56.965	5328.6
200.00	28.124	31.838	59.962	6367.6	58.064	5624.8
205.00	28.917	32.490	61.410	6660.9	59.166	5928.3
210.00	29.708	33.141	62.849	6959.4	60.270	6239.0
215.00	30.497	33.783	64.281	7263.4	61.374	6556.6
220.00	31.281	34.424	65.703	7573.1	62.474	6881.7
225.00	32.060	35.057	67.120	7888.1	63.568	7213.7
230.00	32.839	35.691	68.528	8208.7	64.658	7552.8
235.00	33.614	36.317	69.931	8534.7	65.746	7899.1
240.00	34.383	36.943	71.326	8866.2	66.826	8252.2
245.00	35.153	37.562	72.715	9202.9	67.902	8612.3
250.00	35.918	38.181	74.099	9545.2	68.972	8979.4
255.00	36.680	38.795	75.473	9892.7	70.036	9353.3
260.00	37.438	39.405	76.845	10245.	71.095	9734.0
265.00	38.196	40.014	78.210	10604.	72.149	10122.
270.00	38.948	40.619	79.567	10967.	73.198	10516.
273.15	39.422	40.999	80.421	11199.	73.855	10768.
275.00	39.699	41.221	80.922	11336.	74.240	10917.
280.00	40.447	41.819	82.266	11709.	75.277	11325.
285.00	41.193	42.416	83.609	12088.	76.310	11740.
290.00	41.936	43.009	84.945	12473.	77.337	12161.
295.00	42.677	43.599	86.276	12862.	78.358	12589.
298.15	43.141	43.970	87.110	13109.	78.999	12863.
300.00	43.413	44.187	87.600	13256.	79.376	13024.

H_0^0 AND S_0^0 APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-56 (CONT.)

THERMODYNAMIC FUNCTIONS FOR POTASSIUM PENTABORATE TETRAHYDRATE ($K B_5O_8 \cdot 4H_2O$)

SOLID PHASE

GRAM MOLECULAR WT.=293.264 GRAMS 1 CAL=4.1840 ABS J

T DEG K = 273.15 + T DEG C

T	$-(F^0_T-H^0_0)/T$	$(H^0_T-H^0_0)/T$	$(S^0_T-S^0_0)$	$(H^0_T-H^0_0)$	C^0_P	$-(F^0_T-H^0_0)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
300.00	43.413	44.187	87.600	13256.	79.376	13024.
305.00	44.149	44.773	88.922	13656.	80.387	13465.
310.00	44.883	45.354	90.237	14060.	81.396	13913.
315.00	45.612	45.935	91.546	14469.	82.400	14368.
320.00	46.341	46.513	92.851	14884.	83.399	14829.
325.00	47.065	47.087	94.154	15303.	84.391	15296.
330.00	47.789	47.660	95.449	15728.	85.378	15770.
335.00	48.511	48.231	96.740	16157.	86.360	16251.
340.00	49.228	48.798	98.026	16591.	87.335	16738.
345.00	49.945	49.364	99.309	17031.	88.305	17231.
350.00	50.660	49.926	100.59	17474.	89.271	17731.
355.00	51.372	50.488	101.86	17923.	90.232	18237.
360.00	52.082	51.047	103.13	18377.	91.185	18749.
365.00	52.789	51.604	104.39	18835.	92.134	19268.
370.00	53.494	52.156	105.65	19298.	93.076	19793.

H^0_0 AND S^0_0 APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-57

THERMODYNAMIC FUNCTIONS FOR AMMONIUM PENTABORATE TETRAHYDRATE (N $H_4B_5O_8 \cdot 4H_2O$)

SOLID PHASE

GRAM MOLECULAR WT.=272.204 GRAMS　　　　1 CAL=4.1840 ABS J

T DEG K = 273.15 + T DEG C

T	$-(F^0_T-H^0_0)/T$	$(H^0_T-H^0_0)/T$	$(S^0_T-S^0_0)$	$(H^0_T-H^0_0)$	C^0_P	$-(F^0_T-H^0_0)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
0.00	0.0000	0.0000	0.000	0.000	0.000	0.000
5.00	0.0062	0.0193	0.026	0.097	0.078	0.031
10.00	0.0517	0.1561	0.208	1.561	0.623	0.517
15.00	0.1740	0.5134	0.687	7.701	1.966	2.610
20.00	0.3987	1.1136	1.512	22.272	3.917	7.974
25.00	0.7277	1.8866	2.614	47.165	6.099	18.191
30.00	1.1497	2.7892	3.939	83.678	8.536	34.491
35.00	1.6538	3.7913	5.445	132.70	11.085	57.882
40.00	2.2294	4.8633	7.093	194.53	13.634	89.178
45.00	2.8662	5.9766	8.843	268.95	16.121	128.98
50.00	3.5545	7.1123	10.667	355.62	18.530	177.73
55.00	4.2861	8.2557	12.542	454.06	20.828	235.73
60.00	5.0533	9.3951	14.448	563.70	23.012	303.20
65.00	5.8499	10.524	16.374	684.06	25.103	380.23
70.00	6.6707	11.632	18.303	814.27	26.950	466.95
75.00	7.5103	12.713	20.223	953.49	28.736	563.26
80.00	8.3645	13.771	22.136	1101.7	30.543	669.17
85.00	9.2306	14.807	24.037	1258.6	32.204	784.61
90.00	10.106	15.820	25.925	1423.8	33.853	909.51
95.00	10.988	16.810	27.796	1596.9	35.397	1043.8
100.00	11.875	17.776	29.651	1777.6	36.891	1187.5
105.00	12.765	18.722	31.487	1965.8	38.358	1340.3
110.00	13.657	19.647	33.305	2161.2	39.804	1502.3
115.00	14.551	20.554	35.105	2363.8	41.219	1673.3
120.00	15.444	21.445	36.888	2573.4	42.615	1853.3
125.00	16.337	22.319	38.657	2789.9	43.996	2042.2
130.00	17.230	23.179	40.409	3013.4	45.363	2239.9
135.00	18.120	24.025	42.146	3243.5	46.716	2446.2
140.00	19.009	24.859	43.870	3480.4	48.052	2661.3
145.00	19.896	25.684	45.578	3723.9	49.376	2885.0
150.00	20.780	26.494	47.275	3974.2	50.684	3117.1
155.00	21.662	27.294	48.958	4230.9	51.981	3357.6
160.00	22.541	28.088	50.629	4494.0	53.265	3606.6
165.00	23.418	28.870	52.287	4763.4	54.534	3864.0
170.00	24.290	29.641	53.934	5039.2	55.762	4129.5
175.00	25.163	30.406	55.569	5321.2	57.039	4403.2
180.00	26.028	31.164	57.192	5609.5	58.272	4685.2
185.00	26.893	31.912	58.805	5903.9	59.491	4975.1
190.00	27.753	32.655	60.409	6204.3	60.700	5273.2
195.00	28.611	33.389	62.000	6510.8	61.895	5579.1
200.00	29.465	34.116	63.583	6823.4	63.078	5893.2
205.00	30.318	34.837	65.155	7141.7	64.254	6215.1
210.00	31.166	35.552	66.716	7465.8	65.416	6544.7
215.00	32.010	36.260	68.270	7795.9	66.587	6882.2
220.00	32.851	36.962	69.814	8131.7	67.756	7227.3
225.00	33.690	37.660	71.350	8473.5	68.924	7580.3
230.00	34.524	38.351	72.878	8821.0	70.088	7941.0
235.00	35.359	39.039	74.398	9174.2	71.248	8309.0
240.00	36.188	39.723	75.908	9533.5	72.402	8684.8
245.00	37.012	40.402	77.414	9898.2	73.487	9068.1
250.00	37.835	41.076	78.910	10269.	74.694	9458.9
255.00	38.657	41.745	80.402	10645.	75.829	9857.3
260.00	39.472	42.412	81.886	11027.	76.960	10263.
265.00	40.287	43.074	83.363	11415.	78.081	10676.
270.00	41.099	43.733	84.833	11808.	79.197	11097.
273.15	41.609	44.147	85.755	12059.	79.894	11365.
275.00	41.907	44.388	86.295	12207.	80.306	11524.
280.00	42.713	45.038	87.751	12611.	81.408	11959.
285.00	43.516	45.686	89.202	13021.	82.502	12402.
290.00	44.316	46.331	90.648	13436.	83.592	12852.
295.00	45.112	46.972	92.084	13857.	84.677	13308.
298.15	45.614	47.373	92.988	14125.	85.356	13600.
300.00	45.908	47.610	93.518	14283.	85.753	13772.

H^0_0 AND S^0_0 APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

TABLE B-57 (CONT.)

THERMODYNAMIC FUNCTIONS FOR AMMONIUM PENTABORATE TETRAHYDRATE ($NH_4B_5O_8 \cdot 4H_2O$)

SOLID PHASE

GRAM MOLECULAR WT.=272.204 GRAMS　　　1 CAL=4.1840 ABS J

T DEG K = 273.15 + T DEG C

T	$-(F^0_T-H^0_0)/T$	$(H^0_T-H^0_0)/T$	$(S^0_T-S^0_0)$	$(H^0_T-H^0_0)$	C^0_P	$-(F^0_T-H^0_0)$
DEG K	CAL / DEG MOLE	CAL / DEG MOLE	CAL / DEG MOLE	CAL / MOLE	CAL / DEG MOLE	CAL / MOLE
300.00	45.908	47.610	93.518	14283.	85.753	13772.
305.00	46.699	48.243	94.943	14714.	86.824	14244.
310.00	47.490	48.874	96.365	15151.	87.890	14722.
315.00	48.277	49.503	97.780	15593.	88.946	15207.
320.00	49.061	50.127	99.187	16040.	90.000	15700.
325.00	49.842	50.748	100.59	16493.	91.047	16199.
330.00	50.621	51.367	101.99	16951.	92.086	16706.
335.00	51.401	51.981	103.38	17414.	93.129	17219.
340.00	52.175	52.596	104.77	17882.	94.161	17739.
345.00	52.947	53.205	106.15	18356.	95.194	18266.
350.00	53.717	53.812	107.53	18834.	96.226	18801.
355.00	54.484	54.417	108.90	19318.	97.259	19342.
360.00	55.249	55.019	110.27	19807.	98.301	19890.
365.00	56.013	55.619	111.63	20301.	99.360	20445.
370.00	56.773	56.217	112.99	20800.	100.45	21006.

H^0_0 AND S^0_0 APPLY TO THE REFERENCE STATE OF THE SOLID AT ZERO DEG K

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