NATIONAL BUREAU OF STANDARDS REPORT

7796

PRELIMINARY REPORT
ON THE THERMODYNAMIC PROPERTIES OF
SELECTED LIGHT-ELEMENT AND
SOME RELATED COMPOUNDS

(Supplement to NBS Report 6297, 6484, 6645,
6928, 7093, 7192, 7437, and 7587)

1 January 1963

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

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

Reference: ARPA Order No. 20-63

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

ABSTRACT

This is the ninth semi-annual report on the current experimental, theoretical, and evaluative program, at the National Bureau of Standards, on the thermodynamic properties of selected compounds of primary interest in high-temperature research. This research program emphasizes the compounds of the light elements H, Li, Be, B, C, N, O, F, Al, and Cl, with a secondary interest in the compounds of Mg, Si, K, Ti, Br, I, W, Hg, Pb, and Zr.

New experimental results recently obtained at NBS on gaseous aluminum monofluoride (AlF) and aluminum trifluoride (AlF_3) are presented. The microwave spectrum of AlF was observed in a new apparatus at approximately 600° to 700°C, and has led to accurate values for several of its molecular constants. These results increase the reliability of calculating the thermodynamic properties of this important species at all temperatures.

The new experimental results reported for AlF_3 were calculated from a series of recent precise vapor-pressure measurements in a new transpiration-method apparatus at temperatures near 1000°C. The results define the heat of formation of the gas within the uncertainty of small corrections for the association of the vapor. A critical comparison with earlier data of other investigators—involving different methods, temperature ranges, and degrees of precision—indicates that all results are approximately consistent with the vapor association for this substance recently reported in the literature.

In addition, the results of several comprehensive reviews of the recent literature are given. A survey of the work on light-metal alloy systems revealed new data on the systems Al-Zr, Be-Ti, and Be-Mg, which are summarized. References to measurements of the high-temperature heat capacities of several dozen light-element compounds are tabulated. Low-temperature heat-capacity data for 43 compounds were analyzed in preparation for later critical tables of their thermodynamic properties; their entropies at 298°K also are listed. Another review references new data on the heats of formation of several hundred substances. The last review in the report references and classifies all available investigations in 1962 (over 2000) on chemical thermodynamic properties.

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Chapter 1

EXTENSION OF LITERATURE SURVEY:

REPORTED HIGH-TEMPERATURE HEAT CONTENTS AND HEAT CAPACITIES

by William H. Payne

National Bureau of Standards Report 7192, Chapter 5, pp. 60-76, contained a tabular listing of literature sources of heat-content and heat-capacity data on selected light-element substances. That tabulation has now been extended and partly updated in Table 1 below.

The numbering of references listed at the end of the chapter is a continuation of the numbering in NBS Report 7192. The reference numbers in Table 1 correspond to those at the end of the chapter. Except for the perhaps inevitable addition of a "miscellaneous" category at the end of Table 1, the general presentation and order of listing of the substances remain unchanged: Al, Be, B, Hf, Pb, Li, Mg, Hg, K, Ti, W, and Zr, and the compounds of these elements with H, O, F, Cl, Br, I, N, C, and/or Si.

Sources of Information Covered - In addition to those publications listed in NBS Report 7192, the following sources have now been covered:

1. "Annual Review of Physical Chemistry", Volume 12 - chapter entitled "Thermochemistry and Thermodynamic Properties of Substances", by Zwolinski, B.J., and Danti, A. - Annual Reviews, Inc., Palo Alto, Calif., 1961, pp. 325-354. (Literature surveyed to December 1960.)

2. "Annual Review of Physical Chemistry", Volume 13 - chapter entitled "Thermochemistry and Thermodynamic Properties of Substances", by D. W. Osborne and L. Stein - Annual Reviews, Inc., Palo Alto, Calif., 1962, pp. 127-150. (Literature surveyed to December 1961.)

3. "Progress in International Research on Thermodynamic and Transport Properties", (papers presented at 2nd Symposium on Thermophysical Properties), American Society of Mechanical Engineers, New York, N.Y., 1962. (Not a literature survey; symposium held Jan. 24-26, 1962.)

All references mentioned in Table 1 and listed at the end of this chapter were obtained from the above three sources. Because of lack of time, some of the listed references have not been consulted firsthand, hence, the temperature range is sometimes omitted. The original papers which were consulted have not been critically evaluated.

TABLE 1. REPORTED INVESTIGATIONS OF THE HIGH-TEMPERATURE

HEAT CONTENTS AND HEAT CAPACITIES OF SELECTED SUBSTANCES

Formula	Physical State	Year Reported	Authors and Reference No.	Temp. Range(°K)	Comments
			Aluminum Compounds		
Al_2O_3	c	1959	Lang [43]	?	
	c	1961	McDonald and Stull [94]	278-1620	
	c	1962	Neel and Pears [45]	300-2800 (approx.)	Graph only.
			Beryllium Compounds		
Be	c	1959	Mit'kina [100]	323-973	
BeO	c	1961	Rodigina and Gomel'skii [101]	363-1128	
$BeCl_2$,$(BeCl_2)_2$	c to g	1960	Ryabchikov and Tikhinskii [46]	524-568	Heats of sublim.
			Boron Compounds		
B	c	1959	Akishin, Nikitin, and Gorokhov [44]	2096-2148	Mass spectra.
B_2O_3	?	1959	Gal'chenko, Kornilov, Timofeev, Skuratov [47]		
	l to g	1960	Nesmeyanov and Firsova [68]	1299-1515	Heat of vaporiz.
		1960	Gal'chenko et al [89],[90],[91]		
	c	1961	Krasovitskaya et al [99]	1000-2200	
BF_3	g	1961	Jakes and Papousek [92]	273-1500	Ideal gas
	g	1961	Raw [93]	293-343	Virial coefficients
BCl_3	?	1960	Gal'chenko et al [89]		
	g	1961	Jakes and Papousek [92]	273-1500	Ideal gas
BBr_3	g	1961	Jakes and Papousek [92]	273-1500	Ideal gas
BI_3	g	1961	Jakes and Papousek [92]	273-1500	Ideal gas

TABLE 1 (continued)

Formula	Physical State	Year Reported	Authors and Reference No.	Temp. Range(°K)	Comments
BN		1960	Gal'chenko et al [90]		
	c	1961	McDonald and Stull [94]	279-1682	
$NH_3B_3H_7$	c,g	1959	Westrum and Levitin [95]	5-317	
			Hafnium Compounds		
HfF_4	c	1961	Smith et al [88]	298-1200	
$HfCl_n$(n=2,3,4)	c	1959	Ruzinov and Belov [48]		
HfB_2,HfN,HfC	c	1962	Neel and Pears [45]	300-2800 (approx)	Graph only
			Lead Compounds		
Pb	ℓ	1961	Aldred and Pratt [72]	1000	Vapor pressure data
PbO	c	1960	Kostryukov and Morozova [49]	12-303	
	c to g	1960	Nesmeyanov, Firsova, and Isakova [66]	887-1153	Heat of sublim.
	c,ℓ	1961	Rodigina, Gomel'skii, and Luginina [73]	376-1195	
Pb(OH)I	c	1960	Näsänen and Meriläinen [50]		
			Lithium Compounds		
Li	c,ℓ	1959-60	Martin [51], [52]	20-300	Isotope effect studied
LiH	c	1959	Lang [43]		
	c	1961	Kostryukov [64]	5-300	
Li_2O	c	1961	Rodigina and Gomel'skii [101]	373-1124	
LiF	c to g	1959	Akishin, Gorokhov, and Sidorov [98]		Heat of sublim.
	c to g	1959	Scheffee and Margrave [70]	~1121	Heat of sublim.
	c,g	1959	Evseev et al [65]	926-1052	Heat of sublim.
	g	1960	Wilkins [53]	10-6000	Molec.-const. data
	c to ℓ	1960	Karpachev and Karasik [67]	1115	Heat of fusion calc'd.
	c	1961	Kolesov and Skuratov [60]	298	

TABLE 1 (continued)

Formula	Physical State	Year Reported	Authors and Reference No.	Temp. Range(°K)	Comments
$^{7}Li^{19}F$		1961	Kucirek and Papousek [97]	273-3500	Molec.-const. data
LiCl	c to l	1959	Clark [69]	600-1200	Hi-pressure melting points
	g	1960	Wilkins [53]	10-6000	Molec.-const. data
	c to g	1960	Milne and Klein [85]	~ 800	Heat of sublim.
		1960	Blanc [54]		
LiBr	g	1960	Wilkins [53]	10-6000	Molec.-const. data
		1960	Blanc [54]		
LiI	g	1960	Wilkins [53]	10-6000	Molec.-const. data
Li_2X_2(X=Cl,Br,I)	g	1960	Bauer, Ino and Porter [55]	298-5000	Molec.-const. data
			Magnesium Compounds		
$MgWO_4$	c	1961	King and Weller [75]		
			Mercury Compounds		
$HgCl_2$	c to l	1960	Topol and Ransom [74]	~552.7	Heat of fusion
			Potassium Compounds		
K	l	1960	Makansi [56]		Vapor pressure data
KF	c to l	1960	Karpachev and Karasik [67]	1133	Heat of fusion calc'd.
	c	1960	Karo [57]	5-300	Lattice theory data
KHF_2	c to l	1961	Davis and Westrum [87]	458-523	
KCl		1959	Novikov, Suverov, and Baev [59]		
	c to l	1959	Clark [69]	600-1200	Hi-pressure melting points
	g	1960	Wilkins [53]	10-6000	Molec.-const. data
	c to l	1960	Karpachev and Karasik [67]	1049	Heat of fusion calc'd.
	c	1960	Karo [57]	5-300	Lattice theory data
	c	1960	Enck [58]	300-1043	Mole.-const. data

TABLE 1 (continued)

Formula	Physical State	Year Reported	Authors and Reference No.	Temp. Range(°K)	Comments
KCl	c to g	1960	Milne and Klein [85]	~900	Heat of sublim.
KBr	g	1960	Wilkins [53]	10-6000	Molec.-const. data
		1960	Blanc [54]		
	c	1960	Karo [57]	5-300	Lattice theory data
	c to l	1960	Karpachev and Karasik [67]	1001	Heat of fusion calc'd.
KI		1960	Blanc [54]		
	c to l	1960	Karpachev and Karasik [67]	955	Heat of fusion calc'd.
	c	1960	Karo [57]	5-300	Lattice theory data
			Titanium Compounds		
Ti	c	1961	Stalinski and Bieganski [83]	27-360	
TiO	g	1961	Papousek [84]	50-2500	Ideal gas
$TiCl_4$	g	1960	Seryakov, Vaks, and Sidorina [79]	358-413	Heat of vaporization
$TiBr_4$	c to g	1960	Keavney and Smith [86]	287-309	Heat of sublim.
TiB_2,TiN,TiC	c	1962	Neel and Pears [45]	300-2800 (approx.)	Graph only
			Tungsten Compounds		
W	c	1962	Neel and Pears [45]	300-2800 (approx.)	Graph only
WO_2	c	1959	Morozova and Getskina [61]		
	c	1960	Gerasimov et al [76]	900-1230	Emf method
WO_2, WO_3	c	1960	Vasil'eva, Gerasimov, and Simanov [77]	1073?	
MWO_4 (tungstates)	c	1960	Yakovleva and Rezukhina [71]	294-1073	Cp equation
WF_6, WOF_4	c,l	1961	Cady and Hargreaves [78]		Heats of fusion, transition
Tungsten chlorides and oxychlorides		1960	Shchukarev et al [80]		Previous functions shown wrong

TABLE 1 (continued)

Formula	Physical State	Year Reported	Authors and Reference No.	Temp. Range(°K)	Comments
Tungsten chlorides and oxychlorides	c to g	1961	Shchukarev and Suverov [81], [82]		Heats of sublim.
$MgWO_4$	c	1961	King and Weller [75]		
WB	c	1962	Neel and Pears [45]	300-2800 (approx)	Graph only
WC	c	1962	Neel and Pears [45]	300-2800 (approx)	Graph only
			Zirconium Compounds		
$ZrCl_2$, $ZrCl_3$	c	1959	Ruzinov and Belov [48]		
$ZrCl_4$	g	1960	Wilmshurst [62]		Spectroscopic data
ZrB_2, ZrN, ZrC, $ZrSiO_4$	c	1962	Neel and Pears [45]	300-2800 (approx)	Graph only
			Miscellaneous		
Unipositive ions (88 elements)	g	1960	Green, Poland, and Margrave [63]	100-50,000	Ideal gases
Diatomic hydrides, deuterides, tritides	g	1961	Haar, Friedman, and Beckett [96]	50-5000	Ideal gases
Tungstates (MWO_4)	c	1960	Yakovleva and Rezukhina [71]	294-1073	Cp equation

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Chapter 2

EXTENSION OF LITERATURE SURVEY:

ALLOYS AND INTERSTITIAL COMPOUNDS OF THE LIGHT METALS

by Thomas W. Mears

Aluminum-Zirconium System

Attempts to prepare AlZr by arc-melting of equal amounts of aluminum and zirconium under argon have invariably resulted in mixtures of AlZr and Al_2Zr_3. AlZr is unstable above 1250°C. By subtracting out the well-known lines of Al_2Zr_3 from the x-ray diffraction pattern, the following crystallographic constants have been obtained by difference: a = 3.359A ±0.001, b = 10.887A ±0.003, c = 4.27A ±0.001. Assuming 4AlZr molecules per unit cell, the density of 5.02 g/cm^3 was calculated. A bulk density of 4.8 g/cm^3 was determined. Since Al_2Zr_3 shows an x-ray density of 4.70 g/cm^3 it appears that the mixture prepared in this way is of the ratio AlZr: Al_2Zr_3:: 1:2. [1].

Renouf [2] has continued his earlier studies comparing the structures of Zr_2Al_3 and $ZrAl_2$. He concludes that these structures might be considered as fundamentally similar, differing mainly in the ways the sequences are staggered.

Beryllium-Titanium System

Alloys of titanium and beryllium were prepared containing 88, 90, and 93 atomic percent beryllium [3]. X-ray spectroscopy studies of the 88 and 90 percent samples showed them to be Ti_2Be_{17} (89.4% Be) having a trigonal structure and lattice constants a = 7.40A, c = 10.84A, and c/a = 1.463. The third alloy (93%) was close but not exactly of the Ti_2Be_{17} structure.

Beryllium-Magnesium System

$MgBe_{13}$ was prepared by cold pressing beryllium powder at 60 $tons/in^2$ followed by immersion in a bath of molten magnesium at 750°C for 30 minutes under an argon atmosphere, followed by a water quench [4].

Crystallographic constant a = 10.166 ±0.005A

Atomic positional parameters; y = 0.1789 ±0.0010, z = 0.1143 ±0.008

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Note: The literature was surveyed for compounds of aluminum, beryllium, lithium, and magnesium with each other and with titanium, tungsten, and zirconium. Only the above four were found which were considered appropriate to this survey.

Chapter 3

MICROWAVE SPECTRUM OF ALUMINUM MONOFLUORIDE

by David R. Lide, Jr.

The optical spectrum of AlF has been extensively studied, and there is considerable chemical evidence that AlF is an important constituent of aluminum-fluorine systems at high temperatures. We have now detected the microwave spectrum of AlF and have obtained accurate measurements of several of its molecular constants.

The spectrum was observed in a high-temperature spectrometer of new design which will be described elsewhere. The AlF was generated from a mixture of powdered Al and anhydrous AlF_3. The spectrum was first detected when this mixture was heated to about 620°C and reached maximum intensity at around 675-700°C.

The identification of AlF as the species responsible for the spectrum is quite reliable. The hyperfine structure and Stark effect show that the observed lines result from a $J = 0 \rightarrow 1$ transition. Furthermore, the spacing in the hyperfine pattern clearly indicates the presence of a single quadrupolar nucleus of spin 5/2 (which is the known spin of Al^{27}). A consideration of the magnitude of the rotational constant leaves no possible choice except AlF.

The observed frequencies and derived constants are listed in Table I. The dipole moment was determined from measurements of the Stark effect ($M = 5/2 \rightarrow 7/2$ component). This should be regarded as a tentative value because of the difficulty in measuring the Stark spacing precisely at the operating temperature. Further work on the calibration of the Stark field will be carried out.

While no detailed interpretation of these results in terms of molecular structure has been made, certain implications may be pointed out. The dipole moment of AlF is in the normal range for covalent fluorine compounds; it is actually somewhat less than the values found in typical fluorocarbons (1.8 - 2.0 D). Furthermore, the quadrupole coupling constant eq Q is practically identical to that found for the $^2P_{3/2}$ state of atomic Al. This is in striking contrast with ionic molecules such as the alkali halides, where eq Q is typically only a few percent of its atomic value. Thus it is clear that the bond in AlF is primarily a covalent one, with very little ionic character.

It may be noted that the AlF spectrum is detectable at a temperature somewhat below the melting point of aluminum. The initial reaction thus appears to be of a solid-solid nature. The vapor pressures of pure Al and pure AlF_3 are negligibly small under the conditions of these measurements.

The threshold temperature for observation of the spectrum can provide some information on the heat of formation of AlF. Calculations of the partial pressure of AlF above an $Al-AlF_3$ mixture have been made by Douglas, Neufer, and Goodson[1] for several different values of ΔHf°_0 of AlF. If the threshold pressure for detection of the spectrum can be estimated, a reasonably sensitive estimate of ΔHf°_0 can be made from the observed threshold temperature (about 620°C). Calibration experiments to determine the threshold pressure using alkali halides or other well-known substances are planned. In the meanwhile, a rough guess can be made on the basis of experience with conventional spectrometers. The threshold pressure is likely to be in the range 1 to 10 microns of Hg; a value much less than 1 μ Hg is quite improbable. On this basis we can estimate that ΔHf°_0 of AlF is in the range -58 to -64 kcal/mole, in good agreement with the most widely accepted value of -61.3 kcal/mole. In particular, the recently reported value of -50.9 kcal/mole (discussed in Reference 1) would imply that a temperature of at least 750°C is necessary for detection of the microwave spectrum; this value can therefore be completely excluded.

References

1. NBS Report 7587, National Bureau of Standards, Washington, D. C., 1 July 1962, pp. 114-120.

Table I. Observed Spectrum and Constants of $Al^{27}F$

Transition (J=0→1)	ν(v = 0)	ν(v = 1)
F = 5/2 → 3/2	32981.8 ±0.1 Mc	...
F = 5/2 → 7/2	32978.5 ±0.1	32681.6 ±0.5
F = 5/2 → 5/2	32970.6 ±0.1	32673.9 ±0.5

B_0 = 16488.30 ±0.05 Mc
B_1 = 16339.90 ±0.25

B_e = 16562.5 ±0.3 Mc = 0.55246 cm^{-1}
α_e = 148.4 ±0.3 Mc = 0.00495 cm^{-1}
$(eq\ Q)_{Al^{27}}$ = -37.6 ±1.0 Mc
μ = 1.4 ±0.1 Debye

Chapter 4

LITERATURE SURVEY AND ANALYSIS OF LOW-TEMPERATURE HEAT-CAPACITY DATA OF SELECTED COMPOUNDS OF H, Li, B, N, O, F, Na, Mg, Al, Si, Cl, K, Ti, Br, and I

by G. T. Furukawa

A systematic survey of literature data on heat capacity of substances that should be of interest to the program has been in progress to complement the experimental heat-capacity measurements that are being made. The work presented in this chapter is the result of analysis of existing data and of previous compilations. The calculation of thermal functions as a result of the analysis is expected to be presented in a future report. The status of available heat-capacity data is given in this report.

In this survey the Ohio State University [2a] bibliography and the Kelley and King [38] compilation were examined. For more recent data The Bulletin of Thermodynamics and Thermochemistry, No. 5, 1962, and recent journals were scanned. As in the past reports issued in this program, the original experimental data were examined wherever feasible and comparisons made with different compilations. In most of the recent publications the authors have computed the thermal functions. These values are given and compared in the discussions. The substances are discussed separately with references given in the chronological order of publication date. The atomic weights for the formula weights given are based on C-12 [35]. In Table 1 values of S°_{298} given in the original publications are compared wherever possible with those given by Kelley and King [38]. Mean heat-capacity measurements over a wide temperature range is indicated by $\bar{c}$.

Lithium Monohydrogen Difluoride, $LiHF_2$, 45.94377

Heat-capacity measurements on lithium monohydrogen difluoride, $LiHF_2$, have been reported by Westrum and Burney [79] (7° to 301°K). The sample was prepared by the addition of reagent grade Li_2CO_3 to boiling 48 percent HF solution in a platinum dish. The crystals of $LiHF_2$ that formed on controlled cooling were separated by filtering and dried in a stream of dry air. The partial pressure of HF above the system LiF-$LiHF_2$ is 2 mm at 25°C, therefore some HF was lost on drying $LiHF_2$ in air. The small percentage of LiF present in the sample was reconverted to $LiHF_2$ in a polyethylene desiccator containing $CaSO_4$ and 10 to 20 mm of HF. The sample was loaded into the calorimeter vessel at -10°C. The sample was taken to be 99.48 percent $LiHF_2$ and 0.52 percent LiF on the basis of chemical analysis following the heat-capacity measurements. Corrections were applied for the LiF impurity. Westrum and Burney [79] calculated S°_{298} to be 16.97 eu. from their data.

Magnesium Diboride, MgB_2, 45.9340

Swift and White [76] (18° to 304°K) measured the heat capacity of magnesium diboride, MgB_2. The sample was prepared by heating in a helium atmosphere stoichiometric amounts of the elements at 900 ±25°C for three hours. The chemical analysis of the sample was the following:

	Percent
MgB_2	93.90
MgB_4	1.08
B	3.69
Mg	0.46
MgO	0.73
SiO_2	0.14 (Spectrochemical)

Swift and White [76] calculated S°_{298} from the values of heat capacity corrected for the impurities to be 8.60 eu. Kelley and King [38] calculated S°_{298} = 8.62 ±0.08 eu. from the same data.

Magnesium Tetraboride, MgB_4, 67.5560

Swift and White [76] (17° to 300°K) determined the heat capacity of magnesium tetraboride, MgB_4. The sample was prepared from the elements by heating stoichiometric amounts for three hours at 900 ±25°C. Chemical analysis of the sample was as follows:

	Percent
MgB_4	89.42
B	10.32
SiO_2	0.25 (Spectrochemical)

The value of S°_{298} calculated from the heat capacity corrected for the impurities was 12.41 eu. Kelley and King [38] obtained 12.5 ±0.1 eu. on the basis of the same data.

Sodium, Na, 22.9898

A number of investigators have reported measurements of the heat capacity of sodium in the low-temperature range. They are as follows:

Nordmeyer and Bernoulli [56] ($\bar{c}$: -185° to 20°C)
Nordmeyer [55] ($\bar{c}$: -188° to +20°C)
Koref [42] ($\bar{c}$: -192° to -83° and -78° to 0°C)

Estreicher and Staniewski [21] ($\bar{c}$: -191° to 18° and -80° to 17°C)
Dewar [14] ($\bar{c}$: 20° to 80°K)
Griffiths [29] (0° to 138°C)
Griffiths and Griffiths [30,31] (-160° to 0°C)
Eastman and Rodebush [20] (65° to 294°K)
Günther [33] (87° to 124°K)
Simon and Zeidler [72] (17° to 118°K)
Pickard and Simon [60] (2° to 25°K)
Dauphinee, MacDonald, and Preston-Thomas [10] (55° to 315°K), no tabular values)
Rayne [64] (0.2° to 1°K, no tabular values)
Parkinson and Quarrington [58] (1.5° to 20°K)
Roberts [66] (1.5° to 20°K)
Martin [48,49] (20° to 300°K)
Gaumer and Heer [26] (0.4° to 2°K, no tabular values)
Lien and Phillips [47] (0.14° to 1.4°K, no tabular values)

A martensitic transformation occurs in sodium in which below about 36°K the bcc lattice begins to convert to the hcp structure [48]. During the heat-capacity measurements the partly transformed sample, amount depending upon previous heat treatment, reconverts to the bcc lattice over the range 40° to 80°K. Martin [48] estimated the energy of transformation to be 100 cal/mole. Much of the earlier data below about 80°K differ by as much as 10 percent because of the varying degree of the hcp to bcc structure present in the sample. Martin [49] calculated $S^\circ_{298} = 12.24 \pm 0.12$ eu. from his measurements in the range 20° to 300°K. Kelley and King [38], using data published prior to the measurements of Martin [49], calculated $S^\circ_{298} = 12.24 \pm 0.10$ eu. The analysis of heat-capacity data published prior to that of Kelley and King [38] by Evans, Jacobson, Munson, and Wagman [22] list $S^\circ_{298} = 12.29$ eu.

Disodium Potassium, Na_2K, 85.0816

Krier, Craig, and Wallace [43] (12° to 321°K) reported heat-capacity measurements on disodium potassium, Na_2K. The sample was prepared by mixing two Na-K alloys of known composition in suitable proportions to achieve the Na_2K composition. The compound Na_2K has an incongruent melting point at 6.90°C. Therefore, to prepare the compound, the mixture was cooled rapidly to avoid separation and later heated to a temperature (272°K) slightly below the incongruent melting point and allowed to remain until complete transformation to Na_2K took place. After allowing the sample to remain for 67 hours, a test was made for heat absorption on warming through the eutectic point. From the observed heat effects an estimate was made that the conversion was 99.8 percent complete. From the heat data Krier *et al.* [43] calculated S°_{298} of liquid Na_2K to be 48.21 ± 0.09 eu. Kelley and King [38] calculated $S^\circ_{298} = 48.2 \pm 0.3$ from the same data. Douglas, Ball, Ginnings, and Davis [16] reported measurements of relative enthalpy between 0° and 800°C for a Na (0.5520) - K(0.4480) alloy which is close to the composition of Na_2K, the theoretical composition being Na = 0.5404 and K = 0.4596. The two sets of heat measurements join fairly smoothly.

Sodium Hydride, NaH, 23.99777

Sayre and Beaver [68] (60° to 92°K) reported heat-capacity measurements on sodium hydride, NaH. Data are insufficient to calculate S°_{298}. Westrum [78] lists unpublished measurements on NaH between 6° and 350°K.

Sodium Oxide, Na_2O, 61.9790

Furukawa, Reilly, and Henning [25] (14° to 380°K) list unpublished heat-capacity measurements on sodium oxide, Na_2O. Preliminary calculation of the data prior to correction for the impurities gave S°_{298} = 18.0 ±0.2 eu. Kelley and King [38] estimated S°_{298} = 18.0 ±1.0 eu.

Sodium Peroxide, Na_2O_2, 77.9784

Todd [77] (52° to 296°K) reported heat-capacity measurements on sodium peroxide, Na_2O_2. The analysis of the sample was as follows:

	Percent
Na_2O_2	94.0
Na_2O	3.6
Na_2CO_3	2.4

The heat capacity of Na_2O_2 as compared with NaO_2 and KO_2 [77] is shown to be normal with no peaks. Todd [77] calculated S°_{298} to be 22.6 ±0.3 eu. The heat-capacity values below 52°K were obtained using the Debye-Einstein heat-capacity equation:

$$C = D(252/T) + 3E(399/T)$$

Kelley and King [38] list the same S°_{298} value.

Sodium Superoxide, NaO_2, 54.9886

Todd [77] (52° to 296°K) reported heat-capacity measurements on sodium superoxide, NaO_2. The analysis of the sample was as follows:

	Percent
NaO_2	92.5
Na_2O_2	6.0
Na_2CO_3	1.5

Two heat-capacity peaks at 196.5° and 223.3°K were observed. Todd [77] calculated S°_{298} from the data to be 27.7 ±0.3 eu. The heat-capacity values below 52°K were obtained using the Debye-Einstein heat-capacity equation:

$$C = D(175/T) + 2E(313/T).$$

Kelley and King [38] list the same S°_{298} value.

Sodium Hydroxide, NaOH, 39.99717

Kelley and Snyder [39] (60° to 300°K) reported heat-capacity measurements on sodium hydroxide, NaOH. Only smoothed values of heat capacity are given. The sample was prepared by dissolving reagent grade NaOH in absolute ethyl alcohol. Insoluble impurities were filtered. The alcohol was removed with "slight heating". The thick slurry of mono-alcoholate that resulted was filtered and decomposed by pumping at "slightly elevated" temperatures to obtain pure NaOH. The chemical analysis of the resulting sample was as follows:

	Percent
NaOH	99.84
Na_2CO_3	0.02
SiO_2	0.02
Cl^-	0.005

Kelly and Snyder [39] calculated S°_{298} from the data to be 15.3 ±0.1 eu. In the calculation the values of heat capacity below 60°K were obtained by extrapolation using a Debye-Einstein heat-capacity equation fitted to experimental values at higher temperatures. Kelley and King [38] calculated S°_{298} = 15.4 ±0.3 eu. based on the same data. The values of heat capacity obtained by Kelly and Snyder [39] join fairly smoothly with the values derived from the relative enthalpy measurements at higher temperatures by Douglas and Dever [17]. Recently, Murch and Giauque [81] obtained S°_{298} = 15.40 eu. from new heat-capacity measurements.

Sodium Amide, $NaNH_2$, 39.01244

Heat-capacity measurements on sodium amide $NaNH_2$, have been reported by Coulter, Sinclair, Cole and Roper [8] (14° to 301°K). The sample was prepared by the direct reaction of gaseous ammonia with molten sodium. Anhydrous ammonia, dried with sodium, and reagent grade sodium were used in the preparation. The chemical analysis of the sample showed the following:

Percentage Purity	
99.91	on the basis of total base.
99.77	on the basis of NH_3.

Coulter et al. [8] calculated from the data S°_{298} = 18.380 eu. Kelley and King [38] calculated using the same data S°_{298} = 18.4 ±0.2 eu.

Sodium Aluminate, $NaAlO_2$, 81.9701

King [40] (53° to 298°K) reported heat-capacity measurements on sodium aluminate, $NaAlO_2$. The sample was prepared by prolonged, repeated sintering of reagent grade $NaHCO_3$ and pure hydrated alumina. Six heats, totaling 89 hours, at 1000° to 1050°C were made. The chemical analysis of the final product gave 62.08 percent Al_2O_3 as compared with 62.19 percent theoretical composition. King [40] calculated $S^\circ_{298} = 16.9 \pm 0.2$ eu. from the data. In the calculation the values of heat capacity below 53°K were obtained from the Debye-Einstein heat-capacity relation:

$$C = D(275/T) + E(382/T) + E(595/T) + E(1087/T) .$$

Kelley and King [38] list the same value $S^\circ_{298} = 16.9 \pm 0.2$ eu. Westrum [78] lists, as unpublished, heat-capacity data on $NaAlO_2$ in the range 6° to 350°K.

Sodium Aluminum Fluoride, Na_3AlF_6, 209.9413

The heat capacity of sodium aluminum fluoride, Na_3AlF_6, has been reported by King [41] (54° to 296°K). The Na_3AlF_6 sample was hand-picked crystals of Greenland cryolite. The chemical analysis of the sample gave 32.76 percent Na (theoretical: 32.85 percent) and 13.01 percent Al (theoretical: 12.85 percent). Impurities were 0.036 percent K and 0.007 percent Li. King [41] calculated $S^\circ_{298} = 57.0 \pm 0.4$ eu. from the data. Heat-capacity values below 54°K were obtained from the Debye-Einstein heat-capacity relation:

$$C = D(144/T) + 4E(236/T) + 5E(568/T) .$$

Kelley and King [38] list the same $S^\circ_{298} = 57.0 \pm 0.4$ eu. value.

Sodium Fluoride, NaF, 41.9882

Heat-capacity measurements on sodium fluoride, NaF, have been reported by Koref [42] ($\bar{c}$: -192° to -83° and -75° to 0°C) and by King [41] (54° to 296°K). The NaF sample investigated by King [41] was commercial analytical-reagent grade material which was heated to 700° just prior to use. King [41] calculated $S^\circ_{298} = 12.26 \pm 0.07$ eu. from the data. Below 54°K, the heat-capacity values were obtained using the Debye-Einstein heat-capacity relation:

$$C = D(340/T) + E(391/T) .$$

Kelley and King [38] list the same $S^\circ_{298} = 12.26 \pm 0.07$ eu. value.

Sodium Monohydrogen Difluoride, $NaHF_2$, 61.99457

Westrum and Burney [79] (6° to 296°K) have reported measurements of the heat capacity of sodium monohydrogen difluoride, $NaHF_2$. The sample

was prepared by adding reagent grade Na_2CO_3 to boiling 48 percent reagent HF solution. The crystals of $NaHF_2$ obtained on slow cooling were filtered and dried under vacuum in a Fluorothene container. The material was in addition heated under vacuum in a platinum dish within a Monel container. Chemical analysis of the sample for the hydrogen ion by volumetric acidimetry gave 100.03 ±0.07 percent of the theoretical amount. Gravimetric analysis of the fluoride gave 100.56 ±0.26 percent of the theoretical composition. Westrum and Burney [79] calculated S°_{298} from their measurements to be 21.73 eu.

Sodium Chloride, $NaCl$, 58.4428

The heat-capacity measurements on sodium chloride, $NaCl$, have been reported by the following:

Dewar [11,12,13] ($\bar{c}$: -188° to -78° and -188° to 16°C)
Koref [42] ($\bar{c}$: -188° to -81° and -75° to 0°C)
Russell [67] ($\bar{c}$: 3° to 46°C)
Nernst [54] (25° to 84°K)
McGraw [50] (95° to 245°K)
Clusius, Goldmann and Perlick [7] (11° to 268°K)

Kelley and King [38], using the data reported by the last three groups of investigators, calculated S°_{298} = 17.33 ±0.10 eu. Morrison, Patterson and Dugdale [53] reported measurements of heat capacity of $NaCl$ crystals in the range 4° to 20°K, but no tabular values are given. Patterson, Morrison and Thompson [59] (9° to 21°K) and Morrison and Patterson [52] (12° to 270°K) reported heat-capacity measurements on small particles of $NaCl$ (0.04 to 0.07 micron). No tabular values of the measurements are given.

Sodium Borohydride, $NaBH_4$, 37.83268

Heat-capacity measurements on sodium borohydride, $NaBH_4$, have been reported by Johnston and Hallett [36] (16° to 301°K). The sample was prepared from a material that was initially 95 percent pure. The material was first dissolved in water at 0°C and filtered to remove water-insoluble impurities. The water was removed by pumping in a cold room held at 5°C. The final pumping was done at 80°C to remove the last trace of water. To remove water soluble impurities such as sodium borate, the material was recrystallized twice from anhydrous isopropylamine. The final product freed from solvent analyzed as follows:

99.61 ±0.04	by hydrogen analysis
99.67 ±0.02	by HCl titration
99.66 ±0.22	by NaOH titration.

A solid state transition was observed at about 190°K. Johnston and Hallett [36] calculated S°_{298} = 24.26 eu. Kelley and King [38] using the same data

calculated S°_{298} = 24.21 ±0.10 eu. Douglas and Harman [18] reported measurements of the enthalpy relative to 0°C up to 700°C. The two measurements join smoothly.

Sodium Metaborate, $NaBO_2$, 65.7996

Grenier and Westrum [28] (5° to 345°K) measured the heat capacity of anhydrous sodium metaborate, $NaBO_2$. The sample was prepared from the tetrahydrate. The tetrahydrate was first purified by recrystallization from water. The water of hydration was removed by evacuation at 25° for 3 days, then the sample was heated to 100°C and pumped with a high-speed diffusion pump. The dried sample was heated to above 966°C, the melting point of anhydrous $NaBO_2$, and slowly cooled to 200°C and transferred to a desiccator containing P_2O_5. The chemical analysis of the combined sample from various batches of preparation gave the following:

	Percentage	
	Found	Theoretical
Na_2O	47.11 ±0.20	47.09
B_2O_3	52.91 ±0.13	52.91
H_2O	0.0 ±0.01	0.00

Grenier and Westrum [28] calculated from the data S°_{298} = 17.574 eu. Kelley and King [38] using the same data calculated S°_{298} = 17.57 ±0.05 eu.

Sodium Tetraborate, $Na_2B_4O_7$, 201.2194

Westrum and Grenier [80] reported measurements of the heat capacity of anhydrous crystalline sodium tetraborate, $Na_2B_4O_7$, from 6° to 348°K and of vitreous $Na_2B_4O_7$ from 5° to 344°K. Both samples were prepared from dehydrated commercial analytical-reagent grade sodium tetraborate decahydrate. To avoid any formation of "glass" in the preparation of the crystalline sample the material was not allowed to remain very long above the melting point (742.5°C), in particular above 760°C. The material was heated in a platinum dish in an electric muffle furnace to 750°C and cooled slowly over 10 hours from 750° to 300°C. The sample was transferred to a desiccator containing P_2O_5 and cooled to room temperature. X-ray analysis showed the material to be crystalline $Na_2B_4O_7$. The chemical analysis showed the following:

	Percentage	
	Found	Theoretical
Na_2O	30.79 ±0.01	30.80
B_2O_3	69.18 ±0.03	69.20
H_2O	0.0 ±0.01	0.00

The vitreous sample was prepared by heating to 820°C for 30 minutes and cooling in an anhydrous atmosphere. X-ray diffraction measurements showed the material to be vitreous. The chemical analysis showed the following:

	Percentage	
	Found	Theoretical
Na_2O	30.79 ±0.01	30.80
B_2O_3	69.21 ±0.03	69.20
H_2O	0.0 ±0.01	0.00

Westrum and Grenier [80] calculated from the data S°_{298} = 45.296 eu. for the crystalline $Na_2B_4O_7$ and $(S^\circ_{298}-S^\circ_0)$ = 44.391 eu. for the vitreous $Na_2B_4O_7$. Kelley and King [38] calculated from the same data S°_{298} = 45.3 ±0.2 eu. for the crystalline material and $(S^\circ_{298}-S^\circ_0)$ = 44.4 ±0.2 eu. for the vitreous material. Kelley and King [38] estimated the residual entropy S°_0 to be 3.9 eu.

Sodium Nitrate, $NaNO_3$, 84.9947

Heat-capacity measurements on sodium nitrate, $NaNO_3$, have been reported by Forch and Nordmeyer [24] ($\bar{c}$: -192° to 14°C), Ewald [19] ($\bar{c}$: -191° to -80°, -75° to 0°, and 3° to 55°C), and Southard and Nelson [74] (16° to 289°K). The sample of $NaNO_3$ investigated by Southard and Nelson [74] was recrystallized four times using initially a "c.p." grade material. Southard and Nelson [74] calculated S°_{298} from their own data to be 27.87 ±0.08 eu. Kelley and King [38] calculated S°_{298} = 27.85 ±0.10 eu. from the same data.

Sodium Metasilicate, Na_2SiO_3, 122.0638

Kelley [37] (54° to 294°K) reported heat-capacity measurements on sodium metasilicate, Na_2SiO_3. The sample was prepared by dehydration of the hexahydrate. Most of the water was removed by pumping at room temperature and the remainder by heating to over 1100°C (m.p. of Na_2SiO_3 = 1088°C). By holding the temperature around 1025° to 1050°C complete crystallization was obtained. No chemical analysis of the sample was reported. Kelley [37] calculated S°_{298} = 27.2 ±0.3 eu. from the data. The values of heat capacity below 54°K were obtained for the calculation using the Debye-Einstein heat-capacity relation:

$$C = D(252.5/T) + 2E(292/T) + 2E(618/T) .$$

Kelley and King [38] calculated S°_{298} = 27.2 ±0.2 eu. from the same data.

Sodium Disilicate, $Na_2Si_2O_5$, 182.1486

Kelley [37] (54° to 295°K) reported heat-capacity measurements on sodium disilicate, $Na_2Si_2O_5$. The sample was an anhydrous crystalline material of 98 percent purity. The sample was heated before use to 700°C. Kelley [37] calculated S°_{298} = 39.4 ±0.6 eu. from the data. The heat-capacity values below 54°K were obtained for the calculation from the Debye-Einstein heat-capacity relation:

$$C = D(140/T) + 4E(328/T) + 2E(802/T) + 2E(1228/T) \quad .$$

Kelley and King [38] calculated S°_{298} = 39.4 ±0.3 eu. from the same data.

Sodium Orthosilicate, Na_4SiO_4, 184.0428

Kelley [37] (53° to 299°K) reported heat-capacity measurements on sodium orthosilicate, Na_4SiO_4. The sample was between 97 and 98 percent pure and the remainder mostly Na_2CO_3. Although the chemical analysis was made no values are given. Kelley [37] calculated from the measurements S°_{298} = 46.8 ±0.6 eu. The values of heat capacity below 53°K were obtained for the calculation from the Debye-Einstein heat-capacity relation:

$$C = D(227/T) + 4E(256/T) + 4E(677/T) \quad .$$

Kelley and King [38] calculated S°_{298} = 46.8 ±0.4 eu. from the same data.

Sodium Metatitanate, Na_2TiO_3, 141.8778

Shomate [69] (53° to 296°K) reported heat-capacity measurements on sodium metatitanate, Na_2TiO_3. The sample was prepared by repeated heating of stoichiometric amounts of Na_2CO_3 and TiO_2 at 900° to 1100°C for several hours under vacuum. Chemical analysis of the sample was as follows:

	Percent
Na_2TiO_3	98.4
Na_2SiO_3	1.1
Na_2CO_3	0.5

Shomate [69] calculated S°_{298} from his data to be 29.1 ±0.1 eu. In the calculation the data below 53°K was extrapolated using the Debye-Einstein heat-capacity relation:

$$C = D(234/T) + 2E(3.5/T) + 3E(617/T) \quad .$$

Kelley and King [38] list S°_{298} = 29.1 ±0.2 eu.

Sodium Dititanate, $Na_2Ti_2O_5$, 221.7766

Shomate [69] (53° to 296°K) reported heat-capacity measurements on

sodium dititanate, $Na_2Ti_2O_5$. The sample was prepared by repeated heating of stoichiometric amounts of Na_2CO_3 and TiO_2 at 900°C to 1100°C for several hours under vacuum. The chemical analysis of the product was:

	Percent
$Na_2Ti_2O_5$	98.7
Na_2SiO_3	1.0
Na_2CO_3	0.3

Shomate [69] calculated S°_{298} from the data to be 41.5 ±0.2 eu. Below 53°K the heat-capacity values were extrapolated using the Debye-Einstein heat-capacity relation:

$$C = D(175.6/T) + 3E(295/T) + 4E(585/T) \ .$$

Kelley and King [38] give S°_{298} = 41.5 ±0.3 eu.

Sodium Trititanate, $Na_2Ti_3O_7$, 301.6754

Shomate [69] (53° to 296°K) measured the heat capacity of sodium trititanate, $Na_2Ti_3O_7$. The sample was prepared by repeated heating of stoichiometric amounts of Na_2CO_3 and TiO_2 at 900° to 1100°C for several hours. The chemical analysis of the final product was:

	Percent
$Na_2Ti_3O_7$	98.6
Na_2SiO_3	1.1
Na_2CO_3	0.3

Shomate [69] calculated S°_{298} from the data to be 55.9 ±0.3 eu. In the calculation the values of heat capacity used below 53°K were obtained by extrapolation using the Debye-Einstein heat-capacity relation:

$$C = D(136.5/T) + 4E(266/T) + 6E(606/T) \ .$$

Kelley and King [38] give S°_{298} = 55.9 ±0.4 eu.

Potassium Nitrate, KNO_3, 101.1069

Measurements of the heat capacity of potassium nitrate have been reported by Ewald [19] (mean heat capacity: 1° to 55°, -77° to 0°, and -191° to -80°C) and by Southard and Nelson [74] (16° to 296°K). The sample investigated by the latter authors was prepared by recrystallization of "c.p." quality material and dried in high vacuum. The values of S°_{298} calculated by Southard and Nelson [74] from their data is 31.77 ±0.10 eu. Kelley and King [38] calculated S°_{298} = 31.81 ±0.15 eu. using the data of Southard and Nelson [74].

Potassium Chlorate, $KCl O_3$, 122.5532

Ewald [19] ($\bar{c}$: 1° to 55°, -76° to 0°, and -191° to -80°C) and Latimer, Schutz and Hicks, Jr. [46] (14° to 293°K) reported heat-capacity measurements on potassium chlorate, $KCl O_3$. The sample investigated by the latter authors was prepared from a commercial "c.p." grade material by recrystallization and washing and by drying at 110°C. Only traces of chloride was detected with silver nitrate. The value of S°_{298} calculated by Latimer et al. [46] was 34.17 eu. ±0.05 percent. Kelley and King [38] calculated 34.2 ±0.2 eu. using the data obtained by Latimer et al. [46].

Potassium Perchlorate, $KCl O_4$, 138.5526

Latimer and Ahlberg [45] (13° to 298°K) reported heat-capacity measurements on potassium perchlorate, $KCl O_4$. The sample was prepared from commercial "c.p." grade material by four recrystallizations and by drying under vacuum. Analysis showed the sample to be at least 99.9 percent pure. Latimer and Ahlberg [45] calculated S°_{298} from the data to be 36.1 ±0.3 eu. Kelley and King [38] calculated S°_{298} = 36.1 ±0.2 eu. using the same data.

Potassium Bromate, $KBrO_3$, 167.0092

Ahlberg and Latimer [1] (15° to 296°K) reported heat-capacity measurements on potassium bromate, $KBrO_3$, prepared from commercially available "c.p." material by recrystallization and washing, and by drying at 110°C. Analysis by thiosulfate and permanganate methods was reported to have yielded a 100 percent material within the accuracy of analysis of 0.1 percent. Ahlberg and Latimer [1] calculated S°_{298} from the data to be 35.65 eu. Kelley and King [38] calculated S°_{298} = 35.7 ±0.2 eu. using the same data.

Potassium Iodate, KIO_3, 214.0046

Ahlberg and Latimer [1] (17° to 295°K) measured the heat capacity of potassium iodate, KIO_3. The sample was prepared from a commercial "c.p." grade material by recrystallization and washing and by drying at 110°C. Analysis by thiosulfate and permanganate methods gave 100 percent purity within the accuracy of analysis of 0.1 percent. The value of S°_{298} calculated by Ahlberg and Latimer [1] from the data is 36.20 eu. Kelley and King [38] calculated S°_{298} = 36.2 ±0.2 eu. using the same data.

Ammonium Oxide, $(NH_4)_2O$, 52.07656

Hildenbrand and Giauque [34] (15° to 270°K) reported heat-capacity measurements on ammonium oxide, $(NH_4)_2O$. The sample was prepared from pure ammonia produced from "c.p." grade ammonium chloride and potassium hydroxide. The cooled ammonia solution containing excess ammonia was introduced into the calorimeter vessel through a stainless steel capillary.

The desired composition was achieved by measuring the heat required for eutectic melting and removing the excess ammonia. Hildenbrand and Giauque [34] calculated S°_{298} of liquid $(NH_4)_2O$ from their data to be 63.94 eu. Values of heat capacity were extrapolated from 270° to 300°K. Kelley and King [38] calculated S°_{298} = 63.94 ±0.10 eu. from the same data.

Ammonium Hydroxide, NH_4OH, 87.12251

Hildenbrand and Giauque [34] (15° to 290°K) measured the heat capacity of ammonium hydroxide, NH_4OH. The sample was prepared from pure ammonia and water. Cooled ammonia solution containing excess ammonia was introduced into the calorimeter vessel through a stainless steel capillary. The desired composition was achieved by measuring the heat required for eutectic melting and removing the excess ammonia. Hildenbrand and Giauque [34] calculated S°_{298} from their data to be 39.57 eu. Kelley and King [38] calculated S°_{298} = 39.57 ±0.10 eu. from the same data.

Ammonium Nitrate, NH_4NO_3, 80.04348

Heat-capacity measurements on ammonium nitrate, NH_4NO_3, have been reported by the following:

Forch and Nordmeyer [24] ($\bar{c}$: -190° to 14°C)
Ewald [19] ($\bar{c}$: -189° to -80°, -2° to -78°, -75° to 0°, and 2° to 55°C)
Crenshaw and Ritter [9] (-90° to 0°C)
Stephenson, Bentz, and Stevenson [75] (15° to 314°K)

The data of Stephenson et al. [75] seem most reliable. The sample investigated by Stephenson, et al. [75] was a commercial reagent-grade material. The chemical analysis of the material gave 21.28 percent NH_3 which coincides with the theoretical value. Stephenson et al. [75] calculated S°_{298} = 36.11 ±0.05 eu. from the data. Two solid phase transitions were observed at 256.2° and 305.4°K. Kelley and King [38] using also the data of Crenshaw and Ritter [9] calculated S°_{298} = 36.06 ±0.10 eu.

Ammonium Fluoride, NH_4F, 37.03698

Measurements of the heat capacity of ammonium fluoride have been reported by Simon, Simson and Ruhemann [71a] (-70° to 11°C) and by Benjamins and Westrum [4] (6° to 304°K). Simon et al. [71a] reported a hump in the heat capacity around 242°K (-30.7°C). The measurements of Benjamin and Westrum [4] do not exhibit such a hump. The observations of Simon et al. [71a] may be attributable to moisture in their sample. Labowitz and Westrum [44] have observed a eutectic transition at 244°K and also a peritectic transition at 246°K in the NH_4F-H_2O system. The sample investigated by Benjamins and Westrum [4] was prepared by the addition of excess of 48 percent reagent HF solution to reagent ammonium carbonate contained in a silver beaker. The solution was boiled to expel

carbon dioxide, then gaseous ammonia was bubbled into the solution until the pH of 8 was achieved. The NH_4F crystals, which formed on gradual cooling, were filtered and washed with methanol saturated with ammonia and finally dried in a stream of anhydrous ammonia gas. Chemical analysis of the sample gave 51.46 ±0.15 percent HF and 48.78 ±0.10 percent ammonia, the theoretical composition being, respectively, 51.29 and 48.71 percent. Benjamins and Westrum [4] calculated S°_{298} from the results of the heat-capacity measurements to be 17.201 ±0.02 eu. Kelley and King [38] calculated S°_{298} = 17.20 ±0.05 eu. on the basis of the same data.

Ammonium Fluoride Monohydrate, $NH_4F \cdot H_2O$, 55.05232

Labowitz and Westrum [44] (5° to 319°K) reported heat-capacity measurements on ammonium fluoride monohydrate, $NH_4F \cdot H_2O$. The sample of NH_4F was prepared by treating reagent-grade 48 percent HF solution in a silver beaker with excess ammonia. The warm, strongly ammoniacal solution was filtered, then boiled distilled water was added until the crystals that separated out on cooling were in solution at 40°C. The crystals that separated out on slow cooling from 40° to 0°C were filtered and washed with cold methanol saturated with ammonia. The crystals were then dried in a stream of anhydrous ammonia gas. The chemical analysis for NH_4^+ by the Kjeldahl method gave 48.70 ±0.04 (volumetric buret) and 48.72 ±0.02 (weight buret) percent, the theoretical composition being 48.70 percent. The analysis for F^- gave 51.32 ±0.03 percent, the theoretical being 51.30 percent. The ammonium fluoride monohydrate was prepared by weighing into the calorimeter vessel the above NH_4F sample and stoichiometric amount of water. Labowitz and Westrum [44] calculated S°_{298} from the measurements to be 34.92 eu.

Nitrogen Trifluoride, NF_3, 71.0019

Pierce and Pace [61] (13° to 144°K) measured the heat capacity of nitrogen trifluoride, NF_3. The sample was prepared by electrolysis of ammonium bifluoride. The gases generated at the nickel anode were passed through concentrated solution of KI and condensed in a cold trap. The NF_3 was purified by fractional distillation. The purity was estimated from the melting curve to be 99.999 mole percent. Pierce and Pace [61] calculated from their data the entropy of liquid NF_3 at its normal boiling point (144.15°K) to be 35.21 eu. Using also their heat-of-vaporization data, Pierce and Pace [61] calculated the entropy of ideal gas NF_3 at 144.15°K and at one atmosphere pressure to be 54.50 eu. Pierce and Pace [61] calculated also the entropy of ideal gas NF_3 at 144.15° and 298.15°K from spectroscopic and molecular data and found them to be 54.61 and 62.25 eu., respectively. The value of S°_{298} for the ideal gas NF_3 calculated by Kelley and King [38] on the basis of spectroscopic and molecular data is 62.28 ±0.10 eu.

Nitric Acid, HNO_3, 63.01287

Forsythe and Giauque [24] (14° to 303°K) reported heat-capacity measurements on nitric acid. The sample was prepared by vacuum distillation from a mixture of $NaNO_3$ and concentrated sulfuric acid. The HNO_3 was collected directly in the calorimeter vessel which was kept a few degrees above the melting point (231.51°K). The sample was frozen as soon as the calorimeter vessel was filled to avoid any decomposition. At room temperature the reaction $2HNO_3 = 2NO_2 + H_2O + 1/2O_2$ occurs. From the pre-melting heat capacity the impurity was estimated to be 0.01 mole percent. Forsythe and Giauque [24] calculated S°_{298} for liquid HNO_3 to be 37.19 eu. Kelley and King [38] calculated $S^\circ_{298} = 37.19 \pm 0.10$ eu. from the same data.

Nitric Acid Monohydrate, $HNO_3 \cdot H_2O$, 81.02821

Forsythe and Giauque [24] (15° to 299°K) measured the heat capacity of nitric acid monohydrate, $HNO_3 \cdot H_2O$. The sample was prepared by diluting pure HNO_3 to the proper composition. The HNO_3 was prepared from $NaNO_3$ and concentrated sulfuric acid and vacuum distilled directly into a glass flask immersed in liquid air. The monohydrate was recrystallized and the first 60 percent of the melt discarded. The sample was poured into the calorimeter vessel through a fine capillary. The purity was estimated from the premelting heat capacity to be 99.7 mole percent. The melting point was found to be 235.48°K. Forsythe and Giauque [24] calculated from the heat data $S^\circ_{298} = 51.84$ eu. for liquid $HNO_3 \cdot H_2O$. Kelley and King [38] calculated $S^\circ_{298} = 51.84 \pm 0.10$ eu. from the same data.

Nitric Acid Trihydrate, $HNO_3 \cdot 3H_2O$, 117.05889

Forsythe and Giauque [24] (15° to 296°K) measured the heat capacity of nitric acid trihydrate, $HNO_3 \cdot 3H_2O$. The trihydrate was prepared from reagent grade 70 percent nitric acid. Dry air was first bubbled through the solution to remove oxides of nitrogen. A sample was quickly weighed and frozen to prevent decomposition. After the analysis, a calculated amount of water was added to attain the desired composition. From the premelting heat capacity the impurity was estimated to be 0.02 percent. The melting point was found to be 254.63°K. Forsythe and Giauque [24] calculated S°_{298} of liquid $HNO_3 \cdot 3H_2O$ to be 82.93 eu. Kelley and King [38] calculated $S^\circ_{298} = 82.9 \pm 0.2$ eu. from the same data.

Mercury, Hg, 200.59

A number of investigators have reported low-temperature heat-capacity measurements on mercury (Hg) over the last hundred years or more. They are as follows:

Regnault [65] ($\bar{c}$: -68° to 18° and 8° to 100°C)
Nordmeyer and Bernoulli [56] ($\bar{c}$: -185° to 20°C)
Koref [42] ($\bar{c}$: -78° to -42°, -36° to -3°, and -75° to 0°C)

Barschall [2] ($\bar{c}$: -183 to -78°C)
Pollitzer [62] (-211° to -30°C)
Russell [67] ($\bar{c}$: -4° to 38°C)
Pollitzer [63] (31° to 168°K)
Dewar [14] ($\bar{c}$: 20° to 80°K)
Onnes and Holst [57] ($\bar{c}$: 4.26° to 6.48°K and 2.93° to 3.97°K)
Simon [70] (19° to 232°K)
Simon [71] (10° to 13°K)
Carpenter and Stoodley [6] (198° to 285°K)
Misener [51] (0.1° to 4.1°K)
Pickard and Simon [60] (3° to 95°K)
Douglas, Ball and Ginnings [15] (ΔH: 0° to 450°C)
Busey and Giauque [5] (15° to 326°K)
Smith and Wolcott [73] (1.2° to 20°K)

Douglas et al. [15] calculated S°_{298} of liquid mercury to be 18.12 eu. by correlating their measurements of enthalpy relative to 0°C with available vapor-pressure data, with an estimate of gas imperfection, and with the Sackur-Tetrode equation for the mercury vapor. The above value was shown to be significantly lower than that value calculated on the basis of existing low-temperature heat-capacity data. Subsequent measurements of the low-temperature heat capacity of mercury by Busey and Giauque [5] yielded S°_{298} to be 18.19 eu. Kelley and King [38] using in addition the low-temperature heat-capacity data of Smith and Wolcott [73] calculated S°_{298} to be 18.17 ±0.10 eu. for liquid mercury.

Mercuric Oxide (Red), HgO, 216.5894

Measurements of the heat capacity of red mercuric oxide, HgO, have been reported by Russell [67] ($\bar{c}$: -191° to -78°, -75° to 0°, and 3° to 44°C), Günther [32] (25° to 75°K), and by Bauer and Johnston [3] (15° to 298°K). The material investigated by Bauer and Johnston [3] was a commercial reagent-grade mercuric oxide of high chemical purity. The value of S°_{298} reported by Bauer and Johnston [3] is 16.774 eu. Kelley and King [38] using the data reported by Günther [32] and by Bauer and Johnston [3] calculated S°_{298} to be 16.80 ±0.08 eu.

Mercurous Chloride, $HgC\ell$, 236.0430

Heat-capacity data on mercurous chloride, $HgC\ell$, are somewhat limited. Forch and Nordmeyer [23] reported measurements of the mean heat capacity between -192° and 14°C. Pollitzer [62,63] in his two papers reported measurements in the range 23° to 199°K. Kelley and King [38] using Pollitzer's data [62,63] calculated S°_{298} to be 23.0 ±0.5 eu. Kelley and King [38] also calculated S°_{298} = 23.0 ±0.5 eu. from the cell measurements reported by Gerke [27].

Table 1

ENTROPY OF SOME SELECTED COMPOUNDS OF

H, Li, B, N, O, F, Na, Mg, Aℓ, Si, Cℓ, K, Ti, Br, and I

Chemical Formula	Gram Formula Mass	State	S°_{298} cal/deg mole	REFERENCES	S°_{298} Kelley and King [38] cal/deg mole
$LiHF_2$	45.94377	c*	16.97	[79]	---
MgB_2	45.9340	c	8.60	[76]	8.62 ±0.08
MgB_4	67.5560	c	12.41	[76]	12.5 ±0.1
Na	22.9898	c	12.24 ±0.12	[49]	12.24 ±0.10
Na_2K	85.0816	ℓ	48.21 ±0.09	[43]	48.2 ±0.3
NaH	23.99777	c	---		---
Na_2O	61.9790	c	18.0 ±0.2	[25]	18.0 ±1.0
Na_2O_2	77.9784	c	22.6 ±0.3	[77]	22.6 ±0.3
NaO_2	54.9886	c	27.7 ±0.3	[77]	27.7 ±0.3
NaOH	39.99717	c	15.3 ±0.1 15.40	[39] [81]	15.4 ±0.3
$NaNH_2$	39.01244	c	18.380	[8]	18.4 ±0.2
$NaAlO_2$	81.9701	c	16.9 ±0.2	[40]	16.9 ±0.2
Na_3AlF_6	209.9413	c	57.0 ±0.4	[41]	57.0 ±0.4
NaF	41.9882	c	12.26 ±0.07	[41]	12.26 ±0.07
$NaHF_2$	61.99457	c	21.73	[79]	---
NaCl	58.4428	c	---		17.33 ±0.10
$NaBH_4$	37.83268	c	24.26	[36]	24.21 ±0.10
$NaBO_2$	65.7996	c	17.574	[28]	17.57 ±0.05
$Na_2B_4O_7$	201.2194	c	45.296	[80]	45.3 ±0.2
		glass	44.391 ($S^\circ_{298}-S^\circ_0$)	[80]	44.4 ±0.2 ($S^\circ_{298}-S^\circ_0$)
$NaNO_3$	84.9947	c	27.87 ±0.08	[74]	27.85 ±0.10
Na_2SiO_3	122.0638	c	27.2 ±0.3	[37]	27.2 ±0.2
$Na_2Si_2O_5$	182.1486	c	39.4 ±0.6	[37]	39.4 ±0.3
Na_4SiO_4	184.0428	c	46.8 ±0.6	[37]	46.8 ±0.4
Na_2TiO_3	141.8778	c	29.1 ±0.1	[69]	29.1 ±0.2
$Na_2Ti_2O_5$	221.7766	c	41.5 ±0.2	[69]	41.5 ±0.3
$Na_2Ti_3O_7$	301.6754	c	55.9 ±0.3	[69]	55.9 ±0.4

(Table 1 continued on next page)

Table 1 (Continued)

Chemical Formula	Gram Formula Mass	State	S°_{298} cal/deg mole	REFERENCES	S°_{298} Kelley and King [38] cal/deg mole
KNO_3	101.1069	c	31.77 ±0.10	[74]	31.81 ±0.15
$KClO_3$	122.5532	c	34.17 ±0.05	[46]	34.2 ±0.2
$KClO_4$	138.5526	c	36.1 ±0.3	[45]	36.1 ±0.2
$KBrO_3$	167.0092	c	35.65	[1]	35.7 ±0.2
KIO_3	214.0046	c	36.20	[1]	36.2 ±0.2
$(NH_4)_2O$	52.07656	c	63.94	[34]	63.94 ±0.10
NH_4OH	87.12251	c	39.57	[34]	39.57 ±0.10
NH_4NO_3	80.04348	c	36.11 ±0.05	[75]	36.06 ±0.10
NH_4F	37.03698	c	17.201±0.02	[4]	17.20 ±0.05
$NH_4F \cdot H_2O$	55.05232	c	34.92	[44]	---
NF_3	71.0019	ℓ	35.21 ($S^\circ_{144.15}$)	[61]	35.27 ($S^\circ_{144.15}$)
		g	54.50 ($S^\circ_{144.15}$)	[61]	54.56 ($S^\circ_{144.15}$)
HNO_3	63.01287	ℓ	37.19	[24]	37.19 ±0.10
$HNO_3 \cdot H_2O$	81.02821	ℓ	51.84	[24]	51.84 ±0.10
$HNO_3 \cdot 3H_2O$	117.05889	ℓ	82.93	[24]	82.9 ±0.2
Hg	200.59	ℓ	18.19	[5]	18.17 ±0.10
HgO(Red)	216.5894	c	16.774	[3]	16.80 ±0.08
HgCℓ	236.0430	c	---		23.0 ±0.5

*c = crystal
ℓ = liquid
g = gas

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Chapter 5

NEW LITERATURE RELATING TO HEATS OF FORMATION OF THE LIGHT ELEMENTS AND THEIR COMPOUNDS

by M. C. Bracken and G. T. Armstrong

The following material comprises references to new additions to the files in the Combustion Calorimetry Group of the Heat Division, relating to the heats of formation of the light elements and their compounds. The search was carried out in a systematic way by scanning sections of the Chemical Abstracts, and the tables of contents of a limited number of current journals. Nevertheless, omissions undoubtedly have occurred because subject and formula indices to the abstracts were not available, and, of course, because of the lag between appearance of an article in a journal not examined, and the appearance of its abstract in Chemical Abstracts. Because it represents a collection for a working file, reviews by others have been scanned, and no critical evaluation or selection of values has been made. For the same reason, some material of borderline value is included, such as theoretical studies, empirical correlations, and stability studies, which are inadequate in themselves, but may be helpful in comparing other, more precise studies.

Most of the articles have been examined, except for a few in foreign journals not readily available, in which cases, reliance has been placed on the abstract for the contents of the article.

The references are classified below by substance. The substances are arranged in the alphabetical order of the element symbols, as has been done in a previous review [4], but no attempt is made to differentiate information relating to different phases of the same substance. The brief description of the contents of the article is not necessarily a complete itemization of data to be found in it, but is intended primarily to indicate the type of relevent information included. In addition to the articles referenced in the alphabetical list of substances, a few general reviews [4, 21, 22, 34, 141] are included in the reference list, which were not amenable to this type of classification. In addition, articles by Klyuchnikov [96], Mader [112] and Pohl [145], containing suitable information, could not be obtained in time to enter their contents into the list. Klyuchnikov [96] gives an empirical correlation of enthalpies of

formation of oxides, and the abstract suggests that new measurements are included, but this is not clear. Mader [112] tabulates ideal gas thermodynamic functions, 300-6000°K, for molecular species composed of Al, B, Be, C, Cl, F, H, Li, Mg, N, and O. Pohl [145] correlated heats and free energies of formation of metal oxides, fluorides, and sulfides. The list of substances follows. Numbers in brackets refer to references at the end of this chapter.

Principal abbreviations used in alphabetical list:

calc.	calculated
correl.	correlated
est.	estimated
meas.	measured
rev.	reviewed
tab.	tabulated
thermo.	thermodynamic

Al	[6] tab. H_{298}, H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [40] meas. ΔH solidification. [41] meas. ΔH, ΔS, ΔF mixing with Mg. [76] meas. C_p, ΔH transition. [90] calc. S_{298}. [209] tab. thermo. functions 298-5000°K.
AlBr	[191] tab. thermo. functions 0-6000°K.
$AlBr_3$	[191] tab. thermo. functions 0-6000°K.
AlCl	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas).
$AlCl_2$	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas).
$AlCl_3$	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas).
AlF	[209] rev. ΔHf, tab. thermo. functions 298-5000°K.
AlFO	[209] est. ΔHf, tab. thermo. functions 298-5000°K.
AlF_2	[209] est. ΔHf, tab. thermo. functions 298-5000°K.
AlF_3	[45, 100] meas. ΔHf. [119] meas. ΔF of the equilibrium with $NaAlO_2$, Na_3AlF_6, Al_2O_3. [142] meas. ΔH subl. [209] tab. thermo. functions 298-5000°K.

AlF_4Li	[194] tab. thermo. functions 0-6000°K.
AlF_4Na	[49, 162] meas. equilibrium with NaF and Na_3AlF_6.
AlF_6Na_3	[161] meas. ΔH fusion. See AlF_3, AlF_4Na.
AlH	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [186] correl. D_o. [209] tab. thermo. functions 298-5000°K.
$AlHO$	[209] est. ΔHf, tab. thermo. functions 298-5000°K.
AlH_3	[124] meas. ΔH react. with HCl(aq.), and rept. ΔHf. [209] est. ΔHf.
AlI	[191] tab. thermo. functions 0-6000°K.
AlI_3	[191] tab. thermo. functions 0-6000°K.
AlN	[36] meas. vapor pressure. [191] tab. thermo. functions 0-6000°K.
$AlNaO_2$	See AlF_3.
AlO	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$ (gas). [192] tab. thermo. functions 0-6000°K. [209] tab. thermo. functions 298-5000°K.
Al_2	[209] est. ΔHf, tab. thermo. functions 298-5000°K.
Al_2BeO_4	[192] tab. thermo. functions 0-4500°K.
Al_2Br_6	[191] tab. thermo. functions 0-6000°K.
Al_2I_6	[191] tab. thermo. functions 0-6000°K.
Al_2O	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$. [209] tab. thermo. functions 298-5000°K.
Al_2O_2	[191] tab. thermo. functions 0-6000°K.
Al_2O_3	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$. [85] meas. ΔH fusion. [209] tab. thermo. functions 298-5000°K. See AlF_3.

Al_2O_5Ti	[10] meas. ΔHf from oxides.
Al_4C_3	[28, 66] meas. ΔFf, calc. ΔHf. [177] rev. ΔHf.
B	[9] tab. thermo. functions 0-6000°K. [59] rev. ΔHf. [142] meas. vapor pressure. [186] correl. D_o of B_2. [202] calc. ΔH subl. from mass spectrometer meas. [209] tab. thermo. functions 298-5000°K.
BBr	[59] rev. ΔHf. [191, 194] tab. thermo. functions 0-6000°K.
$BBrCl_2$	[194] tab. thermo. functions 0-6000°K.
$BBrF_2$	[59] est. ΔHf. [133] tab. thermo. functions 100-1700°K. [194] tab. thermo. functions 0-6000°K.
BBr_2	[59] est. ΔHf. [192] tab. thermo. functions 0-6000°K.
BBr_2Cl	[194] tab. thermo. functions 0-6000°K.
BBr_2F	[133] tab. thermo. functions 100-1700°K. [194] tab. thermo. functions 0-6000°K.
BBr_3	[8] meas. vapor pressure. [59] rev. ΔHf. [129] tab. thermo. functions 50-1600°K. [191, 194] tab. thermo. functions 0-6000°K.
BC	[203, 204] calc. decompn. energy from mass spectrometer meas.
$BCFH_3$ (CH_3BF)	[185] meas. appearance potential of ion.
BCF_2H_3 (CH_3BF_2)	[185] meas. appearance potential of ion.
BCH_3O_3 (CH_3BO_3)	[71] tab. H, ΔH vaporization.

BCNO (OBCN)	[59] est. ΔHf.
BC_2	[203, 204] calc. decompn. energy from mass spectrometer meas.
$BC\ell$	[59] rev. ΔHf.
$BC\ell F$	[59] est. ΔHf.
$BC\ell F_2$	[59] est. ΔHf. [133] tab. thermo. functions 100-1700°K. [148] calc. ΔHf from mass spectrometer meas.
$BC\ell O$	[59] est. ΔHf.
$BC\ell_2$	[59] est. ΔHf.
$BC\ell_2F$	[59] est. ΔHf. [133] tab. thermo. functions 100-1700°K. [148] calc. ΔHf from mass spectrometer meas.
$BC\ell_3$	[59, 177] rev. ΔHf. [133] tab. thermo. functions 100-1700°K.
BF	[59] rev. ΔHf. [209] rev. ΔHf, tab. thermo. functions 298-5000°K.
BFH_2O_2 ($BF(OH)_2$)	[148] calc. ΔHf from mass spectrometer meas.
BFO	[43] calc. ΔHf from meas. of equilibrium with BF_3 and B_2O_3. [59] est. ΔHf. [194] tab. thermo functions 0-6000°K. [209] est. thermo. functions 298-5000°K.
BF_2	[59] est. ΔHf. [185] meas. appearance potential of ion from CH_3BF_2. [209] est. ΔHf, tab. thermo. functios 298-5000°K.
BF_2H	[185] calc. B-H bond energy.
BF_2HO ($BF_2(OH)$)	[148] calc. ΔHf from mass spectrometer meas.

BF_3	[44, 148] meas. equilibrium with B_2O_3 and $(BFO)_3$. [45, 59, 177] rev. ΔHf. [132] tab. thermo. functions for isotopic species 100-1600°K. [209] calc. ΔHf, tab. thermo. functions 298-5000°K.
BH	[59] rev. ΔHf. [209] tab. thermo. functions 298-5000°K.
BHO_2 (HBO_2)	[59] rev. ΔHf. [194] tab. thermo. functions 0-1500°K. [209] rev. ΔHf, tab. thermo. functions 298-5000°K.
BH_3	[59] rev. ΔHf. [209] tab. thermo. functions 298-5000°K.
BH_3O_3 (H_3BO_3)	[59] rev. ΔHf. [194] tab. thermo. functions 0-1500°K. [209] tab. thermo. functions 298-5000°K.
BH_7N_2 ($BH_3 \cdot N_2H_4$)	[61] meas. ΔH combustion.
BI	[59] est. ΔHf.
BI_2	[192] tab. thermo. functions 0-6000°K.
BI_3	[129] tab. thermo. functions of isotopic species. [191, 194] tab. thermo. functions 0-6000°K.
$BLiO_2$	[193] tab. thermo. functions 0-6000°K.
BN	[36] meas. vapor pressure. [45, 59, 177] rev. ΔHf. [125] tab. thermo. functions. [186] correl. D_o. [208] rev. C_p. [209] tab. thermo. functions 298-5000°K.
$BNaO_2$	[194] tab. thermo. functions 0-2500°K.
BO	[59] rev. ΔHf. [186] correl. D_o. [193] tab. thermo. functions 0-6000°K. [209] tab. thermo. functions 298-5000°K.
BO_2	[88] est. ΔHf.
BTi	[9] rev. thermo. data. [171] calc. vapor pressure from mass spectrometer meas.
BTi_2	[9] rev. thermo. data.

BW	[9] meas. C_p (1556-2086°K). [125] tab. thermo. functions. [167] rev. and correl. ΔHf.
BW_2	[108] meas. thermo. properties by volatilization. [125] tab. thermo. functions. [167] rev. and correl. ΔHf.
BZr	[167] rev. and correl. ΔHf.
B_2	[59] rev. ΔHf. [186] correl. D_o. [202] calc. D_o from mass spectrometer data. [209] tab. thermo. functions 298-5000°K.
B_2Br_4	[75] rev. vapor pressure and thermo. properties.
B_2C	[203, 204] meas. decompn. energy and equilibrium with B_4C by mass spectrometer.
B_2Cl_4	[75] rev. vapor pressure and thermo. data.
B_2F_4	[75] rev. vapor pressure and thermo. data.
B_2H_6	[68] meas. ΔHf of D compound.
$B_2Li_2O_4$	[192] tab. thermo. functions 0-6000°K.
B_2O_2	[59] rev. [157] calc. ΔHf from equilibrium with C and B_2O_3. [209] tab. thermo. functions 298-5000°K.
B_2O_3	[59] rev. ΔHf. [209] tab. thermo. functions 298-5000°K. See BFO, BF_3, B_2O_2.
B_2O_4Pb	[192] tab. thermo. functions 0-6000°K.
$B_2O_5Pb_2$	[109] calc. ΔFf from emf meas.
$B_2O_6Pb_3$	[109] calc. ΔFf from emf meas.
B_2Ti	[9] rev. thermo. properties, meas. C_p 1733-2417°K. [103] calc. ΔH for formation by reaction of TiO, B_4C and C. [125] tab. thermo. functions. [167] rev. and correl. ΔHf. [171] calc. vapor pressure from mass spectrometer meas. [194] tab. thermo. functions 0-6000°K.

B_2Zr	[9] meas. C_p 1739-2521°K. [108] calc. thermo. properties from volatization meas. [125] tab. thermo. functions. [167] rev. and correl. ΔHf. [194] tab. thermo. functions 0-6000°K.
$B_3F_3O_3$ $(BFO)_3$	[113] reports ΔHf, ΔH fusion, ΔH vaporization, ΔH soln. [194] tab. thermo. functions 0-6000°K. See BF_3.
$B_3H_3O_6$ $(HBO_2)_3$	[59] rev. ΔHf. [194] tab. thermo. functions 0-6000°K.
$B_3H_6N_3$	[94] meas. ΔH combustion.
B_4C	[59, 177] rev. ΔHf. [202, 203, 204] calc. ΔH subl. and equilibrium with B_2C, B and C from mass spectrometer meas. See B_2Ti.
B_4Cl_4	[75] rev. vapor pressure and thermo. data.
$B_4Li_2O_7$	[192] tab. thermo. functions 0-5000°K.
B_4O_7Pb	[192] tab. thermo. functions 0-2000°K.
B_5Ti_2	[9] rev. thermo. data. [167] rev. and correl. ΔHf.
B_5W_2	[125] tab. thermo. functions. [167] rev. and correl. ΔHf.
$B_6Li_2O_{10}$	[192] tab. thermo. functions 0-5000°K.
$B_6Na_2O_{10}$	[194] tab. thermo. functions 0-2000°K.
$B_6O_{10}Pb$	[192] tab. thermo. functions 0-2000°k.
$B_8Li_2O_{13}$	[192] tab. thermo. functions 0-5000°K.
$B_{10}H_{14}$	[52] meas. ΔHf by thermal decompn. [194] tab. thermo. functions 0-6000°K.
$B_{10}O_{17}Pb_2$	[192] tab. thermo. functions 0-2000°K.
$B_{12}Zr$	[167] rev. and correl. ΔHf.

$B_nH_{3n}N_n$ $(BH_2NH)_n$ [61] meas. ΔH combustion.

B-C-Ti System [164] gives phase diagram and indicated calc. of ΔFf.

B-C-W System [164] gives phase diagram and indicates calc. of ΔFf.

B-C-Zr System [164] gives phase diagram and indicates calc. of ΔFf.

B-N-Ti System [164] indicates calc. of ΔFf from phase diagram.

B-N-Zr System [164] gives phase diagram and indicates calc. of ΔFf.

Be [9] rev. thermo. data and tab. thermo. functions 0-6000°K. [90] calc. S_{298}.

BeBr [191] tab. thermo. functions 0-6000°K.

$BeBr_2$ [19] calc. ΔH dissoc. to ions. [23] rev. thermo. data and tab. thermo. functions. [191] tab. thermo. functions 0-6000°K.

BeC_2 [194] tab. thermo. functions 0-6000°K.

$BeC\ell$ [192] tab. thermo. functions 0-6000°K.

$BeC\ell_2$ [14] studied gas with mass spectrometer. [19] calc. ΔH dissoc. to ions. [23] rev. thermo. data and tab. thermo. functions. [198] meas. ΔH soln. of Be and $BeC\ell_2$ and calc. ΔHf. [191] tab. thermo. functions 0-6000°K.

BeF [194] tab. thermo. functions 0-6000°K.

BeF_2 [19] calc. ΔH dissoc. to ions. [23] rev. thermo. data and tab. thermo. functions. [63] meas. vapor pressure and calc. ΔH vaporization.

BeH	[186] correl. D_o.
BeI	[191] tab. thermo. functions 0-6000°K.
BeI_2	[19] calc. ΔH dissoc. to ions. [23] rev. thermo. data and tab. thermo. functions. [191] tab. thermo. functions 0-6000°K.
BeO	[9] rev. thermo data and tab. thermo. functions 0-6000°K.
Be_2C	[192] tab. thermo. functions 0-4000°K.
Br	[27] discusses theory of dissociation energy. [186] correl. D_o of Br_2.
BrCN	[193] tab. thermo. functions 0-6000°K.
BrCl	[194] tab. thermo. functions 0-6000°K.
BrClHg	[115] meas. stability constant (aq.).
$BrCl_3Ti$	[128] tab. thermo. functions 50-1600°K.
BrF	[193] tab. thermo. functions 0-6000°K.
BrF_3	[193] tab. thermo. functions 0-6000°K.
BrF_5	[93] tab. thermo. functions 300-1000°K. [193] tab. thermo. functions 0-6000°K.
BrH	[186] correl. D_o.
BrH_4N (NH_4Br)	[192] tab. thermo. functions 0-1000°K.
BrHg	[191] tab. thermo. functions 0-6000°K.
BrHgI	[115] meas. stability constant (aq.).
$BrHgI_2^-$	[115] meas. stability constant (aq.).
$BrHgI_3^{-2}$	[115] meas. stability constant (aq.).

BrI [192] tab. thermo. functions 0-6000°K.

BrLi [1] correl. ΔH fusion. [15] studied dimerization with mass spectrometer.

BrLi-BrNa System [110] correl. ΔH mixing.

$BrLiO_3$ [18] meas. ΔH solution.

BrNO [192] tab. thermo. functions 0-6000°K.

BrNa [1] correl. ΔH fusion. [87] calc. ΔH fusion. [90] calc. S_{298}.

BrNa-BrLi System See BrLi-BrNa

$BrNaO_3$ [18] meas. ΔH solution.

BrPb [192, 193] tab. thermo. functions 0-6000°K.

BrTi [51] calc. ΔH from meas. equilibrium of Ti, $TiBr_2$, $TiBr_3$ $TiBr_4$. [191] tab. thermo. functions 0-6000°K.

Br_2 [191] tab. thermo. functions 0-6000°K. See Br.

Br_2Hg [23] rev. thermo. data and tab. thermo. functions. [192] tab. thermo. functions 0-6000°K. See HgO.

Br_2HgI^- [115] meas. stability constant (aq.).

$Br_2HgI_2^{-2}$ [115] meas. stability constant (aq.).

Br_2Hg_2 [192] tab. thermo. functions 0-1500°K.

Br_2Li_2 [15] studied gas with mass spectrometer.

Br_2Mg [14] studied dimerization by mass spectrometer. [19] calc. ΔH dissoc. to ions. [23] rev. thermo. data and tab. thermo. functions.

Br_2Pb [23] rev. thermo. data and tab. thermo. functions. [116] meas. vapor pressure. [192] tab. thermo. functions 0-6000°K.

Br_2Ti	[23] rev. thermo. data and tab. thermo. functions. [191] tab. thermo. functions 0-6000°K. See BrTi.
Br_2Zr	[111] reported ΔHf. [192] tab. thermo. functions 0-6000°K.
$Br_3C\ell Ti$	[128] tab. thermo. functions 50-1600°K.
Br_3HgI^{-2}	[115] meas. stability constant (aq.).
Br_3Ti	[191] tab. thermo. functions 0-2000°K. See BrTi.
Br_3Zr	[111] reported ΔHf. [192] tab. thermo. functions 0-6000°K.
Br_4Mg_2	[14] studied gas with mass spectrometer.
Br_4Pb	[131] tab. thermo. functions 50-1600°K. [193] tab. thermo. functions 0-6000°K.
Br_4Ti	[177] rev. ΔHf. [191] tab. thermo. functions 0-6000°K. See BrTi.
Br_4Zr	[131] tab. thermo. functions 50-1600°K. [192] tab. thermo. functions 0-6000°K.
C	[6] tab. H_{298}, H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [9] meas. C_p 1993-2483°K., tab. thermo. functions 0-6000°K. [143] rev. ΔHf(gas). [208] rev. C_p. See C_2.
$CC\ell F_3$	[7] meas. ΔHf.
$CC\ell N$ ($C\ell CN$)	[120] tab. thermo. functions 100-6000°K.
$CC\ell_2F_2$	[5] correl. vapor pressure and ΔH vaporization.
$CC\ell_2O$	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas).
$CC\ell_3F$	[5] correl. vapor pressure and ΔH vaporization. [7] meas. ΔHf.

$CC\ell_4$	[7] meas. ΔHf. [99] meas. ΔH mixing with $TiC\ell_4$. See $C\ell_2O$.
CF_2	[114] calc. ΔHf from mass spectrometer meas.
CF_3	[25] rev. and correl. ΔHf and ΔFf.
CF_3H	[77] meas. vapor pressure and C_p. [201] meas. vapor pressure, C_p, ΔH fusion, ΔH subl.
CF_4	[7] meas. ΔHf. [25] rev. and correl. ΔHf and ΔFf. [131] tab. thermo. functions 50-1600°K. [173] rev. properties.
CF_n	[147] meas. ΔH reaction of F and graphite.
CH	[143] rev. ΔHf. [186] correl. D_o.
CHN	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [120] tab. thermo. functions 100-6000°K.
CH_2	[143] rev. ΔHf.
$CH_2N_2O_4$	[180] meas. ΔH dissoc.
CH_3	[143] rev. ΔHf.
CH_3NO_2	[53, 152] meas. ΔHf.
CH_4	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [143] rev. ΔHf. [155] correl. vapor pressure. [196] tab. thermo. functions.
CH_4O	See $C\ell NO$.
CIN	[194] tab. thermo. functions 0-6000°K.
CI_4	[62] tab. thermo. functions 273-1000°K. [169] tab. thermo. functions 100-1000°K.
CN	[12, 13] calc. ΔHf and dissoc. from mass spectrometer meas. [199] meas. ΔH dissoc. of C_2N_2.

CO	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [155] correl. vapor pressure. [186] correl. D_o.
CO_2	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [120] tab. thermo. functions 100-6000°K. [153] tab. thermo. functions 1000-24,000°K.
CTi	[9] meas. C_p 2023-2506°K., rev. thermo. data. [90] S_{298}-S_{2000}. [102] calc. ΔH for formation by reduction of TiO_2 by C. [167] rev. and correl. ΔHf. [177] rev. ΔHf. [205] calc. ΔHf and ΔFf from spectrophotometer meas.
CW	[165] est. ΔH transition. [167] rev. and correl. ΔHf. [177] rev. ΔHf.
CZr	[9] meas. C_p 1639-2499°K. [90] calc. S_{298}. [167] rev. and correl. ΔHf. [177] rev. ΔHf. [192] tab. thermo. functions 0-6000°K. [205] calc. ΔHf and ΔFf from spectrophotometer meas.
C_2	[9] tab. thermo. functions 0-6000°K. [154] calc. potential energy. [186] correl. D_o.
C_3	[9] tab. thermo. functions 0-6000°K.
Cℓ	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [27] discusses theoretical dissociation energy. [186] correl. D_o of $C\ell_2$.
$C\ell F_2N$	[74] rev. properties. [82] rev. chem. equilibria.
CℓH	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [186] correl. D_o. [197] meas. vapor pressure.
$C\ell HO_4$	[179] meas. ΔHf.
$C\ell H_4N$ ($NH_4C\ell$)	[117] calc. dissoc. energy from equilibrium meas.

ClH_4NO_4 (NH_4ClO_4) [6] list ΔHf, H_{298}.

ClH_6NaO_5 ($NaClO_2 \cdot 3H_2O$) [80] meas. ΔH solution.

ClHg [191] tab. thermo. functions 0-6000°K.

ClHgI [115] meas. stability constant (aq.).

ClI [79] meas. ΔH dissoc. spectroscopically. [186] correl. D_o. [192] tab. thermo. functions 0-6000°K.

ClLi [1] correl. ΔH fusion. [15] studied dimerization with mass spectrometer. [90] calc. S_{298}. [193] tab. thermo. functions 0-6000°K.

ClLi-ClNa System [110] correl. ΔH mixing.

$ClLiO_4$ [84] meas. ΔH solution and dilution.

ClMg [168] studied thermo. of formation from $TiCl_4$ and Mg.

ClNO [58] tab. thermo. functions. [152] meas. ΔH reaction with CH_3OH.

$ClNO_2$ [149] tab. thermo. functions 100-1000°K. [200] calc. ΔHf, tab. thermo. functions 200-1200°K.

ClNa [1] correl. ΔH fusion. [33] calc. ΔH of dimer and trimer formation from mass spectrometer meas. [49, 162] meas. equilibrium of Na_3AlF_6 and $NaAlF_4$ in NaCl. [87] calc. ΔH fusion. [90] calc. S_{298}-S_{2000}. [158] calc. ΔH fusion from cryoscopic data.

ClNa-ClLi System See ClLi-ClNa.

$ClNaO_2$ [80] meas. ΔH solution.

$ClNaO_4$ [179] meas. ΔHf.

Cl_2O_2	[67] meas. vapor pressure.
ClPb	[192, 193] tab. thermo. functions 0-6000°K.
$ClZr^{+3}$	[118] meas. stability constant.
Cl_2	[6] tab. H_{298}, H_{3000}, S_{3000}, constants for $C_p(T)$(gas). See Cl.
Cl_2Hg	[23] rev. thermo. data and tab. thermo. functions. [191, 192] tab. thermo. functions 0-6000°K. See HgO.
Cl_2Li_2	[15] studied gas with mass spectrometer. [193] tab. thermo. functions 0-6000°K.
Cl_2Mg	[14] studied dimerization of gas with mass spectrometer. [19] calc. ΔH dissoc. to ions. [23] rev. thermo. data and tab. thermo. functions. [38] calc. ΔFf from emf meas. [144] meas. vapor pressure of aq. solution.
Cl_2Na_2	See ClNa.
Cl_2O	[106] meas. ΔHf and ΔH dilution in CCl_4.
Cl_2OTi	[39] meas. ΔH solution in $TiCl_4$.
Cl_2O_2W	[175] calc. ΔHf from experimental meas. [194] tab. thermo. functions 0-6000°K.
Cl_2Pb	[23] rev. thermo. data and tab. thermo. functions. [192] tab. thermo. functions 0-6000°K.
Cl_2Ti	[17] related ΔFf to emf meas. [23] rev. thermo. data and tab. thermo. functions. [140] give ΔF for reduction by Na. [168] calc. thermo. of reduction of $TiCl_4$ by Ti and Mg. [178] meas. equilibrium with Ti and $TiCl_3$ in KCl. See Cl_4Ti.
Cl_2W	[194] tab. thermo. functions 0-6000°K.

Cl_2Zr [111] reported ΔHf. [193] tab. thermo. functions 0-6000°K.

Cl_2Zr^{+2} [118] meas. stability constant.

Cl_3Li_3 [193] tab. thermo. functions 0-6000°K.

Cl_3Na_3 See ClNa.

Cl_3Ti [17] related ΔFf to emf meas. [81] meas. ΔH for reduction of $TiCl_4$. [140] calc. ΔF for reduction of $TiCl_4$ by Na. [168] calc. thermo. of reduction of $TiCl_4$ by Mg. [181] calc. ΔHf in fused NaCl-KCl from emf meas. See Cl_2Ti, Cl_4Ti.

Cl_3Zr [111] reported ΔHf. [191] tab. thermo. functions 0-6000°K. [193] tab. thermo. functions 0-3000°K.

Cl_3Zr^{+} [118] meas. stability constant.

Cl_4Mg_2 [14] studied gas with mass spectrometer.

Cl_4OW [175] calc. ΔHf from experimental meas. [194] tab. thermo. functions 0-6000°K.

Cl_4Pb [131] tab. thermo. functions 50-1600°K. [192, 193] tab. thermo. functions 0-6000°K.

Cl_4Ti [17] related ΔFf in molten mixtures to emf meas. [174] calc. ΔF of reaction with O_2. [177] rev. ΔHf. See CCl_4, ClMg, Cl_2Ti, Cl_3Ti, Cl_2OTi.

Cl_4W [194] tab. thermo. functions 0-6000°K.

Cl_4Zr [118] meas. stability constant. [131] tab. thermo. functions 50-1600°K. [177] rev. ΔHf.

Cl_6W [175] calc. ΔHf from experimental meas.

F [27] discusses theory of dissociation energy of F_2. [173] rev. properties. [186] correl. D_o of F_2. [209] tab. thermo. functions 298-5000°K.

FH [173] reviews properties. [186] correl. D_o. [190] calc. ΔH assoc. in gas phase. [209] tab. thermo. functions 298-5000°K.

FH_2N [74] rev. properties.

FH_6NO ($NH_4F \cdot H_2O$) [208] rev. C_p and phase behavior.

FHg [19] tab. thermo. functions 0-6000°K.

FI [192] tab. thermo. functions 0-6000°K.

FLi [1] correl. ΔH fusion. [15] studied dimerization of gas with mass spectrometer. [87] calc. ΔH fusion. [90] calc. S_{298}-S_{2000}. [194] tab. thermo. functions 0-6000°K. [209] tab. thermo. functions 298-5000°K.

FLi-FNa System [110] correl. ΔH mixing.

FNO [74] rev. properties. [83] meas. ΔH of reaction of F_2 and NO.

FNO_2 [74] rev. properties. [104, 149] tab. thermo. functions 100-1000°K. [192] tab. thermo. functions 0-6000°K. [200] calc. ΔHf, tab. thermo. functions 200-1200°K.

FNO_3 [195] meas. ΔHf.

FN_3 [74] rev. properties.

FNa [1] correl. ΔH fusion. [87] calc. ΔH fusion. [90] calc. S_{298}-S_{2000}. See AlF_4Na.

FNa-FLi System See FLi-FNa

FPb	[192, 193] tab. thermo. functions 0-6000°K.
FW	[194] tab. thermo. functions 0-6000°K.
F_2	[209] tab. thermo. functions 298-5000°K. See F.
F_2H^-	[173] rev. aq. properties.
F_2HN	[74, 82] rev. properties.
F_2HNa ($NaF \cdot HF$)	[208] rev. C_p and phase behavior.
F_2H_5N ($NH_4F \cdot HF$)	[208] rev. C_p and phase behavior.
F_2Hg	[23] rev. thermo. data and tab. thermo. functions. [191] tab. thermo. functions 0-6000°K. [192] tab. thermo. functions 0-2000°K.
F_2Hg_2	[192] tab. thermo. functions 0-1500°K.
F_2Li_2	[15] studied gas with mass spectrometer. [194] tab. thermo. functions 0-6000°K. [209] est. ΔHf, tab. thermo. functions 298-5000°K.
F_2Mg	[14] studied dimerization of gas with mass spectrometer. [19] calc. ΔH dissoc. of gas to ions. [23] rev. thermo. data and tab. thermo. functions. [45] reports meas. of ΔHf.
F_2N	[72] tab. thermo. functions 273-3000°K. [82] meas. equilibrium with N_2F_4. [89] discussed theory of binding energy. [91] calc. ΔHf from dissoc. equilibrium of N_2F_4.
F_2N_2	[74] rev. properties. [166] tab. thermo. functions 100-6000°K.
F_2N_2O	[82] rev. chemical equilibria.

F_2O	[136] tab. thermo. functions 100-1700°K.
F_2O_2	[95] meas. ΔH decomposition.
F_2O_3	[95] meas. vapor pressure and ΔH decomposition.
F_2Pb	[23] rev. thermo. data and tab. thermo. functions. [100] meas. ΔH reaction with Al. [192] tab. thermo. functions 0-6000°K.
F_2Ti	[23] rev. thermo. data and tab. thermo. functions.
$F_3H_2^-$	[173] rev. properties (aq.).
F_3Li_3	[194] tab. thermo. functions 0-6000°K.
F_3N	[74, 173] rev. properties. [89] discussed theory of binding energy.
F_3Zr	[191] tab. thermo. functions 0-6000°K.
F_4H_7N $(NH_4F \cdot 3HF)$	[208] rev. C_p and phase behavior.
F_4Mg_2	See F_2Mg.
F_4N_2	[74] rev. properties. See F_2N.
F_4OW	[193] tab. thermo. functions 0-6000°K.
F_4Pb	[131] tab. thermo. functions 50-1600°K. [173] rev. properties. [193] tab. thermo. functions 0-6000°K.
F_4Ti	[45, 64] meas. ΔHf. [177] rev. ΔHf. [208] rev. C_p and phase behavior.
F_4Zr	[26] meas. equil. with F_5Zr^- and $F_6Zr^=$. [121] meas. C_p, ΔH fusion. [182] tab. thermo. functions to 1500°K. [208] rev. C_p and phase behavior.

F_5I	[93] tab. thermo. functions 300-1000°K. [134] tab. thermo. functions 100-1300°K. [192] tab. thermo. functions 0-6000°K.
F_5Zr^-	See F_4Zr.
F_6W	[45] reports meas. ΔHf. [130] tab. thermo. functions 50-1600°K. [194] tab. thermo. functions 0-6000°K.
$F_6Zr^=$	See F_4Zr.
F_7I	[92] tab. thermo. functions 300-1000°K. [134] tab. thermo. functions 100-1300°K. [192] tab. thermo. functions 0-6000°K.
F_nH_n	[24, 190] calc. ΔH of polymerization.
H	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$. [176] tab. equilibrium in $H-H_2$ to 20,000°K. [186] correl. D_o. [209] tab. thermo. functions 298-5000°K.
HI	See I_3^-.
HLi	[123] meas. ΔH fusion. [186] correl. D_o. [194] tab. thermo. functions 0-2000°K. [209] tab. thermo. functions 298-5000°K.
HLiO	[209] calc. ΔHf, tab. thermo. functions 298-5000°K.
HN	[29] meas. dissoc. energy.
HNO_2	[86] ΔHf calc. from equilibrium with NO, NO_2, H_2O.
HNaO (NaOH)	[56] meas. ΔH solution and dilution. [127] meas. ΔH solution, C_p.
HO	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [150] meas. D_o. [186] correl. D_o. [209] tab. thermo. functions 298-5000°K.
$HO_{21}W_6^{-5}$	[37] meas. ΔH for formation from WO_4^{-2}.

HPb	[192, 193] tab. thermo. functions 0-6000°K.
H_2	[6] tab. H_{298}, H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [97] meas. ΔH mixing of isotopes. [151] correl. H and S of liquid. [159, 160] tab. thermo. functions 20-300°K. [163] tab. thermo. functions 300-100,000°K. [187] calc. thermo. properties of o-p solid solutions. [209] tab. thermo. functions 298-5000°K. See H.
H_2O	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [120] tab. thermo. functions 100-6000°K. [209] tab. thermo. functions 298-5000°K.
H_2O_2	See I_3^-.
H_2O_4W $(WO_2)(OH)_2$	[57] meas. equilibrium with H_2O and WO_3.
H_2Zr	[48] ΔH combustion of protium and duterium compound meas.
H_3N	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [209] tab. thermo. functions 298-5000°K.
H_3NaO_2 $(NaOH \cdot H_2O)$	[127] meas. ΔH solution and C_p.
H_4IN (NH_4I)	[192] tab. thermo. functions 0-2000°K.
$H_4N_2O_3$ (NH_4NO_3)	[20] meas. vapor pressure.
$H_nO_mTi_r$	[73] calc. ΔH for solution of H in TiO from equilibrium meas.
H-Ti System	[184] calc. ΔH from equil. studies at low pressures.

H-Zr System [122, 172] meas. dissoc. pressure and calc. thermo. functions. [184] calc. ΔH from equilibrium studies at low pressures.

Hg [30] tab. thermo. properties of gas. [31] meas. ΔH vaporization. [191] tab. thermo. functions 0-6000°K.

HgI [191] tab. thermo. functions 0-6000°K.

HgI_2 [192] tab. thermo. functions 0-6000°K. See HgO.

HgO [65] studied S by emf meas. [107] meas. ΔH solution in HX-$HCl O_4$ mixtures (X = I, Cl, Br). [193] tab. thermo. functions 0-1000°K.

Hg_2I_2 [192] tab. thermo. functions 0-1500°K.

I [27] discusses theory of dissociation energy of I_2. [146] tab. thermo. functions 200-7000°K. [186] correl. D_o of I_2. [191] tab. thermo. functions 0-6000°K.

ILi [15] studied dimerization of gas with mass spectrometer.

ILi-INa System [110] correl. ΔH mixing.

INO [192] tab. thermo. functions 0-6000°K.

INa [1] correl. ΔH fusion. [87] calc. ΔH fusion. [90] calc. S_{298}.

INa-ILi System See ILi-INa.

IO [186] correl. D_o.

IO_3^- [188] meas. ΔHf (aq).

IPb [192, 193] tab. thermo. functions 0-6000°K.

ITi See I_4Ti.

I_2 See I.

I_2Hg [23] rev. thermo. data and tab. thermo. functions.

I_2Li_2 [15] studied gas with mass spectrometer. [60] calc. ΔHf from mass spectrometer meas.

I_2Mg [14] studied dimerization of gas with mass spectrometer. [19] calc. ΔH dissoc. of gas to ions. [23] rev. thermo. data and tab. thermo. functions.

I_2O_5 [191] tab. thermo. functions 0-6000°K.

I_2Pb [23] rev. thermo. data and tab. thermo. functions. [192] tab. thermo. functions 0-6000°K.

I_2Ti [23] rev. thermo. data and tab. thermo.functions. [191] tab. thermo. functions 0-6000°K. See I_4Ti.

I_2Zr [111] reported ΔHf. [193] tab. thermo. functions 0-6000°K.

I_3^- [188] meas. ΔHf. [189] meas. ΔH of formation from aqueous H_2O_2 and HI.

I_3Li_3 [60] calc. ΔHf from mass spectrometer meas.

I_3Ti [191] tab. thermo. functions 0-2500°K. See I_4Ti.

I_3Zr [111] reported ΔHf. [193] tab. thermo. functions 0-3000°K.

I_4Mg_2 [14] studied gas with mass spectrometer.

I_4Pb [131] tab. thermo. functions 50-1600°K. [193] tab. thermo. functions 0-6000°K.

I_4Ti [50] meas. equilibria with Ti and lower iodides. [191] tab. thermo. functions.

I_4Zr [3] tab. thermo. functions 298-1500°K. [131] tab. thermo. functions 50-1600°K. [192] tab. thermo. functions 0-6000°K.

Li [186] correl. D_o of Li_2. [193] tab. thermo. functions 0-6000°K. [209] tab. thermo. functions 298-5000°K.

Li (in NH_3) [69] meas. ΔH solution in liquid NH_3.

$LiNO_3$-$NaNO_3$ System [156] correl. ΔH mixing.

LiO [209] rev. ΔHf, tab. thermo. functions 298-5000°K.

LiO_3Ti [210] correl. ΔHf and ΔFf.

Li_2 [193] tab. thermo. functions 0-6000°K. [209] tab. thermo. functions 298-5000°K. See Li.

Li_2O [137] meas. vapor pressure and calc. ΔH subl. [209] rev. ΔHf and tab. thermo. functions 298-5000°K.

Li_2O_4Ti [210] correl. ΔHf and ΔFf.

Mg [9] rev. thermo. data and tab. thermo. data 0-6000°K. [90] calc. S_{298}. [183] meas. vapor pressure. [194] tab. thermo. functions 0-6000°K. See Aℓ.

MgO [9] rev. thermo. data and tab. thermo. functions 0-6000°K. [90] calc. S_{298}-S_{2000}.

MgO_3Ti ($MgTiO_3$) [10] meas. ΔH of formation from oxides. [210] correl. ΔHf and ΔFf.

Mg_2O_4Ti (Mg_2TiO_4) (10) meas. ΔH of formation from oxides. [210] correl. ΔHf and ΔFf.

Mg_2O_5Ti (Mg_2TiO_5) [10] meas. ΔH of formation from oxides.

Mg-O System [101] meas. ΔFf for Mg-O phases.

N [2] tab. thermo. functions and species equilibria 293-30,000°K. [6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [9] rev. thermo. data and tab. thermo. functions 0-6000°K. [170] calc. equilibria from shock wave to 24,000°K. [186] correl. D_o of N_2. [209] tab. thermo. Functions 298-5000°K.

$NNaO_3$-$LiNO_3$ System ($NaNO_3$) [156] correl. ΔH mixing.

NO [6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [42] lists ΔH of reaction with O_2 to form NO_2. [78] meas. vapor pressure. [186] correl. D_o. [209] tab. thermo. functions 298-5000°K. See HNO_2.

NO_2 [42] lists ΔH for dimerization. [70] calc. ΔH for dimerization from IR intensity meas. of equilibrium. [120] tab. thermo. functions 100-6000°K. [135] tab. thermo. functions of isotopic species 200-2000°K. See NO, HNO_2.

NTi [9] meas. C_p 2050-2512°K. [36] meas. vapor pressure. [90] calc. S_{298}. [167] rev. and correl. ΔHf.

NW [167] rev. and correl. ΔHf.

NZr [90] calc. S_{298}-S_{2000}. [167] rev. and correl. ΔHf.

N_2 [2] tab. thermo. functions 293-30,000°K. [6] tab. H_{298}, H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [9] rev. thermo. data and tab. thermo. functions 0-6000°K. [35] rev. and tab. vapor pressure and thermo. functions. [155] correl. vapor pressure data. [170] calc. equilib. from shock wave to 24,000°K. [209] tab. thermo. functions 298-5000°K. See N.

N_2O	[16] meas. relative vapor pressures of isotopic species. [32] meas. vapor pressure and meas. ΔH vaporization. [120] tab. thermo. functions 300-6000°K.
N_2O_4	See NO_2.
Na	[186] correl. D_o of Na_2. [193] tab. thermo. functions 0-6000°K. [206] meas. vapor pressure. [207] meas. H, S, C_p of gas and calc. dimerization energy to Na_2.
Na (in NH_3)	[69] meas. ΔH solution in liquid NH_3.
NaO_3Ti	[210] correl. ΔHf and ΔFf.
Na_2	[193] tab. thermo. functions 0-6000°K. See Na.
Na_2O	[193] tab. thermo. functions 0-3000°K.
Na_2O_4Ti	[210] correl. ΔHf and ΔFf.
Na_2O_4W	[98] meas. ΔH of formation from oxides.
$Na_2O_7W_2$	[98] meas. ΔH of formation from oxides.
$Na_2O_{13}W_4$	[98] meas. ΔH of formation from oxides.
O	[6] tab. H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [9] rev. thermo. data and tab. thermo. functions 0-6000°K. [170] calc. equilibria from shock wave to 24,000°K. [186] correl. D_o of O_2. [193] tab. thermo. functions 0-6000°K. [209] tab. thermo. functions 298-5000°K.
OPb	[138, 139] meas. vapor pressure and calc. ΔH sublimation. [192] tab. thermo. functions 0-6000°K.
OTi	[90] calc. S_{298}. See B_2Ti, $H_nO_mTi_r$.
OW	[9] rev. thermo. data and tab. thermo. functions 0-6000°K. [193] tab. thermo. functions 0-6000°K.

O_2 [6] tab. H_{298}, H_{3000}, S_{3000}, constants for $C_p(T)$(gas). [9] rev. thermo. data and tab. thermo. functions 0-6000°K. [126] rev. ΔH of phase changes. [155] correl. vapor pressure. [170] calc. equilibrium from shock wave to 24,000°K. [209] tab. thermo. functions 298-5000°K. See O.

O_2Pb [192] tab. thermo. functions 0-2000°K.

O_2Ti [174] calc. ΔF of formation from $TiCl_4$ and O_2. See CTi, O_3Ti_2.

O_2W [9] rev. thermo. data and tab. thermo. functions 0-6000°K. [54] studies ΔFf from elements by emf meas. [193] tab. thermo. functions 0-6000°K.

O_2Zr [10] measure pressure-temperature function.

$O_{2.72}W$ [54] calc. ΔFf from emf. meas.

O_3 [170] calc. equilibria from shock wave to 24,000°K. [209] tab. thermo. functions 298-5000°K.

O_3PbTi [210] correl. ΔHf and ΔFf.

O_3Ti_2 [102] calc. ΔH for formation by H_2 reduction of TiO_2.

O_3W [9] rev. thermo. data and tab. thermo. functions. 0-6000°K. [193] tab. thermo. functions 0-6000°K. See H_2O_4W.

O_4PbW [211] calc. ΔHf and ΔFf from reduction by H_2.

O_4Pb_2Ti [210] correl. ΔHf and ΔFf.

O_4Pb_3 [192] tab. thermo. functions 0-2000°K.

O_4TiZr [11] meas. ΔH of formation from oxides and from elements.

O_4W^{-2}	[37] meas. ΔH for condensation to $HW_6O_{21}^{-5}$.
O_9W_3	[193] tab. thermo. functions 0-6000°K.
O-Ti System	[73] gives activities of Ti and O. [101] meas. ΔFf.
O-W System	[105] meas. $\Delta\bar{F}_o$ of oxygen in W.
O-Zr System	[101] meas. ΔFf.
Pb	[90] calc. S_{298}. [146] tab. thermo. functions 200-7000°K. [192] tab. thermo. functions 0-6000°K.
Pb_2	[192] tab. thermo. functions 0-6000°K.
Ti	[9] rev. thermo. data and tab. thermo. functions 0-6000°K. [55] meas. ΔH transition. [90] calc. S_{298}. [205] meas. vapor pressure, est. ΔH fusion, and calc. ΔH sublimation.
W	[9] rev. thermo. data and tab. thermo. functions 0-6000°K. [90] calc. S_{298}. [191] tab. thermo. functions 0-6000°K.
Zr	[9] rev. thermo. data and tab. thermo. functions 0-6000°K. [46, 47, 205] meas. vapor pressure and calc. ΔH sublimation. [55] meas. ΔH transition. [90] calc. S_{298}.

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Chapter 6

SUBSTANCE - PROPERTY INDEX FOR 1962

by

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The demands of modern science and technology have resulted in a tremendous increase in the output of published data in chemical thermodynamics. As a result it has become more and more difficult for individual scientists to keep up with this output. Therefore we have prepared an index to the literature of thermochemistry and chemical thermodynamics of inorganic and metal-organic compounds published or abstracted during the year 1962.

In preparing this index, each of the issues of Chemical Abstracts from October, 1961 to September, 1962 was carefully searched for references to any articles that contained thermodynamic data. Because of the time lag inherent in the abstracting process, this produced many references published prior to 1962. In order to obtain as many current references as possible, the following journals were searched, issue by issue, as they were received by our Library:

J. Am. Chem. Soc.
J. Chem. Phys.
J. Phys. Chem.
J. Molecular Spectroscopy
J. Chem. Soc.
Trans. Faraday Soc.
Z. physik. Chem. (Leipzig)
Z. physik. Chem. (Frankfurt)
Z. anorg. u. allgem. Chem.
Dissertation Abstracts
J. Research NBS
J. Inorg. and Nuclear Chem.
J. Chem. Eng. Data
Inorganic Chem.
Zhur. Neorg. Khim.
Zhur. Fiz. Khim.
Optika i Spektroskopiya
Acta Chem. Scand.
Spectrochim. Acta
Can. J. Chem.
Can. J. Phys.

It is hoped that in this manner we have searched the principal portion of current thermodynamic research; recent articles in journals not in the list above will have to be uncovered by a search of subsequent issues of C. A.

The substances for which data have been obtained are listed in the column headed "Substance". The order of arrangement is essentially that used in NBS Circular 500, with some slight modifications as shown in Figure 1. This corresponds with the Standard Order of Arrangement of the Elements adopted by the Manufacturing Chemists Association and National Research Council Data Projects and with that used by NBS for the revision of Circular 500. In the case of a metal-organic complex for which the structural formula of the organic portion is not clearly apparent, the name of the organic portion is listed immediately below the formula.

The state of the substance investigated is indicated in the column headed "State". Standard designations are used here, except that the term "non-aq" is used to include fused-salt and other high-temperature liquid systems as well as those involving the usual non-aqueous liquid solvents. The absence of a state designation implies that the state is the same as that immediately preceding.

In the column labeled "Prop." is a code letter or series of letters which designate the particular properties or types of measurement which have been made on that compound in the article indicated by the reference number in the last column, headed "Ref.". The properties to which the code letters refer are as follows:

Property letter	Property identification
a	Physical properties (density, refractive index, boiling point, freezing or triple point)
i	Critical state data
j	P-V-T data
k	Vapor pressures
m	Temperature, heat, and entropy of transition, fusion, and vaporization
n	Heats of chemical reactions
p	Standard heat of formation ($\Delta Hf°$), standard free energy of formation ($\Delta Gf°$)
q	Heats of solution, mixing, and dilution; heats of wetting and adsorption
r	Enthalpy or enthalpy function, $H° - H_0^\circ$ or $(H° - H_0^\circ)/T$ and $(H_{satd}-H_0^\circ)/T$
s	Gibbs energy function, $(G°-H_0^\circ)/T$ or $(G_{satd}-H_0^\circ)/T$
t	Entropy of gas, liquid, or solid; or entropy increments
v	Heat capacity of gas, liquid, or solid
x	Equilibria of chemical reactions
y	Electrochemical data
z	Reviews, compilations

The number in the "Ref." column is the number of the reference in the bibliography immediately following the property index. These finding numbers start with 500 because this index is to be combined with an index to the organic chemical literature and published in the Bulletin of Thermodynamics and Thermochemistry, which is prepared under the sponsorship of the International Union of Pure and Applied Chemistry.

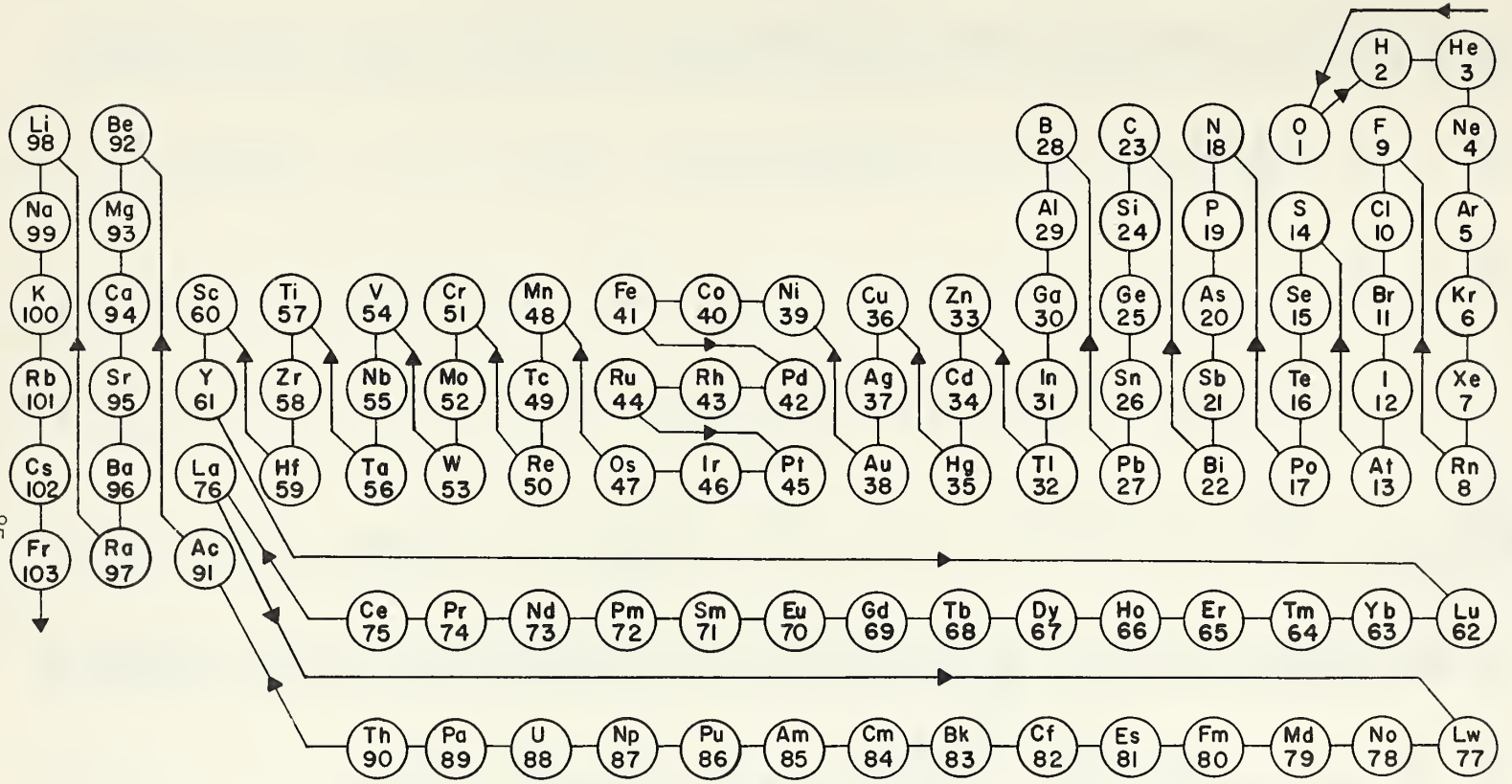

TABLE II.

Standard Order of Arrangement of the Elements and Compounds
based on the
Periodic Classification of the Elements

Explanation: key "finding numbers" below the chemical symbol for each element.

Substance - Property Index

Substance	State	Prop.	Ref.
O	g	rt	614
		rsxz	886
O_2	c	m	800
	liq	aj	522
		q	1166
		q	1284
		q	1317
	g	q	593
		rt	614
		rsxz	886
		jrstvz	944
		j	953
		jrstvx	961
		jrstvxz	1158
		rstv	1369
O_2^+	g	rstv	1369
O_3	c	aijkmp	1257
		rstvz	1257
	liq	aijkmp	1257
		rstvz	1257
	g	aijkmp	1257
		rstvz	1257
H	g	rt	614
		rsxz	886
H_2	liq	ajz	599
		q	877
		v	943
	g	ajz	599
		rt	614
		jrtz	753
		jz	844
		rsxz	886
		jrstvz	944
		j	953
		jvx	1091
		rx	1096
		jvxz	1363
		rstv	1369
D_2	c	m	985
	liq	q	877
HD	liq	q	877
H_3^+	g	x	857
OH	g	rt	614
		x	732
		rsxz	886
		t	970
		rstv	1369
OH^+	g	rstv	1369
HO_2	g	x	1054
H_2O	c	m	1171
	liq	jvz	552
		v	585
		iv	586
		ijz	759
		ijz	834
		ijvz	835
		ijrz	836
		aj	937
		kz	1004
		jv	1142
		x	1164
		k	1186
		arz	1236
	g	j	551
		jvz	552
		iv	586
		rt	614
		ijz	759
		rstv	762
		ijz	834
		ijvz	835
		ijrz	836
		rsxz	886
		aj	938
		jtv	1006
		jv	1142
		jz	1159
		jz	1237
D_2O	liq	q	574
		aj	662
		aj	743
		aj	744
		v	745
		x	1164
HDO	liq	n	574
		x	1164
H_2O_2	g	x	1054
	aq	n	668
He	c	v	1483
		kv	1497
	liq	kz	952
		tv	1222
	g	jrtz	763
		j	883
		j	953
HeH^+	g	x	857

Substance	State	Prop.	Ref.
Ne	liq	kz	952
		k	1181
		k	1223
	g	rt	614
		j	821
		j	953
NeH^+	g	x	857
Ar	c	kmv	1059
		kmv	1060
		a	1435
		akmvz	1519
	liq	kz	952
		kmv	1059
		kmv	1060
		q	1166
		k	1223
		q	1284
		q	1317
		kmv	1519
	g	jrtv	711
		j	821
		jrtz	906
		j	953
		rx	1096
ArH^+	g	x	857
Kr	c	kmv	1135
		a	1435
		akmvz	1518
	liq	kz	952
		k	984
		kmv	1135
		kmv	1518
	g	j	524
		j	821
		j	953
KrH^+	g	x	857
KrD^+	g	x	857
Xe	c	a	1435
		q	1480
	liq	kz	952
		k	984
	g	j	953
Rn	g	rs	719
		rs	1516
F	g	rt	614
F_2	g	rt	614
OF_2	g	rstv	681
O_2F_2	liq	n	869
O_3F_2	liq	kn	869
	g	np	1368

Substance	State	Prop.	Ref.
HF	g	rt	614
		s	706
		s	1111
Cl	g	rt	614
Cl_2	g	rt	614
		x	736
ClO_2	liq	km	975
HCl	g	rt	614
		q	955
		ijv	1055
	aq	y	649
		y	1074
$HClO_4$	liq	q	920
	g	st	1018
	aq	n	806
		n	1097
		q	1155
$HClO_4 \cdot H_2O$	c	q	920
$HClO_4 \cdot 2H_2O$	liq	q	920
Br^-	aq	x	713
Br_2	aq	n	1396
Br_3^-	aq	x	1076
BrO^-	aq	np	1396
HBr	c	y	958
	g	q	955
	aq	y	517
	non-aq	y	1410
BrF	g	npx	627
BrF_3	g	npx	627
BrF_5	g	npx	627
		rstv	767
Br_2Cl^-	aq	x	1075
I	g	rs	719
		rs	1516
		rstv	996
I_2	c	x	935
		k	1321
I_3^-	aq	n	668
		x	1407
		x	1505
I_4^{--}	aq	x	1505
I_6^{--}	aq	x	1505
I_8^{--}	aq	x	1505
I_9^{---}	aq	x	1505
IO	g	x	1194

Substance	State	Prop.	Ref.
IO_3^-	aq	x	1334
HIO_3	c	np	626
I_2OH^-	aq	x	1330
IF_5	g	rstv	674
IF_7	g	rstv	859
		rstv	1439
ICl_2^-	aq	x	1384
ICl_3	aq	x	1384
I_2Cl^-	aq	x	1384
At^-	aq	pz	801
S	g	rt	614
S_2	liq	v	532
		k	726
S_2^{--}	aq	y	1313
		y	1314
S_3^{--}	aq	y	1313
		y	1314
S_4^{--}	aq	y	1313
		y	1314
S_5^{--}	aq	y	1313
		ny	1314
SO	g	rt	614
		x	769
SO_2	liq	ikmnp	845
		km	1090
	g	rt	614
		rstv	762
		ij	845
		j	846
		jrz	848
		y	1050
SO_3	c	km	1442
		m	1443
		km	1481
	liq	k	960
		k	1442
		km	1481
	g	rstv	827
$SO_3 \cdot xH_2O$	c	k	1442
		k	1481
SO_4^{--}	aq	x	818
H_2S	g	rt	614
		rstv	762
	aq	xz	718
		x	829
H_2S_2	g	x	870
HSO_4^-	aq	x	818
		q	1155
		x	1337
H_2SO_4	aq	q	912
		y	1356
		q	1514
	non-aq	v	843
$SF_5 \cdot SO_3F$	liq	km	1033
SF_5Cl	liq	ikm	761
	g	rstv	505
Se	c	km	923
	liq	km	1192
SeO_2	c	km	781
		km	1469
H_2SeO_3	aq	k	819
Te	c	km	923
		y	1156
	liq	km	1192
	g	rs	719
		rstv	996
		rs	1516
Te^+	g	rstv	1417
TeO_2	c	km	728
		r	881
H_2Te	g	y	1156
H_2Te_2	g	y	1156
$H_5TeO_5^-$	aq	x	1032
H_6TeO_6	aq	x	1032
Po	g	rs	719
		rs	1516
N	g	rst	530
		rt	614
N^+	g	rst	529
N_2	liq	jz	1115
		q	1166
		q	1284
		q	1317
	g	rst	530
		q	593
		j	598
		rt	614
		jz	844
		j	883
		j	953
		jrstvx	961
		t	970
		jrstvz	1069
		jz	1115

Substance	State	Prop.	Ref.
N_2	g	jrstvxz	1158
		rstv	1369
N_2^+	g	rstv	1369
NO	liq	k	967
	g	rst	530
		rt	614
		rvxz	1043
		rstv	1369
NO^+	g	rst	529
		rstv	1369
NO_2	liq	m	1316
		z	1362
	g	rstv	683
		rstv	762
		x	969
		ryxz	1043
		x	1414
		x	1427
		x	1457
		x	1521
NO_3	g	rstv	947
N_2O	liq	k	1089
		k	1175
	g	j	513
		rstv	762
		aijkm	1123
		x	1338
		x	1371
N_2O_3	g	t	945
		rstv	947
N_2O_4	g	rstv	947
		x	969
		rvxz	1043
		x	1338
		x	1414
		x	1457
		x	1521
N_2O_5	g	rstv	947
NH	g	rt	614
NH_3	liq	ajz	733
		a	929
		jz	1258
	g	aj	929
		jrt	514
		jz	1258
NT_3	g	rstv	664
HN_3	g	x	1338
	aq	x	1116
NH_2OH	aq	x	748

Substance	State	Prop.	Ref.
HNO_3	liq	z	1362
	g	x	1338
NH_4NO_3	c	km	1108
	liq	km	1108
	aq	kqz	832
NF_2	g	rstv	954
		x	1373
		p	1415
N_2F_2	g	rstv	756
N_2F_4	g	x	1373
NOF	g	mp	930
NO_2F	g	rstv	619
		rstv	715
NO_3F	c	np	623
NOF_2	g	np	1366
$NOF(HF)_3$	liq	km	1269
$NOF(HF)_6$	liq	km	1269
ClNO	g	rstv	997
NO_2Cl	g	rstv	715
$ClNO_3$	liq	km	608
		km	1310
NO_2ClO_4	c	npq	1012
NH_4Cl	c	x	696
		x	782
NH_4ClO_4	c	npq	1011
	aq	y	1037
$N_2H_4 \cdot HClO_4$	c	npq	661
$BrNO_3$	liq	k	608
$Br(NO_3)_3$	liq	km	610
NH_4Br	c	x	782
N_2H_5Br	c	m	641
NH_4I	c	x	782
$NH_4I \cdot NH_3$	c	x	820
NSF	liq	km	1007
NSF_3	liq	km	1007
	g	rstv	735
$(NH_4)_2SeO_4$	c	q	629
P	g	rt	614
P_4	g	rstv	1440
PO	g	rt	614
P_4O_{10}	c	npq	1389
	g	rt	614

Substance	State	Prop.	Ref.
PH	g	rt	614
PH_3	g	px	590
PT_3	g	rstv	664
HPO_4^{--}	aq	x	1411
$H_2PO_4^-$	aq	x	1097
H_3PO_4	c	np	1389
	aq	q	912
		rs	1031
		q	1389
		x	1450
		rsy	1468
		q	1514
PF_3	c	kmsv	702
	g	s	702
PO_3F^{--}	aq	x	758
		x	1450
HPO_3F^-	aq	x	758
		x	1450
$F_2PO(OH)$	liq	km	812
PCl_3	liq	km	699
	g	rstv	1309
$POCl_3$	liq	k	699
PN	g	rt	614
As	c	k	666
AsH_3	g	px	590
AsT_3	g	rstv	664
H_3AsO_4	aq	x	1450
AsF_3	g	rstv	1376
AsO_3F^{--}	aq	x	1450
$HAsO_3F^-$	aq	x	1450
$AsCl_3$	g	rstv	1376
$AsBr_3$	g	rstv	1376
AsS	c	k	666
$SF_4 \cdot AsF_5$	c	kx	1476
Sb	c	m	1344
	liq	kx	742
		v	1355
Sb_2O_3	c	np	770
Sb_2O_4	c	np	770
SbH_3	g	px	590
SbF_5	g	rstv	682
$SbCl_3$	g	rstv	1281
		rstv	1376
$SbCl_5$	g	rstv	1281
$SbBr_3$	g	rstv	1376
SbI_3	liq	kx	1112
Sb_2I_4	liq	x	1112
Sb_2S_3	c	tv	864
Sb_2Se_3	c	km	653
Sb_2Te_3	c	np	965
Bi	g	rs	719
		rstv	996
		rs	1516
Bi_2O_3	c	m	571
		y	1071
BiH_3	liq	km	1140
$BiCl_3$	c	rv	519
	g	rstv	1376
$BiCl_5^{--}$	aq	x	1058
$BiBr_3$	c	rv	519
	liq	y	622
$BiBr_5^{--}$	aq	x	1058
$BiCl_4Br^{--}$	aq	x	1058
$BiCl_3Br_2^{--}$	aq	x	1058
$BiCl_2Br_3^{--}$	aq	x	1058
Bi_2Te_3	c	mnp	965
		v	1183
Si	c	k	559
		m	1010
		tv	1053
	liq	q	1015
	g	rt	614
		rstv	996
Si_2	g	rstv	562
SiO	c	m	1326
	g	x	555
		rt	614
SiO_2	c	np	542
		q	546
		np	613
		q	616
		np	999
		v	1232
		m	1326
		y	1429
		z	1466
		np	1491

Substance	State	Prop.	Ref.
SiO_2	g	x	555
		rt	614
SiH	g	rt	614
SiH_4	g	px	590
SiF	g	rt	614
SiF_2	g	rt	614
		rstv	681
		x	780
SiF_4	g	np	542
		np	613
		rt	614
		np	1491
SiH_3F	g	rstv	634
SiD_3F	g	rstv	684
SiF_3D	g	rstv	504
SiF_3H	g	rstv	504
SiCl	g	rt	614
$SiCl_2$	g	rt	614
$SiCl_4$	liq	k	699
		q	909
		q	1470
	g	np	534
		rt	614
Si_5Cl_{12}	c	km	1252
$SiHCl_3$	g	np	534
SiH_3Cl	g	rstv	684
SiD_3Cl	g	rstv	684
SiF_3Cl	g	prst	786
SiF_2Cl_2	g	prst	786
$SiFCl_3$	g	prst	786
$SiBr_4$	liq	kq	697
SiH_3SiH_2Br	liq	km	549
SiI_4	g	rstv	1138
SiH_3I	g	rstv	684
SiD_3I	g	rstv	684
$SiBr_3I$	g	rstv	687
$F_2SiS_2SiF_2$	liq	km	1307
$P(SiH_3)_3$	liq	km	1141
SiC	c	px	559
		n	1431
$(CH_3)_3HSi$	g	x	963
$(CH_3)_4Si$	g	rstv	1441
$(C_6H_5)_4Si$	c	np	1176
$(C_6H_5CHCH)_4Si$	c	np	1178
$CH_3SiH_2SiH_2CH_3$	liq	km	1121
$(SiO)_4(CH_3)_8$ (octamethylcyclotetrasiloxane)	c	m	1084
$((CH_3)_3SiSi(CH_3)_2)_2O$	liq	km	1122
$(((CH_3)_3SiSi(CH_3)_2O)Si(CH_3)_2)_2$	liq	km	1122
$SiCl_3(CH_3)$	liq	q	1470
$SiCl_2(CH_3)_2$	liq	q	1470
$SiCl(CH_3)_3$	liq	q	1470
CH_3SiSiH_2Cl	liq	km	1122
$SiH_3SeCH_2CH_2CH_3$	liq	km	1029
SiH_3SeCF_3	liq	km	1029
$(CH_3)_3SiN_3$	liq	km	1125
$(CH_3)_3SiCN$	liq	km	1360
$(CH_3)_2Si(CH_2NH_2)_2$	liq	km	988
$(SiH_3)_2NCN$	liq	km	1028
$(CH_3)_3SiSi(CH_3)_2CN$	liq	km	1122
Ge	c	m	1010
		tv	1053
		v	1511
GeO^-	aq	y	1104
GeO_2	c	mmpry	771
GeH_4	g	px	590
GeH_3F	g	rstv	986
$GeHF_3$	liq	km	1251
$GeHCl_3$	g	rstv	686
GeH_3Br	g	rstv	986
$GeHBr_3$	g	rstv	686
GeSe	c	km	618
		km	823
GeTe	c	km	618
		km	823
		km	962
$(CH_3)_4Ge$	g	x	963
$(C_6H_5)_4Ge$	c	np	1176
$(C_6H_5CHCH)_4Ge$	c	np	1177
$CH_3CO_2GeH_3$	liq	km	670
GeH_3NCO	liq	km	670

Substance	State	Prop.	Ref.
GeH_3NCS	liq	km	670
Sn	c	m	1344
		v	1494
		v	1511
	liq	q	536
		km	1128
	g	rstv	996
Sn^{++}	non-aq	y	1324
Sn_2	g	x	1128
SnH_4	g	px	590
		rstv	1372
SnF^+	aq	x	1403
$SnCl^+$	aq	x	521
		x	1408
$SnCl_2$	aq	x	521
		x	1408
$SnCl_3^-$	aq	x	521
		x	1408
$SnCl_4$	liq	q	909
$SnCl_4^{--}$	aq	x	521
SnH_3Cl	liq	km	1139
$SnBrCl_3$	g	rstv	675
$SnBr_3Cl$	g	rstv	675
SnS	c	km	876
		m	1085
	liq	k	876
Sn_2S_2	c	m	1085
$(NH_4)_2SnCl_6$	c	q	629
$SnSb_x$	c	v	1494
$SnBi_x$	c	v	1022
		v	1494
	liq	y	1323
$(C_6H_5)_4Sn$	c	np	1176
$(CH_3)_2SnOH^+$	aq	x	520
$(CH_3)_2Sn(OH)_2$	aq	x	520
$((CH_3)_2SnOH)_2^{++}$	aq	x	520
$((CH_3)_2Sn)_2(OH)_3^+$	aq	x	520
$((CH_3)_2Sn)_3(OH)_4$	aq	x	520
Pb	c	m	1344
	liq	q	536
		k	742
	g	rs	719
		rstv	996
		rs	1516
Pb^{++}	non-aq	y	1324
PbO	c	km	691
		y	1071
		z	1466
PbF_2	c	y	611
		n	910
		n	978
PbF_4	g	rstv	680
$PbCl^+$	aq	x	884
$PbCl_2$	c	km	696
	aq	x	884
$PbCl_3^-$	aq	x	884
		x	1058
$PbCl_4$	g	rstv	680
$Pb(ClO_4)_2$	c	q	570
$PbBr^+$	aq	x	1293
$PbBr_2$	liq	y	805
		k	901
	aq	x	1293
$PbBr_3^-$	aq	x	1293
$PbBr_4$	g	rstv	680
$PbBr_4^{--}$	aq	x	1058
		x	1293
$PbBr_5^{---}$	aq	x	1293
$PbBr_6^{----}$	aq	x	1293
$PbBr_7^{-5}$	aq	x	1293
$PbCl_3Br^{--}$	aq	x	1058
$PbCl_2Br_2^{--}$	aq	x	1058
$PbClBr_3^{--}$	aq	x	1058
PbI^+	aq	x	512
PbI_2	aq	x	512
PbI_3^-	aq	x	512
PbI_4	g	rstv	680
PbI_4^{--}	aq	x	512
		x	1058
$PbBr_3I^{--}$	aq	x	1058
$PbBr_2I_2^{--}$	aq	x	1058
$PbBrI_3^{--}$	aq	x	1058
PbS	c	mx	1085
Pb_2S_2	c	m	1085
$Pb(NO_3)^+$	aq	x	884
$Pb(NO_3)_2$	aq	x	884

Substance	State	Prop.	Ref.
$Pb(NO_3)_3^-$	aq	x	884
$PbSb_x$	c	x	742
	liq	q	1344
$PbCO_3$	c	x	688
PbC_2O_4	c	nqtvx	853
$Pb(CH_3)_2H_2$	liq	km	1311
$Pb(CH_3)_3H$	liq	km	1311
$Pb(HCO_2)^+$	aq	x	1336
$Pb(HCO_2)_2$	aq	x	1336
$Pb(CH_3CO_2)^+$	aq	x	1336
$Pb(HCO_2)_3^-$	aq	x	1336
$Pb(C_2H_5CO_2)^+$	aq	x	1336
$Pb(CH_3CO_2)_2$	aq	x	1336
$Pb(C_3H_7CO_2)^+$	aq	x	1336
$Pb(CH_3CO_2)_3^-$	aq	x	1336
$Pb(C_2H_5CO_2)_2$	aq	x	1336
$Pb(C_3H_7CO_2)_2$	aq	x	1336
$Pb(C_2H_5CO_2)_3^-$	aq	x	1336
$Pb(C_3H_7CO_2)_3^-$	aq	x	1336
$Pb(NCS)_6^{-6}$	aq	x	1218
$PbSiO_3$	c	rv	556
		z	1466
$PbSn_x$	liq	q	648
$PbSnS_2$	c	x	1085
$PbSn_xSb_y$	c	mv	1188
	liq	v	1188
B	c	km	617
		km	644
		km	1133
		km	1493
	g	rt	614
B_2	g	rt	614
BO	g	rt	614
BO_2	g	x	856
		x	1496
B_2O_2	g	rstvx	545
		rt	614
		x	1209
B_2O_3	c	m	814
		np	1421
	liq	x	1209
		k	1418
		km	1428
		k	1496
	g	rstvx	545
		rt	614

Substance	State	Prop.	Ref.
B_2O_3	g	x	1114
	amorph	np	503
BH	g	rt	614
		x	880
B_2H_6	g	r	972
B_4H_{10}	g	np	1393
B_5H_9	g	np	1393
B_5H_{11}	g	np	1393
B_6H_{10}	liq	k	1393
	g	np	1393
$B_{10}H_{14}$	c	np	1024
BD	g	x	880
B_2D_6	g	npr	972
HBO_2	g	rstvx	545
		rt	614
H_3BO_3	g	rt	614
$(BOH)_3$	g	x	724
$(HBO_2)_3$	g	rstvx	545
BF	g	rt	614
BF_3	liq	k	1184
		np	539
		np	613
		rt	614
	g	rstv	678
		np	1491
BF_4^-	aq	x	792
	non-aq	x	1093
$(BOF)_3$	g	x	724
		xp	1041
		xp	1042
$B(OH)_2F$	g	x	723
$BOHF_2$	g	x	723
BF_3OH^-	aq	x	792
$B_3O_3FH_2$	g	x	724
$B_3O_3F_2H$	g	x	724
BCl	g	rt	614
BCl_3	liq	np	1421
	g	rt	614
		rstv	678
		np	1025
BF_2Cl	g	rstv	677
		x	723
$BFCl_2$	g	rstv	677
		x	723

Substance	State	Prop.	Ref.
BBr_3	liq	kq	697
		km	1165
		km	1367
	g	rstv	676
BF_2Br	g	rstv	677
$BFBr_2$	g	rstv	677
BCl_2Br	g	rstv	677
$BClBr_2$	g	rstv	677
BI_3	g	rstv	676
BS_2	g	s	1496
B_2S_2	g	s	1496
B_2S_3	liq	m	1496
	g	s	1496
HBS_2	g	sx	1496
$(HBS_2)_2$	g	sx	1496
$(HBS_2)_3$	g	s	1496
$BF_3 \cdot SF_4$	c	kx	1476
BN	c	np	613
		np	1026
		kx	1047
		x	1083
		x	1134
		np	1421
		x	1486
		np	1491
	g	rt	614
$BH_3 \cdot N_2H_4$	c	np	994
$(BH_2NH)_x$	c	np	994
BP	c	x	667
		x	904
B_6P	c	x	667
BPO_4	c	x	1493
$B_2Cl_4 \cdot 2PCl_3$	c	x	1482
BC	g	x	1283
BC_2	g	x	1283
B_2C	g	x	1283
B_4C	c	px	617
$B(CH_3)_3$	g	x	957
$B(CH_3)_2(C_2H_3)$	liq	km	998
$B(CH_3)(C_2H_5)_2$	liq	km	998
$B(C_2H_3)_3$	liq	km	998
$B(B_4H_9)_3$	liq	np	1485
$B(C_6H_{11})_3$	liq	n	573

Substance	State	Prop.	Req.
$B(C_6H_{13})_3$	liq	n	573
$B(C_8H_{17})_3$	liq	n	573
$B_3C_2H_5$	liq	km	640
$C_2H_5B_5H_8$	liq	km	1488
$C_3H_7B_5H_8$	liq	km	1488
$C_4H_9B_5H_8$	liq	np	1485
		km	1487
		km	1488
$C_2H_5B_{10}H_{13}$	liq	np	1485
$C_2H_5O_2B$	liq	kmx	1499
$B(CH_3O)_3$	liq	k	981
	g	ij	981
		rstv	1437
$BH((CH_3)_2CHO)_2$	liq	np	1170
$B(C_4H_9O)_2(C_4H_9)$	c	np	1023
B_4H_8CO	liq	km	1119
$BF_2(CF_2CF)$	liq	km	1386
$(CF_2CF)_3B$	liq	km	1386
$BF_2(C_2H_3)$	liq	km	998
		km	1380
		km	1506
$BF_2(C_3H_5)$	liq	km	1380
$BF_2(C_3H_7)$	liq	km	1380
$BF(CH_2CH)_2$	liq	km	1380
		km	1506
$B(CH_2CH)Cl_2$	liq	km	998
		km	1380
		km	1506
$B(CHCHCl)Cl_2$	liq	km	1250
$B(CH_3)(C_2H_3)Cl$	liq	km	998
$B(CH_2CH)_2Cl$	liq	km	998
		km	1380
		km	1506
$B(C_2H_5)(CHCHCl)Cl$	liq	km	1250
$B(CHCHCl)_2Cl$	liq	km	1250
$B(C_2H_5)(CHCHCl)_2$	liq	km	1250
$B(CHCHCl)_3$	liq	km	1250
$B(CF_2CF)Cl_2$	liq	km	1386
$B(CF_2CF)_2Cl$	liq	km	1386
$(CH_3)_2NB(CH_3)_2$	liq	k	964
$(CH_3)_2NB_2H_5$	g	np	934
$(CH_3)_3NBF_2CH_3$	liq	km	1387
	g	x	1387
$(CH_3)_3NBF_2C_2H_3$	liq	km	1387
	g	x	1387

Substance	State	Prop.	Ref.
$(CH_3)_3NBF_2C_2H_5$	liq	km	1387
	g	x	1387
$(CH_3)_3NBF_2C_3H_7$	liq	km	1387
	g	x	1387
$(CH_3)_2NBCH_3Cl$	liq	k	1261
$((CH_3)_2NBCl_2)_2$	c	km	1261
$((CH_3)_2NBCH_3Cl)_2$	c	km	1261
$(CH_3)_3PB(CH_3)_3$	liq	k	964
$CH_3C(CH_2O)_3P\cdot B(CH_3)_3$	c	x	957
$F_2PN\cdot(CH_3)_2B_4H_8$	liq	km	560
BSi	g	x	1283
BCSi	g	x	1283
$B_2O_3\cdot PbO$	c	y	813
Al	c	v	1197
	g	rt	614
Al^{+++}	aq	x	717
AlO	g	rt	614
Al_2O	g	rt	614
Al_2O_3	c	q	579
		q	616
		v	785
		mrv	850
		k	1221
		rv	1249
		mr	1358
		z	1466
		n	1477
		r	1512
		r	1515
	liq	r	1358
	g	rt	614
$Al_2O_3\cdot H_2O$	c	x	1206
		tv	1454
$Al_2O_3\cdot 3H_2O$	c	x	1206
AlH	g	rt	614
AlH_3	c	np	796
AlF	g	rt	614
		n	978
AlF_3	c	np	910
		np	978
		mrstvz	1395
		m	1493
	g	rt	614
AlF_4^-	non-aq	x	751
AlF_6^{---}	non-aq	x	751

Substance	State	Prop.	Ref.
AlCl	g	rt	614
$AlCl_3$	g	rt	614
	aq	n	796
AlBr	g	x	1190
AlN	c	x	1083
		nprtv	1456
		x	1486
$AlCl_3\cdot xNH_4Cl$	liq	x	1296
AlSb	c	m	1010
Al_4C_3	c	x	977
$(CH_3)_3Al$	c	mrstv	764
	liq	kmrstv	764
$AlSi_x$	liq	mq	1034
$Al_2O_3\cdot 2SiO_2\cdot 2H_2O$	c	n	1448
		tv	1454
$AlSn_x$	liq	q	1235
$Al(BO_2)^{++}$	aq	x	656
$Al(BO_2)_2^+$	aq	x	656
$Al(BO_2)_3$	c	x	656
$Al(BO_2)_6^{---}$	aq	x	656
Ga	c	v	1066
	liq	km	1086
		v	1355
Ga_2O	g	x	1062
		x	1086
		x	1088
Ga_2O_3	c	np	1027
		x	1062
		np	1464
		z	1466
$Ga(OH)_4^-$	aq	y	1035
GaF^{++}	aq	x	872
GaF_2^+	aq	x	872
GaF_3	aq	x	872
GaF_4^-	aq	x	872
GaF_5^{--}	aq	x	872
GaCl	g	x	1262
GaBr	g	x	1262
GaI	g	x	1262
Ga_2S_3	c	v	1027
Ga_2Se_3	c	npv	1027
Ga_2Te_3	c	v	1027

Substance	State	Prop.	Ref.
GaP	c	x	1312
GaAs	c	x	1401
		x	1426
GaSb	liq	v	1355
$Ga(C_2H_3)_3$	liq	k	797
$GaSn_x$	liq	q	1235
In	c	v	1113
		q	1406
		v	1511
	liq	q	536
In^+	aq	xy	1174
In^{+++}	aq	xy	1174
		n	1472
$InOH^{++}$	aq	x	1277
		n	1472
$In(OH)_2^+$	aq	n	1472
$In_2(OH)_2^{++++}$	aq	x	1277
		n	1472
InF	g	x	1262
InCl	g	x	1262
InBr	g	x	1262
InI	g	x	1262
In_2S_3	c	tv	864
In_2Se_3	c	mv	1390
InP	c	x	1426
InAs	c	x	1426
$InAs_xP_y$	c	x	1426
InSb	c	np	645
		np	1419
		y	1420
$InSn_x$	c	v	1022
		v	1494
	liq	q	1235
$InSn_xSb_y$	c	v	1022
		v	1494
$InPb_x$	liq	q	1217
Tl	c	km	694
		km	1019
	liq	q	536
	g	rs	719
		rstv	996
		rs	1516
Tl_2O_3	c	km	637
	liq	km	637
$TlOH^{++}$	aq	x	750

Substance	State	Prop.	Ref.
TlF	g	x	1262
	non-aq	x	1092
TlF_3	non-aq	x	1092
TlCl	c	x	581
	g	x	1262
	aq	x	581
TlBr	g	x	1262
	aq	x	643
		x	1294
$TlBr_2^-$	aq	x	643
		x	1294
$TlBr_3^{--}$	aq	x	1294
$TlBr_4^{---}$	aq	x	643
		x	1294
TlI	g	x	1262
	aq	x	1294
TlI_2^-	aq	x	1294
TlI_3^{--}	aq	x	1294
TlI_4^{---}	aq	x	1294
TlSe	c	km	653
Tl_2Se	c	km	653
Tl_2Se_3	c	x	653
$TlNO_3$	c	q	874
		m	1145
TlCNS	c	x	1241
	aq	x	1241
$Tl(CNS)_2^-$	aq	x	1241
$Tl(CNS)_3^{--}$	aq	x	1241
$Tl(C_{12}H_8N_2)_2^{+++}$ (1, 10 - phenanthroline)	aq	q	1353
$Tl(C_{10}H_8N_2)_2^{+++}$ (2, 2' - bipyridine)	aq	q	1353
$TlSn_x$	c	r	647
	liq	q	1235
$TlPb_x$	liq	q	1217
Zn	c	v	565
		k	567
		a	865
		m	1344
	liq	km	1192
ZnO	c	z	1466
$Zn(OH)_2$	c	n	806
$ZnCl^+$	aq	x	1256
$ZnCl_2$	aq	x	1256
$ZnCl_3^-$	aq	x	1256

Substance	State	Prop.	Ref.
$ZnCl_4^{--}$	aq	x	1256
$Zn(ClO_4)_2$	aq	n	806
$ZnBr^+$	aq	x	1256
$ZnBr_2$	aq	x	1256
$ZnBr_3^-$	aq	x	1256
$ZnBr_4^{--}$	aq	x	1256
ZnI_2	liq	x	1049
$ZnSO_4$	c	x	1050
	aq	x	847
$ZnO \cdot 2ZnSO_4$	liq	x	1050
ZnSe	c	x	607
		km	915
$ZnP_3O_{10}^{---}$	aq	x	1143
$Zn(P_3O_{10})_2^{-8}$	aq	x	1143
$Zn_2(P_3O_{10})^-$	aq	x	1143
$Zn_3(P_3O_{10})_2^{----}$	aq	x	1143
$ZnSb_x$	liq	q	1217
$Zn(CH_3)_2$	liq	km	824
$Zn(C_6H_{18}N_4)^{++}$ (triethylenetetramine)	aq	q	1204
$Zn(SCN)^+$	aq	x	1242
$Zn(SCN)_2$	aq	x	1242
$Zn(SCN)_3^-$	aq	x	1242
$Zn(SCN)_4^{--}$	aq	x	1242
$Zn(SCN)_5^{---}$	aq	x	1242
$Zn(SCN)_6^{----}$	aq	x	1242
Zn_2SiO_4	c	z	1466
$ZnSn_x$	liq	kq	600
		q	1344
$ZnSnAs_2$	c	x	1426
$ZnBi_xSn_y$	liq	x	1409
$ZnPb_x$	c	y	1327
$ZnSn_xIn_y$	liq	x	1409
$ZnBi_xIn_y$	liq	x	1409
Cd	c	v	1430
	liq	k	601
Cd^{++}	aq	y	1424
CdO	c	x	1253
		z	1466
$Cd(OH)_2$	c	n	806
		x	1253

Substance	State	Prop.	Ref.
$CdCl_2$	c	rv	519
	liq	km	901
$CdCl_2 \cdot 5/2H_2O$	c	q	852
$CdCl_3^-$	aq	x	1058
$Cd(ClO_4)_2$	aq	n	806
$Cd(ClO_4)_2 \cdot 6H_2O$	c	q	1423
$CdBr_2$	c	rv	519
		rtv	942
	liq	y	802
$CdBr_3^-$	aq	x	1058
$CdBr_4^{--}$	aq	x	1058
$CdCl_2Br^-$	aq	x	1058
$CdClBr_2^-$	aq	x	1058
$CdClBr_3^{--}$	aq	x	1058
CdI_2	c	rv	519
	liq	x	1049
CdI_4^{--}	aq	x	1058
$CdCl_2I^-$	aq	x	1058
$CdCl_2I_2^{--}$	aq	x	1058
$CdClI_3^{--}$	aq	x	1058
$CdBr_3I^{--}$	aq	x	1058
$CdBr_2I_2^{--}$	aq	x	1058
$CdBrI_3^{--}$	aq	x	1058
CdS	c	x	607
$CdSO_4 \cdot 8/3H_2O$	c	x	700
CdSe	c	ktx	535
		km	915
CdTe	c	m	787
CdN_3^+	aq	x	1381
$Cd(N_3)_2$	aq	x	1381
$Cd(N_3)_3^-$	aq	x	1381
$Cd(N_3)_4^{--}$	aq	x	1381
$Cd(N_3)_5^{---}$	aq	x	1381
$CdNO_3^+$	aq	x	561
		x	1399
$Cd(NO_3)_2$	c	q	561
		q	510
	aq	q	508
		q	509
$(NH_4)_2Cd_2(SO_4)_3$	c	mrstv	625
$CdP_3O_{10}^{---}$	aq	x	1143
$Cd(P_3O_{10})_2^{-8}$	aq	x	1143

Substance	State	Prop.	Ref.
$Cd_2(P_3O_{10})^-$	aq	x	1143
$Cd_3(P_3O_{10})_2^{----}$	aq	x	1143
$CdSb_x$	liq	k	601
CdC_2O_4	c	np	852
	aq	x	791
$Cd(C_2O_4)_2^{--}$	aq	x	791
$Cd(C_2O_4)_3^{----}$	aq	x	791
$Cd(C_2H_3O_2)^+$	aq	x	1375
$Cd(NH_2CH_2COOH)^{++}$	aq	x	1282
$Cd(HOC_2H_4NH_2)^{++}$	aq	x	1298
$Cd(C_3H_7O_2N)^{++}$ (alanine)	aq	x	1282
$Cd(C_4H_9O_2N)^{++}$ (piperidinic acid)	aq	x	1282
$Cd((HOC_2H_4)_2NH)^{++}$	aq	x	1298
$Cd(NH_2CH_2COOH)_2^{++}$	aq	x	1282
$Cd(HOC_2H_4NH_2)_2^{++}$	aq	x	1298
$Cd(C_5H_{11}O_2N)^{++}$ (valine)	aq	x	1282
$Cd(C_6H_{13}O_2N)^{++}$ (leucine)	aq	x	1282
$Cd((HOC_2H_4)_3N)^{++}$	aq	x	1298
$Cd(C_3H_7O_2N)_2^{++}$	aq	x	1282
$Cd(NH_2CH_2COOH)_3^{++}$	aq	x	1282
$Cd(HOC_2H_4NH_2)_3^{++}$	aq	x	1298
$Cd(C_6H_5CHNH_2COOH)^{++}$	aq	x	1282
$Cd(C_4H_9O_2N)_2^{++}$	aq	x	1282
$Cd((HOC_2H_4)_2NH)_2^{++}$	aq	x	1298
$Cd(C_3H_7O_2N)_3^{++}$	aq	x	1282
$Cd(C_5H_{11}O_2N)_2^{++}$	aq	x	1282
$Cd(C_6H_{13}O_2N)_2^{++}$	aq	x	1282
$Cd((HOC_2H_4)_3N)_2^{++}$	aq	x	1298
$Cd(NH_2C_3H_6COOH)_3^{++}$	aq	x	1282
$Cd((HOC_2H_4)_2NH)_3^{++}$	aq	x	1298
$Cd(C_5H_{11}O_2N)_3^{++}$	aq	x	1282
$Cd(C_6H_5CHNH_2COOH)_2^{++}$	aq	x	1282
$Cd(C_6H_{13}O_2N)_3^{++}$	aq	x	1282
$Cd((HOC_2H_4)_3N)_3^{++}$	aq	x	1298
$Cd(C_6H_5CHNH_2COOH)_3^{++}$	aq	x	1282
$Cd(CNSe)^+$	aq	x	1003
$Cd(CNSe)_2$	aq	x	1003
$Cd(CNSe)_3^-$	aq	x	1003
$Cd(CNSe)_4^{--}$	aq	x	1003
$Cd(CNSe)_5^{---}$	aq	x	1003
$Cd(CNSe)_6^{----}$	aq	x	1003
$CdSiO_3$	c	z	1466
$CdPb_x$	liq	x	1039
$CdZn_x$	liq	q	1217
Hg	c	v	1066
	liq	k	1438
Hg^+	aq	y	606
Hg^{++}	aq	y	606
HgO	c	n	806
		y	989
		x	1080
		x	1081
		mx	1154
$HgOH^+$	aq	x	1080
		x	1081
		x	1131
$Hg(OH)_2$	aq	x	1080
		x	1081
		x	1131
$Hg_2(OH)^{+++}$	aq	x	1131
$Hg_2(OH)_2^{++}$	aq	x	1131
$Hg_4(OH)_3^{+5}$	aq	x	1131
$HgCl^+$	aq	q	1397
$HgCl_2$	c	rv	519
Hg_2Cl_2	c	y	1074
$Hg(ClO_4)_2$	aq	n	806
$Hg(ClO_4)_2 \cdot 6H_2O$	c	q	1423
$HgBr^+$	aq	q	1397
$HgBr_4^{--}$	aq	x	1058
HgClBr	aq	x	671
HgI^+	aq	q	1398
HgI_4^{--}	aq	x	1058
HgClI	aq	x	671
HgBrI	aq	x	671
$HgBr_3I^{--}$	aq	x	1058
$HgBr_2I_2^{--}$	aq	x	1058
$HgBrI_3^{--}$	aq	x	1058
HgS	c	tv	862
Hg_2SO_4	c	rstv	705

Substance	State	Prop.	Ref.
$Hg(S_2O_3)_2^{--}$	aq	x	760
$Hg(S_2O_3)_3^{----}$	aq	x	760
$Hg(CH_3)_2$	liq	km	824
	g	x	963
$Hg(C_2H_3O_2)^+$	aq	x	1375
$Hg(CN)_3^-$	aq	x	1385
$Hg(C_2H_8N_2)_2^{++}$ (ethylenediamine)	aq	x	1473
$Hg(CH_3CHNH_2CH_2NH_2)_2^{++}$	aq	x	1473
$Hg(C_4H_{13}N_3)_2^{++}$ (diethylenetriamine)	aq	x	1473
$Hg(CN)_3Cl^{--}$	aq	x	1385
$Hg(CN)_3Br^{--}$	aq	x	1385
$Hg(SCN)_2$	aq	x	564
$Hg(SCN)_3^-$	aq	x	564
$Hg(CN)_3SCN^{--}$	aq	x	1385
$Hg(SCN)_4^{--}$	aq	x	564
$Hg(NH_2CSNHNH_2)_4^{++}$	aq	x	1354
HgCd	c	x	700
Cu	c	v	785
		v	1056
		v	1198
		v	1433
		n	1443
		mr	1475
	liq	k	987
Cu^+	aq	x	1490
Cu^{++}	aq	x	1490
Cu_2	g	rstv	562
Cu_2O	c	tv	992
CuCl	c	km	660
		kx	1045
$CuCl^+$	aq	x	878
		x	1193
$CuCl_2$	c	rstv	1416
	aq	x	878
		x	1193
$CuCl_3^-$	aq	x	878
		x	1193
$CuCl_4^{--}$	aq	x	878
		x	1193
Cu_3Cl_3	g	km	660
		x	1045
Cu_6Cl_6	g	x	1045
CuBr	c	km	660
CuBr	c	kx	1045
$CuBr^+$	aq	x	1220
Cu_3Br_3	g	km	660
		x	1045
Cu_6Br_6	g	x	1045
CuI	c	km	660
CuI_4^{---}	aq	x	1058
Cu_3I_3	g	km	660
$CuSO_4 \cdot 5H_2O$	c	v	1434
$CuSeO_4 \cdot 5H_2O$	c	v	1434
$Cu(NH_3)_4SO_4 \cdot H_2O$	c	v	956
$CuP_3O_{10}^{---}$	aq	x	1143
$Cu(P_3O_{10})_2^{-8}$	aq	x	1143
$Cu_2(P_3O_{10})^-$	aq	x	1143
$Cu_3(P_3O_{10})_2^{----}$	aq	x	1143
$Cu(C_2O_4)_2^{--}$	aq	x	791
$Cu(C_5H_7O_2)_3$ (acetylacetonate)	c	np	1191
$Cu(C_6H_{18}N_4)^{++}$ (triethylenetetramine)	aq	x	1204
$Cu(C_6H_6O_6N)^-$ (nitrilotriacetate)	aq	x	885
$Cu(C_3H_6O_2)_2$ (alaninate)	c	np	1191
$Cu(C_4H_8O_2N_2)_2$ (dimethylglyoximate)	c	x	1392
$Cu(C_5H_{10}O_2N)_2$ (valinate)	c	np	1191
$Cu(SCN)_4^{---}$	aq	x	1058
$Cu(NH_2CH_2CH_2NH_2)_2SO_4 \cdot 4H_2O$	c	x	991
CuI_3SCN^{---}	aq	x	1058
$CuI_2(SCN)_2^{---}$	aq	x	1058
$CuI(SCN)_3^{---}$	aq	x	1058
CuSn	g	x	1128
$CuAl_2$	c	v	528
$CuCd_3$	c	x	1339
Cu_2Cd	c	x	1339
Cu_4Cd_3	c	x	1339
Cu_5Cd_8	c	x	1339

Substance	State	Prop.	Ref.
Ag	c	k	916
		v	1051
		k	1136
		km	1286
		k	1329
		q	1406
		v	1433
		v	1511
	liq	k	987
		km	1286
		m	1428
Ag^+	non-aq	y	1324
AgO	c	y	1225
Ag_2O	c	v	716
		y	989
		rstv	990
		tv	1017
		y	1067
		y	1068
		y	1205
		y	1225
		x	1364
$Ag(OH)_2$	aq	x	1364
AgF	aq	x	1403
AgCl	c	y	888
		q	1508
	liq	y	541
		y	902
$AgCl_4^{---}$	aq	x	1058
AgBr	c	py	517
		y	958
		q	1508
	liq	y	902
	aq	x	778
$AgBr_2^-$	aq	x	778
$AgBr_4^{---}$	aq	x	1058
		x	1061
Ag_2Br^+	aq	x	778
$AgCl_3Br^{--}$	aq	x	1058
$AgClBr_3^{--}$	aq	x	1058
		x	1061
AgI	c	q	1508
$AgIO_3$	c	x	1334
AgI_3^{--}	aq	x	1061
AgI_4^{---}	aq	x	1061
$AgICl_2^{--}$	aq	x	1061
$AgIBr_2^{--}$	aq	x	1061
AgI_2Br^{--}	aq	x	1061
Ag_2S	c	rstv	615
Ag_2SO_4	c	x	700
Ag_2Se	c	rstv	615
Ag_2SeO_3	c	nx	642
		nx	652
		x	819
Ag_2Te	c	rstv	615
$AgNO_3$	c	m	1147
	liq	q	1412
	aq	x	847
$Ag(NH_3)^+$	aq	y	1224
$Ag(NH_3)_2^+$	aq	y	1224
$AgNH_3Cl$	aq	x	809
$Ag(NH_3)_2Cl$	aq	x	809
$Ag(NH_3)_2Br$	aq	x	809
$Ag(NH_3)_2Br_2^-$	aq	x	809
AgBi	liq	y	563
$AgBi_x$	liq	y	1332
$AgSb_x$	c	y	1238
$Ag_2C_2O_4$	c	y	1449
$Ag(C_2H_4)^+$	aq	x	1107
AgCN	aq	x	779
$Ag(CN)_2^-$	aq	x	779
$Ag_2(CN)^+$	aq	x	779
$Ag(NH_2CH_2CH_2OH)^+$	aq	x	1087
$AgNO_3 \cdot C_4H_6$	c	x	918
$Ag((HOCH_2CH_2)_3N)^+$	aq	x	1107
$Ag((HOCH_2CH_2)_3N)_2^+$	aq	x	1107
$Ag((HOCH_2CH_2)_3N)_2 \cdot C_2H_4^+$	aq	x	1107
$2AgNO_3 \cdot C_4H_6$	c	x	918
$Ag(NH_2CSNH_2)_3^+$	aq	x	1354
$Ag(NH_2CSNHNH_2)_3^+$	aq	x	1354
Ag(NCSe)	aq	x	1002
$Ag_2(NCSe)^+$	aq	x	1002
$Ag_3(NCSe)^{++}$	aq	x	1002
$Ag_4(NCSe)^{+++}$	aq	x	1002
AgSn	g	x	1128
$AgSn_x$	liq	q	538
$AgBF_4 \cdot C_2H_4$	c	x	1272
$AgBF_4 \cdot 3/2C_2H_4$	c	x	1272

Substance	State	Prop.	Ref.
$AgBF_4 \cdot 2C_2H_4$	c	x	1272
$AgBF_4 \cdot 3C_2H_4$	c	x	1272
$AgBF_4 \cdot 2C_3H_6$	c	x	1272
$AgBF_4 \cdot 2C_4H_8$	c	x	1272
$AgBF_4 \cdot 3C_3H_6$	c	x	1272
$AgBF_4 \cdot 3C_4H_8$	c	x	1272
$AgAl_x$	liq	y	1346
$AgIn_x$	c	q	1406
$AgZn_xCd_y$	c	x	1379
Au	c	v	565
		a	865
		km	959
		k	1136
		a	1151
		k	1329
		q	1391
		v	1433
	liq	k	987
Au^+	non-aq	y	1324
$AuBr_2^-$	aq	x	713
$AuBr_4^-$	aq	x	713
AuSn	g	x	1128
$AuCu_x$	c	x	1329
Ni	c	v	609
		k	914
		q	1391
		q	1474
Ni^{++}	non-aq	y	1324
$Ni(OH)_4$	c	x	1300
NiCl	g	x	1262
NiBr	g	x	1262
$NiBr^+$	aq	x	822
NiI	g	x	1262
$NiSe_2$	c	rstv	979
$NiSe_x$	c	tv	1203
NiAs	c	x	531
$NiAs_2$	c	x	531
$Ni(C_6H_4(CO_2)_2)$ (phthalate)	aq	x	1267
$Ni(NH_2C_2H_4NHCH_3)^{++}$ (methylethylenediamine)	aq	x	858
$Ni(NH_2C_3H_6NH_2)^{++}$ (trimethylenediamine)			

Substance	State	Prop.	Ref.
$Ni(C_4H_{12}N_2)^{++}$ (ethylethylenediamine)	aq	x	858
$Ni(C_3H_{10}N_2)_2^{++}$	aq	x	858
$Ni(C_6H_{18}N_4)^{++}$ (triethylenetetramine)	aq	q	1204
$Ni(C_4H_{12}N_2)_2^{++}$	aq	x	858
$Ni(C_3H_{10}N_2)_3^{++}$	aq	x	858
$Ni(C_4H_{12}N_2)_3^{++}$	aq	x	858
$Ni(NH_2CH_2CH_2OH)^{++}$	aq	nx	663
		x	1087
$Ni(NH_2CH_2CH_2OH)_2^{++}$	aq	nx	663
$Ni(C_4H_{12}ON_2)^{++}$ (hydroxyethylethylenediamine)	aq	x	858
$Ni(C_5H_{14}ON_2)^{++}$ (hydroxypropylethylenediamine)	aq	x	858
$Ni(NH_2CH_2CH_2OH)_3^{++}$	aq	nx	663
$Ni(C_4H_8O_2N_2)_2$ (dimethylglyoximate)	c	x	1392
$Ni(C_4H_{12}ON_2)_2^{++}$	aq	x	858
$Ni(C_5H_{14}ON_2)_2^{++}$	aq	x	858
$Ni(C_5H_{14}ON_2)_3^{++}$	aq	x	858
$NiNCS^+$	aq	x	887
$Ni(CH_3C_5H_4N)_4(SCN)_2 \cdot (C_6H_4(CH_3)_2)_x$	c	q	1378
$Ni(CH_3C_5H_4N)_4(SCN)_2 \cdot (C_6H_4Cl_2)_x$	c	q	1378
Ni_2SiO_4	c	x	807
$Ni(BO_2)_2 \cdot 4H_2O$	c	x	654
$Ni(BO_2)_3^-$	aq	x	654
$(NiBO_2(SCN)_2)^-$	aq	x	654
$NiAl_x$	c	v	516
$NiCu_x$	c	y	737
$NiCu_xZn_y$	c	x	1101
$NiAu_x$	c	qr	1391
Co	c	k	502
Co^{++}	non-aq	y	1324
CoO	c	x	1161
Co_3O_4	c	x	1161
$Co(OH)_3$	c	x	755
$CoCl_2$	c	rstv	1099
		q	1290
	aq	v	1290
$CoCl_2 \cdot 6H_2O$	liq	q	1290

Substance	State	Prop.	Ref.
$CoBr^{+}$	aq	x	822
$CoSO_4 \cdot 2H_2O$	c	tv	1014
$Co(NH_3)_5H_2O^{+++}$	aq	x	543
		x	568
$Co(NH_3)_4(ClO_4)_3 \cdot H_2O$	c	x	890
$Co(NH_3)_4(ClO_4)_3 \cdot 2H_2O$	c	x	890
$Co(NH_3)_5H_2OCl_3$	c	x	1400
$Co(NH_3)_5H_2OBr_3$	c	x	1400
$Co(NH_3)_5I^{++}$	aq	x	543
$CoSb$	c	xy	1021
$CoSb_2$	c	xy	1021
$CoSb_3$	c	xy	1021
$Co(C_6H_4(CO_2)_2)$ (phthalate)	aq	x	1267
$Co(C_5H_7O_2)_3$ (acetylacetone)	c	np	1191
		km	1248
$Co(C_{10}H_9O_2)_3$ (benzoylacetone)	c	km	1248
$Co(C_8H_4O_3F_3)_3$ (furoyltrifluoroacetone)	c	km	1248
$Co(C_{10}H_6O_2F_3)_3$ (benzoyltrifluoroacetone)	c	km	1248
$Co(C_8H_4O_2F_3S)_3$ (thenoyltrifluoroacetone)	c	km	1248
$Co(CN)_5N_3^{---}$	aq	x	946
$Co(C_3H_{10}N_2)^{++}$ (trimethylenediamine)	aq	x	858
$Co(C_3H_{10}N_2)^{++}$ (methylethylenediamine)	aq	x	858
$Co(C_4H_{12}N_2)^{++}$ (ethylethylenediamine)	aq	x	858
$Co(C_6H_{18}N_4)^{++}$ (triethylenetetramine)	aq	q	1204
$Co(C_3H_{10}N_2)_2^{++}$	aq	x	858
$Co(C_4H_{12}N_2)_2^{++}$	aq	x	858
$Co(C_3H_{10}N_2)_3^{++}$	aq	x	858
$Co(C_4H_{12}N_2)_3^{++}$	aq	x	858
$Co(NH_3)_4C_2O_4^{+}$	aq	x	889
$Co(NH_3)_5HC_2O_4^{++}$	aq	x	568
$Co(C_4H_{12}ON_2)^{++}$ (hydroxyethylethylenediamine)	aq	x	858
$Co(C_5H_{14}ON_2)^{++}$ (hydroxypropylethylenediamine)	aq	x	858

Substance	State	Prop.	Ref.
$Co(CN)_5OH^{--}$	aq	x	946
$Co(C_4H_{12}ON_2)_2^{++}$	aq	x	858
$Co(C_5H_{14}ON_2)_2^{++}$	aq	x	858
$CoCl_2(C_5H_5N)_2$	non-aq	x	1413
$CoCl_2(C_5H_5N)_4$	non-aq	x	1413
$Co(NH_2CH_2CH_2NH_2)_3(ClO_4)_3$	aq	y	1404
$Co(CN)_5NCS^{---}$	aq	x	946
$Co(SeCN)^{+}$	aq	x	1301
$Co(SeCN)_4^{--}$	aq	x	1301
Co_2SiO_4	c	x	650
$Co(BO_2)_4^{--}$	aq	x	654
$Co(BO_2)_2 \cdot 2H_2O$	c	x	654
$(Co(BO_2)(SCN)_3)^{--}$	aq	x	654
Fe	c	j	527
		mr	1046
		v	1227
		q	1474
		mr	1475
	liq	j	527
		q	1015
Fe^{++}	aq	y	606
Fe^{+++}	aq	y	606
FeO	c	x	734
		x	739
		x	1001
		z	1466
Fe_2O_3	c	x	569
		x	620
Fe_3O_4	c	x	569
		x	620
		x	739
$Fe(OH)_2$	g	x	1169
$FeCl^{++}$	aq	x	612
$FeCl_2$	c	x	950
	aq	x	847
$FeCl_2^{+}$	aq	x	1058
$FeCl_3$	c	x	950
	g	rstv	1281
	aq	x	847
Fe_2Cl_6	c	kmrx	1124
	g	x	950
FeS	c	x	698
		x	1350
FeS_2	c	rstv	979
		x	1350

Substance	State	Prop.	Ref.
$FeSO_4^+$	aq	x	925
$FeSe_2$	c	rstv	979
$FeTe_x$	c	y	1020
FeN_3^{++}	aq	x	1116
		x	1394
$(NH_4)_2Fe(SO_4)_2 \cdot 2H_2O$	c	x	1215
		x	1306
$(NH_4)_2Fe(SO_4)_2 \cdot 4H_2O$	c	x	1215
		x	1306
$(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$	c	x	1215
		x	1306
FeAs	c	x	1350
$FeAs_2$	c	x	1350
Fe_2As	c	x	1350
FeAsS	c	x	666
		x	1350
$FeSb_x$	c	y	968
FeC_x	c	mr	1328
		x	1340
$Fe(C_2O_4)$	aq	x	655
$Fe(C_2O_4)^+$	aq	x	655
$Fe(C_2O_4)_2^-$	aq	x	655
$Fe(C_2O_4)_2^{--}$	aq	x	655
$Fe(C_2O_4)_3^{---}$	aq	x	655
$Fe(C_7H_5O_4)^{++}$	aq	x	1320
$Fe(C_7H_5O_4)_2^+$	aq	x	1320
$Fe(C_5H_7O_2)_3$ (acetylacetone)	c	np	1191
$Fe(C_7H_5O_4)_3$	aq	x	1320
$Fe(C_6H_{18}N_4)^{++}$ (triethylenetetramine)	aq	q	1204
$HFe(CN)_6^{+++}$	aq	x	1322
$H_2Fe(CN)_6^{++}$	aq	x	1322
$Fe(SCN)_2^+$	aq	x	1058
$FeFSCN^+$	aq	x	533
$FeClSCN^+$	aq	x	1058
FeSi	c	tv	919
$FeSi_2$	c	tv	919
Fe_3Si	c	tv	919
Fe_3Si_7	c	tv	919
Fe_5Si_3	c	tv	919
Fe_2SiO_4	c	x	808
		z	1466
$FeAl_x$	c	x	974
		x	976
$ZnFe_2O_4$	c	nx	861
		v	1357
$FeCu_x$	c	v	1056
		v	1198
$CuFe_2O_4$	c	nx	861
$FeAg_x$	c	r	1216
$FeNi_x$	c	q	1474
$NiFe_2O_4$	c	x	721
		v	1357
		v	1436
$Ni_xFe_{(2-x)}O_4$	c	v	1436
$FeCo_x$	c	r	1216
$CoFe_2O_4$	c	v	1436
Pd	c	km	951
		km	1130
		k	1136
		k	1221
		km	1486
$PdCl^+$	aq	x	1243
$PdCl_2$	c	kx	799
	aq	x	1243
$PdCl_3^-$	aq	x	1243
$PdCl_4^{--}$	aq	x	1243
PdAu	g	x	1130
Rh	c	kmz	1082
		v	1179
		km	1486
		v	1511
		v	1522
$RhCl_2$	g	x	1167
$RhCl_3$	c	x	1167
Ru	c	km	701
		km	1493
	g	rs	719
		rstv	996
		rs	1516
Ru^{+++}	aq	y	1153
Ru^{++++}	aq	y	1153
RuF_6	c	k	1383
$RuCl^{++}$	aq	x	1126

Substance	State	Prop.	Ref.
$RuCl_2^+$	aq	x	1126
$RuCl_3$	aq	x	1126
RuI_3	c	x	635
$Ru(SC(NH_2)_2)^{+++}$	aq	x	1212
$Ru(SC(NH_2)_2)_3^{+++}$	aq	x	1212
Pt	c	k	1136
		km	1486
$PtCl_4^{--}$	aq	x	1144
$PtCl_6^{--}$	aq	x	1265
$PtBr_6^{--}$	aq	x	1265
PtI_6^{--}	aq	x	1265
$Pt(NH_3)_2(H_2O)_2^{++}$	aq	x	1382
$Pt(NH_3)Cl_3^-$	aq	x	1144
$Pt(NH_3)_2Cl_2$	aq	x	983
		x	1144
		x	1382
$Pt(NH_3)_3Cl^+$	aq	x	1144
$Pt(NH_3)_2ClH_2O^+$	aq	x	1382
Ir	c	km	1486
		km	1493
	g	rstv	996
IrF_6	g	rstv	679
		rstv	1377
$IrCl_6^{---}$	aq	x	725
$Ir(H_2O)Cl_5^{--}$	aq	x	725
Os	c	km	701
	g	rstv	996
Mn^{++}	aq	y	1226
		y	1388
MnO	c	z	1466
	liq	x	1471
MnO_2	c	y	1226
		y	1388
$MnOH^+$	aq	x	712
MnCl	g	x	1262
$MnCl^+$	aq	x	894
$MnCl_2$	c	rstv	1099
	g	x	754
	aq	x	894
$MnCl_3^-$	aq	x	894
MnBr	g	x	1262
$MnBr_2$	c	v	1361
MnI	g	x	1262
MnS	c	x	1459
MnP	c	np	1289
MnAs	c	np	1289
MnSb	c	np	1289
MnBi	c	np	1289
$Mn_{23}C_6$	c	x	1137
$MnCO_3$	c	v	1185
$MnC_6H_4(CO_2)_2$ (phthalate)	aq	x	1267
$Mn(NH_2CH_2CH_2NH_2)^{++}$	aq	x	842
$Mn(C_6H_{18}N_4)^{++}$ (triethylenetetramine)	aq	q	1204
MnSi	c	x	754
$MnSi_2$	c	x	754
Mn_5Si_3	c	x	754
$MnSiO_3$	c	z	1466
Mn_2SiO_4	c	z	1466
$Mn(BO_2)_2$	c	y	813
$MnAl_x$	c	v	1197
Mn_3AlC	c	v	624
$MnCu_x$	c	v	1120
		v	1433
Mn_3ZnC	c	v	624
$MnZn_xCu_y$	c	x	1264
$MnNi_x$	c	x	1299
$MnFe_x$	c	r	1216
$MnFe_2O_4$	c	nx	861
Tc	g	rs	719
		rs	1516
TcF_6	c	k	1374
	liq	k	1374
Re	g	rstv	996
ReO_2	c	km	1072
ReO_3	c	km	1072
		np	1500
ReF_6	c	km	776
	liq	km	776
	g	rstv	1095
		rstv	1377

Substance	State	Prop.	Ref.
$ReCl_5$	c	x	1500
ReS_2	c	np	765
		km	1072
		np	1500
Re_2S_7	c	np	765
		np	1500
$(Re(CO)_5)_2$	c	km	1079
$HRe(CO)_5$	liq	km	1163
Cr	c	km	554
		km	692
		km	1130
Cr^{+++}	non-aq	y	1324
CrO_2	c	x	1460
CrO_4^{--}	aq	x	597
		x	1335
$Cr_2O_7^{--}$	aq	x	597
$HCrO_4^-$	aq	x	597
CrCl	g	x	1262
$CrCl_2$	c	x	1099
		rstvx	1416
CrOCl	c	nx	604
CrBr	g	x	1262
CrI	g	x	1262
$CrSO_4^+$	aq	x	1318
CrN_3^{++}	aq	x	1255
		x	1259
$Cr_{23}C_6$	c	x	1352
$Cr(C_5H_7O_2)_3$ (acetylacetone)	c	np	1191
$(Cr(CH_2NH_2COOH)(H_2O)_5)^{+++}$ (glycine)	aq	x	1207
$(Cr(CH_2NH_2COOH)_2(H_2O)_4)^{+++}$ (glycine)	aq	x	1207
		x	1208
$(Cr(CH_2NH_2COOH)_3(H_2O)_3)^{+++}$	aq	x	1207
		x	1208
$(Cr(CH_2NH_2COOH)_4(H_2O)_2)^{+++}$	aq	x	1207
		x	1208
$(Cr(CH_2NH_2COOH)_5(H_2O))^{+++}$	aq	x	1207
		x	1208
$(Cr(CH_2NH_2COOH)_6)^{+++}$	aq	x	1207
		x	1208

Substance	State	Prop.	Ref.
Ag_2CrO_4	c	x	1335
CrAu	g	x	1130
$CrNi_x$	c	x	1333
CrFe	c	v	646
$CrFe_x$	c	r	1216
$CrFe_xAl_y$	c	x	974
Mo	c	r	867
		r	1351
		r	1462
		v	1511
		v	1522
	g	rstv	996
MoO_2	c	x	1009
MoO_3	c	q	908
		x	1008
		n	1295
		km	1305
MoO_4	c	n	572
MoO_4^{--}	aq	x	1077
$(MoO_3)_3$	c	k	1008
$Mo_7O_{24}^{-6}$	aq	x	1077
$Mo_8O_{26}^{----}$	aq	x	1077
$MoO_2(OH)_2$	c	x	1008
MoF_6	g	rstv	679
		rstv	1094
		rstv	1377
$MoCl_2$	c	n	1295
$MoCl_3$	c	n	1295
$MoCl_4$	c	n	1295
$MoCl_5$	c	n	1295
MoO_2Cl_2	c	k	630
		n	1295
$MoO_2Cl_2 \cdot H_2O$	c	q	630
$MoOCl_3$	c	n	572
$MoOCl_4$	c	n	1295
$MoBr_2$	c	nps	657
MoO_2Br_2	c	x	507
	aq	q	507
MoS_2	c	x	1359
Mo_2C	c	x	1009
$MoRh_x$	c	v	1511

Substance	State	Prop.	Ref.
W	c	r	866
		r	868
		r	1187
	g	rstv	996
WO_2	c	x	592
		x	739
WO_3	c	x	592
		x	1008
WO_4^{--}	aq	nx	1268
		x	1276
$W_{18}O_{49}$	c	x	592
WO_x	c	y	922
H_2WO_4	c	q	908
		x	1008
		n	1295
$HW_6O_{21}^{-5}$	aq	nx	1268
		x	1276
WF_6	g	rstv	679
		rstv	1377
WCl_2	c	n	1295
WCl_4	c	n	1295
WCl_5	c	n	1295
	g	n	1295
WCl_6	c	n	1295
	g	n	1295
W_2Cl_{10}	g	n	1295
WO_2Cl_2	c	n	1295
$WOCl_4$	c	n	1295
W_2B	c	x	1513
WNi_4	c	r	729
WCo_3	c	x	739
W_6Co_7	c	r	730
$CoWO_4$	c	r	558
W_6Fe_7	c	r	730
$MnWO_4$	c	r	558
V	c	r	1000
VO	c	r	537
		np	1455
VO_2^+	aq	x	602
VO_3^-	aq	x	602
V_2O_3	c	r	537
		x	1149
		np	1455
V_2O_4	c	np	1455
$V_2O_4 \cdot 2H_2O$	c	x	1233
V_2O_5	c	np	863
		np	1455
V_3O_5	c	x	1149
$V_3O_9^{---}$	aq	x	602
HVO_3	aq	x	602
HVO_4^{--}	aq	x	602
$HV_{10}O_{28}^{-5}$	aq	x	602
VCl_2	c	x	634
		x	798
VCl_3	c	np	631
		x	798
VCl_4	g	x	798
$VOCl_3$	liq	x	659
	g	rstv	685
VBr_2	c	x	632
		x	658
VBr_3	c	x	632
		n	636
		x	658
VBr_4	g	x	632
		x	658
VC	c	x	1425
V_2C	c	x	1352
V_4C_3	c	x	1352
$VO(C_5H_7O_2)_3$ (acetylacetone)	c	np	1191
VSi	c	r	1000
VSi_2	c	r	1000
V_5Si_3	c	r	1000
VMn_x	liq	x	1038
NbO_2	c	np	926
Nb_2O_5	c	np	841
		np	891
		np	911
NbH_x	c	x	1349
$NbCl_5$	c	km	882
	liq	km	882
	g	rstv	682
$NbOCl_3$	c	n	638

Substance	State	Prop.	Ref.
$NbBr_5$	c	n	633
		np	1285
$NbOBr_3$	c	n	633
NbI_4	c	x	1504
NbI_5	c	x	1504
$NbOI_2$	c	x	605
$NbOI_3$	c	x	605
NbN	c	k	595
$NbO_2 \cdot C_2O_4$	aq	x	500
		x	501
Ta	c	v	1522
	g	rstv	996
Ta_2O_5	c	np	911
TaH_2	c	tv	566
TaH_x	c	x	775
Ta_2H	c	tv	591
		mtv	1510
TaD_2	c	tv	566
TaF_6^-	aq	x	511
TaF_7^{--}	aq	x	511
TaF_8^{---}	aq	x	511
TaF_9^{----}	aq	x	511
$TaBr_5$	c	np	1285
TaN	c	x	1331
Ta_2N	c	x	1331
TaB_x	c	x	1513
Ti	c	km	895
TiO	c	r	1036
TiO_2	c	q	550
		q	616
		z	1466
Ti_2O_3	c	r	1036
		v	1445
TiH_2	c	rstv	1308
TiH_x	c	x	673
$Ti(OH)^{++}$	aq	x	710
$TiOH^{+++}$	aq	x	1078
TiF_4	c	np	993
	liq	rtv	1451
	g	rtv	1451
$TiCl_3$	c	y	578
		x	941
		rtv	1451
$TiCl_4$	liq	q	909
	g	x	941
TiBr	c	x	1064
$TiBr_2$	c	x	1064
$TiBr_3$	c	x	1064
		rtv	1451
$TiBr_4$	c	mrtv	1451
	liq	kx	1064
		rtv	1451
	g	rtv	1451
$Ti(OH)Br_2^+$	aq	y	1078
$TiBrCl_3$	g	rstv	675
$TiBr_3Cl$	g	rstv	675
TiI	c	x	1063
TiI_2	c	x	1063
TiI_3	c	x	1063
TiI_4	c	mrtv	1451
	liq	kx	1063
$TiOSO_4$	aq	x	1303
$TiO(SO_4)_2^{--}$	aq	x	1303
TiN	c	x	1134
		x	1486
TiC	c	np	828
		np	893
$TiO(C_2O_4)$	aq	x	982
$TiO(C_2O_4)_2^{--}$	aq	x	982
$TiCl_4 \cdot HCO_2C_4H_9$	liq	q	830
$TiCl_4 \cdot HCO_2C_5H_{11}$	liq	q	830
$TiCl_4 \cdot CH_3CO_2C_5H_{11}$	liq	q	830
$TiCl_4 \cdot CH_3CO_2C_8H_{17}$	liq	q	830
$TiCl_4 \cdot 2HCO_2C_4H_9$	liq	q	830
$TiCl_4 \cdot 2HCO_2C_5H_{11}$	liq	q	830
$TiCl_4 \cdot 2CH_3CO_2C_5H_{11}$	liq	q	830
$TiCl_4 \cdot 2CH_3CO_2C_8H_{17}$	liq	q	830
TiB_2	c	np	540
		px	644
		np	828
Al_2TiO_5	c	p	1200
TiCo	c	v	669

Substance	State	Prop.	Ref.
Ti_4Co_3Ni	c	v	669
TiFe	c	v	669
$TiMo_x$	c	v	948
		v	1230
Zr^{++}	non-aq	y	1341
Zr^{++++}	non-aq	y	1341
ZrO	c	x	1523
ZrO_2	c	kx	1523
ZrH	c	x	816
ZrH_x	c	x	673
		v	1348
ZrD_x	c	v	1348
ZrF_4	c	rt	580
		mrv	766
		np	993
		rt	1467
$ZrCl_2$	c	y	1325
$ZrCl_3$	c	y	1325
$ZrCl_4$	c	y	1325
	g	rstv	680
		rstv	1281
$ZrBr_4$	g	rstv	680
ZrI_4	g	rstv	680
		rstv	1138
$Zr(SO_4)^{++}$	aq	x	757
$Zr(SO_4)_2$	c	rt	580
		rt	1467
	aq	x	757
$Zr(SO_4)_3^{--}$	aq	x	757
ZrN	c	x	1134
$Zr(C_2O_4)^{++}$	aq	x	784
$Zr(C_2O_4)_2$	aq	x	784
$(ZrO(C_2O_4)_2)^{--}$	aq	x	1213
$((ZrO)_2C_2O_4)^{++}$	aq	x	1213
$(ZrO(C_2O_4)\cdot(H_2O_2))$	aq	x	1213
$Zr(C_2O_4)_2\cdot 2Zr(OH)_4$	aq	x	1213
$ZrCl_4\cdot HCO_2C_2H_5$	liq	q	831
$ZrCl_4\cdot CH_3CO_2C_2H_5$	liq	q	831
$ZrCl_4\cdot C_2H_5CO_2C_2H_5$	liq	q	831
$ZrCl_4\cdot 2HCO_2C_2H_5$	liq	q	831
$ZrCl_4\cdot 2CH_3CO_2C_2H_5$	liq	q	831
$ZrCl_4\cdot 2C_2H_5CO_2C_2H_5$	liq	q	831
$ZrBr_4\cdot HCO_2C_2H_5$	liq	q	831
$ZrBr_4\cdot CH_3CO_2C_2H_5$	liq	q	831
$ZrBr_4\cdot C_2H_5CO_2C_2H_5$	liq	q	831
$ZrBr_4\cdot 2HCO_2C_2H_5$	liq	q	831
$ZrBr_4\cdot 2CH_3CO_2C_2H_5$	liq	q	831
$ZrBr_4\cdot 2C_2H_5CO_2C_2H_5$	liq	q	831
$ZrSiO_4$	c	p	1200
$ZrSn_x$	c	v	905
ZrB_2	c	x	810
$ZrAl_2$	c	x	645
Zr_2Al_3	c	x	645
Zr_4Al_3	c	x	645
$ZrIn_x$	c	v	905
$ZrZn_x$	c	y	1239
$ZrAg_x$	c	v	905
$ZrFe_2$	c	x	645
$ZrTiO_4$	c	p	1201
Hf	c	k	921
	g	rs	719
		rstv	996
		rs	1516
HfO_2	c	x	526
HfH_2	c	x	1030
HfF_4	c	r	582
$HfCl_2$	c	y	1325
$HfCl_3$	c	y	1325
$HfCl_4$	c	y	1325
	g	rstv	680
$HfBr_4$	g	rstv	680
HfI_4	g	rstv	680
$Hf(SO_4)^{++}$	aq	x	757
$Hf(SO_4)_2$	aq	x	757
HfC	c	x	526
$Hf(C_2O_4)^{++}$	aq	x	784
$Hf(C_2O_4)_2$	aq	x	784
HfB_2	c	x	921
Sc	c	tv	557
		km	855
		km	1129
Sc_2O_3	c	np	1464

Substance	State	Prop.	Ref.
$ScCl^{++}$	aq	x	709
$ScCl_2^{+}$	aq	x	709
$ScBr^{++}$	aq	x	709
$ScBr_2^{+}$	aq	x	709
$Sc(C_2O_4)^{+}$	aq	x	672
$Sc_2(C_2O_4)_3$	aq	x	672
Y	c	km	854
		km	1129
		mr	1512
	liq	k	1288
		r	1512
Y_2O_3	c	rtv	704
YH_2	c	vx	1065
	g	rstvx	1052
YD_2	g	rstvx	1052
YF^{++}	aq	x	1405
YF_2^{+}	aq	x	1405
YF_3	aq	x	1405
YCl^{++}	aq	x	709
YBr^{++}	aq	x	709
$Y(N(CH_2CO_2)_3)$	aq	x	885
$Y(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Y(C_{10}N_2H_{12}O_8)^{-}$ (ethylenediaminetetracetate)	aq	n	772
Lu	c	m	1428
LuO	g	x	1370
Lu_2O_3	c	x	1370
$Lu(C_2H_5OSO_3)_2 \cdot 9H_2O$	c	rstv	1016
$Lu(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Lu(N(CH_2CO_2)_3)$	aq	x	885
$Lu(C_{10}N_2H_{12}O_8)^{-}$ (ethylenediaminetetracetate)	aq	n	772
Yb	c	mr	1512
	liq	r	1512
Yb_2O_3	c	x	1370
YbH_x	c	x	1489
$Yb(OH)_3$	c	x	1297
$Yb(N(CH_2CO_2)_3)$	aq	x	885
$Yb(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Yb(C_{10}N_2H_{12}O_8)^{-}$ (ethylenediaminetetracetate)	aq	n	772
Tm_2O_3	c	x	1370
$TmCl_3$	aq	qv	1503
$Tm(C_2H_5OSO_3)_2 \cdot 9H_2O$	c	rstv	1016
$Tm(N(CH_2CO_2)_3)$	aq	x	885
$Tm(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Tm(C_{10}N_2H_{12}O_8)^{-}$ (ethylenediaminetetracetate)	aq	n	772
Er	c	km	515
		m	1428
$Er(OH)_3$	c	x	1297
$Er(OH)_{2.5}Cl_{0.5}$	c	x	1297
$Er(C_5H_7O_2)_3 \cdot H_2O$	c	x	722
$Er(C_5H_7O_2)_3 \cdot H_2O \cdot CH_3OH$	c	x	722
$Er(N(CH_2CO_2)_3)$	aq	x	885
$Er(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Er(C_{10}N_2H_{12}O_8)^{-}$ (ethylenediaminetetracetate)	aq	n	772
Ho	c	km	515
		m	1428
		km	1484
	liq	km	1484
HoO	g	x	1370
Ho_2O_3	c	x	1370
$HoCl_3$	c	x	548
	aq	qv	1503
HoOCl	c	x	548
HoC_2	c	x	1484
$Ho(N(CH_2CO_2)_3)$	aq	x	885
$Ho(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Ho(C_{10}N_2H_{12}O_8)^{-}$ (ethylenediaminetetracetate)	aq	n	772
Dy	c	v	826
		v	1073
		m	1428
DyO	g	x	1370
Dy_2O_3	c	x	1370
$DyCl_3$	aq	qv	1503
$Dy(C_5H_7O_2)_3 \cdot H_2O$ (acetylacetone)	c	x	722
$Dy(C_5H_7O_2)_3 \cdot H_2O \cdot CH_3OH$	c	x	722
$Dy(N(CH_2CO_2)_3)$	aq	x	885

Substance	State	Prop.	Ref.
$Dy(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Dy(C_{10}N_2H_{12}O_8)^-$ (ethylenediaminetetracetate)	aq	n	772
$DyCo_5$	c	mtv	1510
Tb	c	m	1428
	liq	m	1428
TbO	g	x	1370
Tb_2O_3	c	x	1370
$TbCl_3$	aq	x	689
$TbBr_3$	aq	x	689
$Tb(N(CH_2CO_2)_3)$	aq	x	885
$Tb(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Tb(C_{10}N_2H_{12}O_8)^-$ (ethylenediaminetetracetate)	aq	n	772
Gd	c	km	515
	liq	m	1428
Gd_2O_3	c	rtv	704
$Gd(OH)_3$	c	x	913
$GdCl_3$	aq	qv	1503
$Gd(N(CH_2CO_2)_3)$	aq	x	885
$Gd(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Gd(C_{10}N_2H_{12}O_8)^-$ (ethylenediaminetetracetate)	aq	n	772
Eu	c	km	515
		mr	1512
	liq	r	1512
Eu_2O_3	c	rtv	704
$Eu(CH_3CO_2)^{++}$	aq	x	1315
$Eu(HOCH_2CO_2)^{++}$	aq	x	1315
$Eu(CH_3CO_2)_2^+$	aq	x	1315
$Eu(HOCH_2CO_2)_2^+$	aq	x	1315
$Eu(CH_3CO_2)_3$	aq	x	1315
$Eu(HOCH_2CO_2)_3$	aq	x	1315
$Eu(HSCH_2CO_2)^{++}$	aq	x	1315
$Eu(HSCH_2CO_2)_2^+$	aq	x	1315
$Eu(HSCH_2CO_2)_3$	aq	x	1315
$Eu(N(CH_2CO_2)_3)$	aq	x	885
$Eu(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Eu(C_{10}N_2H_{12}O_8)^-$ (ethylenediaminetetracetate)	aq	n	772

Substance	State	Prop.	Ref.
Sm	c	v	825
Sm_2O_3	c	rtv	704
$SmCl_3$	aq	qv	1503
$Sm(N(CH_2CO_2)_3)$	aq	x	885
$Sm(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Sm(C_{10}N_2H_{12}O_8)^-$ (ethylenediaminetetracetate)	aq	n	772
Nd	liq	m	1428
NdO	g	x	1246
		x	1247
Nd_2O_3	c	rtv	704
		x	1247
$NdCl_3$	c	km	589
		km	696
		q	838
		x	839
$NdBr_3$	c	km	589
NdI_3	c	km	589
$Nd(N(CH_2CO_2)_3)$	aq	x	885
$Nd(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Nd(C_{10}N_2H_{12}O_8)^-$ (ethylenediaminetetracetate)	aq	n	772
$NdPb_x$	c	x	833
Pr	c	mr	1512
	liq	m	1428
		r	1512
PrO	g	x	1246
Pr_2O_3	c	m	1498
$PrCl_2$	c	x	840
$PrCl_3$	c	km	589
		km	696
		q	838
		x	839
	g	x	840
$PrBr_3$	c	km	589
PrI_3	c	km	589
$Pr(N(CH_2CO_2)_3)$	aq	x	885
$Pr(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Pr(C_{10}N_2H_{12}O_8)^-$ (ethylenediaminetetracetate)	aq	n	772
$PrPb_x$	c	x	833
CeO	g	x	1246

Substance	State	Prop.	Ref.
CeO_2	c	x	928
Ce_2O_3	c	x	928
CeH_x	c	x	1489
$CeCl_3$	c	km	589
		km	696
		q	838
		x	839
$CeBr_3$	c	km	589
$Ce(SO_4)_2$	aq	x	703
$Ce_2(SO_4)_3$	aq	x	703
$CePO_4$	c	x	1228
$Ce_3(PO_4)_4$	c	x	1228
$Ce(N(CH_2CO_2)_3)$	aq	x	885
$Ce(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$Ce(C_{10}N_2H_{12}O_8)^-$ (ethylenediaminetetracetate)	aq	n	772
$CePb_x$	c	x	833
La	c	km	1129
		mr	1512
	liq	r	1512
LaO	g	x	1246
		x	1247
La_2O_3	c	rstv	1211
		x	1247
LaH_x	c	x	1489
$LaCl_3$	c	km	589
		km	696
		q	838
		x	839
$LaBr_3$	c	km	589
LaI_3	c	km	589
$La(N(CH_2CO_2)_3)$	aq	x	885
$La(N(CH_2CO_2)_3)_2^{---}$	aq	x	885
$La(C_{10}N_2H_{12}O_8)^-$ (ethylenediaminetetracetate)	aq	n	772
		x	1302
$Am(CH_3CO_2)^{++}$	aq	x	1315
$Am(HOCH_2CO_2)^{++}$	aq	x	1315
$Am(CH_3CO_2)_2^+$	aq	x	1315
$Am(HOCH_2CO_2)_2^+$	aq	x	1315
$Am(CH_3CO_2)_3$	aq	x	1315
$Am(HOCH_2CO_2)_3$	aq	x	1315
$Am(HSCH_2CO_2)^{++}$	aq	x	1315
$Am(HSCH_2CO_2)_2^+$	aq	x	1315
$Am(HSCH_2CO_2)_3$	aq	x	1315
PuO_2	c	km	897
PuO_2OH^+	aq	x	896
$PuO_2(OH)_2$	c	x	896
$PuO_2(OH)_3^-$	aq	x	896
PuF_6	g	rstv	679
		rstv	1377
$PuCl^{+++}$	aq	x	1279
$PuCl_2^{++}$	aq	x	1279
$PuCl_3^+$	aq	x	1279
$Pu(SO_4)^{++}$	aq	x	783
$Pu(SO_4)_2$	aq	x	783
$Pu(SO_4)_3^{--}$	aq	x	783
$Pu(NO_3)^{+++}$	aq	x	1279
$Pu(NO_3)_2^{++}$	aq	x	1279
$Pu(NO_3)_3^+$	aq	x	1279
Np^{+5}	aq	y	606
Np^{+6}	aq	y	606
NpF_6	g	rstv	679
		rstv	1377
$NpO_2(C_2O_4)^-$	aq	x	1291
$NpO_2(C_2O_4)_2^{---}$	aq	x	1291
$NpO_2HC_2O_4$	aq	x	1291
$NpO_2(C_{10}H_{12}O_8N_2)^{---}$ (ethylenediaminetetracetate)	aq	x	1291
U	c	k	1458
	g	rstv	996
U^{++++}	aq	y	583
		x	1254
UO_2	c	x	665
		x	746
		y	871
UO_2^{++}	aq	y	583
		x	694
		x	1254
$U_2O_5^{++}$	aq	x	693
U_3O_7	c	rstv	547
U_3O_8	c	x	665
		mv	860
		y	871

Substance	State	Prop.	Ref.
U_4O_9	c	x	665
UO_x	c	x	746
		y	871
		x	1492
$(UO_2)_2(OH)_2^{++}$	aq	x	1278
$U_3O_8OH^+$	aq	x	694
$(UO_2)_3(OH)_4^{++}$	aq	x	1278
$(UO_2)_4(OH)_6^{++}$	aq	x	1278
$(UO_2)_5(OH)_8^{++}$	aq	x	1278
UH_3	c	x	544
		x	1070
UD_3	c	x	544
		x	1070
UOH^{+++}	aq	x	1231
$U(OH)_2^{++}$	aq	x	1231
$UO_2(OH)_2$	c	x	1157
$U(OH)_3^+$	aq	x	1231
$U(OH)_4$	aq	x	1231
UF_4	c	mrtv	1446
	liq	rtv	1446
$UF_4 \cdot 5/2H_2O$	c	np	777
UF_6	g	rstv	679
		rstv	1377
UO_2F^+	aq	x	927
UCl_3	non-aq	y	1274
UCl_4	c	n	777
UO_2Cl^+	aq	x	1398
$UOCl_2$	c	y	577
UO_2SO_4	aq	x	1398
$UO_2(SO_4)_2^{--}$	aq	x	1398
$UO_2NO_3^+$	aq	x	1398
$UO_2(NO_3)_2$	aq	x	1398
$UO_2(NO_3)_3^-$	aq	x	1398
$(UO_2)_3(PO_4)_2$	c	x	1228
UC_x	c	x	811
$UO_2(CO_3)_2^{--}$	aq	x	1304
$UO_2(CO_3)_3^{----}$	aq	x	1157
		x	1304
$UO_2((CH_3CO)_2CH)_2$	c	q	1202
$UO_2((C_2H_5CO)_2CH)_2$	c	q	1202
$UO_2(C_5H_7O_2)_3$ (acetylacetone)	c	np	1191
UO_2SCN^+	aq	x	1398
$UO_2(SCN)_2$	aq	x	1398
$UO_2(SCN)_3^-$	aq	x	1398
UCd_4	c	x	506
UCd_{11}	c	y	931
UZr_xO_y	c	y	1150
Th	g	rs	719
		rstv	996
		rs	1516
ThO	g	x	1524
ThO_2	c	kx	1524
	g	kx	1524
ThH_2	c	x	714
$ThC_2O_4^{++}$	aq	x	1229
$Th(C_2O_4)_2$	c	x	1229
$Th(C_5H_7O_2)_3$ (acetylacetone)	c	np	1191
Ac	g	rs	719
		rs	1516
Be	c	n	621
	g	rt	614
BeO	c	mx	793
		x	898
		x	1114
	g	rt	614
BeH	g	rt	614
Be_2OH^{++}	aq	x	1102
$Be_3(OH)_3^{+++}$	aq	x	1102
BeF	g	rt	614
BeF_2	g	rt	614
BeCl	g	rt	614
$BeCl_2$	c	np	621
		np	932
		p	1517
	g	rt	614
	aq	q	1517
	non-aq	y	576
$Be_3(PO_4)_2$	c	x	1228
$Be(H_2PO_4)_2 \cdot H_2O$	c	x	587
$BeNH_4PO_4$	c	x	1228
Be_2C	c	x	898
		x	1422

Substance	State	Prop.	Ref.
$Be_4O(C_6H_5COOH)_6$	c	x	924
$Be_4O(C_6H_5COOH)_6 \cdot 1/2C_6H_5CH_3$	c	x	924
$Be_4O(C_6H_5COOH)_6 \cdot 1/2C_6H_5CHCH_2$	c	x	924
$Be_4O(C_6H_5COOH)_6 \cdot 3C_6H_6$	c	x	924
$Be_4O(C_6H_5COOH)_6 \cdot 3C_6H_5CH_3$	c	x	924
$Be_4O(C_6H_5COOH)_6 \cdot 3C_6H_5CHCH_2$	c	x	924
$BeCl_2 \cdot 2(C_2H_5)_2O$	c	x	584
$BeCl_2 \cdot 3(CH_3)_2S$	c	x	584
$Be(BO_2)_2$	g	x	1114
Mg	g	rt	614
	liq	ai	768
	c	v	1430
		k	1520
MgO	c	mx	793
		v	817
		np	863
		z	1466
		km	1486
	g	rt	614
MgH	g	rt	614
MgF	g	rt	614
MgF_2	c	mk	1172
		z	1466
	liq	z	1466
	g	rt	614
MgCl	g	rt	614
$MgCl_2$	c	mk	1172
	liq	x	1048
		k	1507
	g	rt	614
$MgCl_2 \cdot xMgO \cdot yH_2O$	c	xz	1342
$MgBr_2$	c	mk	1172
MgI_2	c	mk	1172
MgS	c	x	1459
$MgSO_4$	aq	x	847
Mg_3N_2	c	x	1486
$MgCO_3$	c	n	1448
$MgCO_3 \cdot 3H_2O$	c	x	949
$Mg(C_5H_7O_2)_3$ (acetylacetone)	c	np	1191
$MgSiO_3$	c	z	1466
Mg_2SiO_4	c	x	980
		z	1466
MgSn	c	x	1152
$MgAl_x$	c	rv	1249
$MgAl_2O_4$	c	x	980
MgZn	c	np	645
$MgZn_2$	c	np	645
Mg_2Zn_{11}	c	np	645
$MgCd_3$	c	v	566
Mg_3Cd	c	v	566
$MgCu_2$	c	x	1520
Mg_2Cu	c	x	1520
$MgNi_2$	c	tv	566
		x	1520
Mg_2Ni	c	x	1520
$MgFe_2O_4$	c	mx	861
		v	1287
		v	1436
$MgFe_xO_y$	c	x	1345
$MgMn_x$	c	v	1271
$MgMoO_3$	c	x	738
$MgMoO_4$	c	x	738
$MgTiO_3$	c	p	1200
$MgTi_2O_5$	c	p	1200
Mg_2TiO_4	c	p	1200
MgV_2O_4	c	np	863
$Mg_2V_2O_7$	c	np	863
MgY	c	x	1520
Mg_5Y_2	c	x	1520
$Mg_{17}Y_3$	c	x	1520
Ca	c	mr	907
		k	1478
		k	1520
	liq	r	907
CaO	c	mx	793
		np	863
		z	1466
		n	1477
$CaOH^+$	aq	x	1103
$CaCl_2$	liq	x	1048
$Ca(NO_3)_2$	c	q	873
		mq	1432
		m	1461

Substance	State	Prop.	Ref.
$Ca_3(PO_4)_2$	c	n	628
$CaHPO_4$	c	x	849
$Ca_{10}(PO_4)_6(OH)_2$	c	n	628
$Ca_{10}(PO_4)_6F_2$	c	n	628
		x	1040
$CaCO_3$	c	x	1160
CaC_2O_4	c	q	1508
$CaCN_2$	c	xz	1263
$Ca(N(CH_2CO_2)_3)^-$	aq	x	885
Ca_2Si	c	np	639
$CaSiO_3$	c	y	1429
		z	1466
Ca_2SiO_4	c	y	1429
		z	1466
Ca_3SiO_5	c	z	1466
$Ca_3Si_2O_7$	c	y	1429
		z	1466
Ca_2Sn	c	np	639
Ca_2Pb	c	np	639
$Ca(BF_4)_2$	c	x	1280
$CaAl_2$	c	rx	907
		m	1234
		npx	1477
$CaAl_4$	c	x	907
		npx	1477
$CaAl_x$	c	nx	1477
		x	1478
$12CaO \cdot 7Al_2O_3$	c	x	1273
$CaAl_2Si_2O_8$	c	np	1162
		tv	1452
		z	1466
	amorph	z	1466
$CaAl_2Si_2O_8 \cdot 2H_2O$	c	np	1162
		tv	1452
$Ca_2Al_2Si_2O_7$	c	z	1466
	amorph	z	1466
$Ca_2Al_4Si_8O_{24} \cdot 7H_2O$	c	np	1162
		tv	1452
$CaAlGaSi_2O_8$	c	z	1466
$CaO \cdot xFeO \cdot yZnO \cdot zSiO_2$	liq	v	1479
$CaO \cdot xFeO \cdot ySiO_2 \cdot zAl_2O_3 \cdot wZnO$	c	rv	1098
$CaWO_4$	c	r	558
$CaWO_6 \cdot H_2O$	c	n	1182
$CaWO_6 \cdot 2H_2O$	c	n	1182
$CaWO_6 \cdot 3H_2O$	c	n	1182
$CaWO_8 \cdot 3H_2O$	c	n	1182
CaV_2O_6	c	np	863
		tv	1210
$Ca_2V_2O_7$	c	np	863
		tv	1210
$Ca_3V_2O_8$	c	tv	1210
$CaAu$	g	x	1244
$CaFe_2O_4$	c	nx	861
$CaTiO_3$	c	p	1201
$CaTiSiO_5$	c	p	1201
		z	1466
$CaZrO_3$	c	p	1201
$CaUO_4$	c	np	939
		v	1044
$CaMg_2$	c	x	1520
$CaMgSiO_4$	c	z	1466
$CaMgSi_2O_6$	c	z	1466
$Ca_2MgSi_2O_7$	c	z	1466
	amorph	z	1466
$Ca_3MgSi_2O_8$	c	z	1466
SrO	c	mx	793
		z	1466
$SrOH^+$	aq	x	1103
$SrCl_2$	liq	x	1048
$SrBr_2$	c	rtv	525
		rstv	1465
		mrstv	1495
	liq	rstv	1465
$SrSe$	c	x	695
$Sr(NO_3)_2$	c	rtv	525
		q	875
		mq	1432
		m	1461
		rstv	1465
		rstv	1495
	liq	rstv	1465
$SrPO_4^-$	aq	x	1005
$SrP_2O_7^{--}$	aq	x	1005
$SrP_3O_9^-$	aq	x	1005
$SrP_3O_{10}^{---}$	aq	x	1005
$SrP_4O_{12}^{--}$	aq	x	1005
$SrHPO_4$	aq	x	1005

Substance	State	Prop.	Ref.
$SrH_2PO_4^+$	aq	x	1005
$SrHP_3O_{10}^{--}$	aq	x	1005
$SrCO_3$	c	m	1266
Sr_2SiO_4	c	z	1466
SrB_6	c	kp	596
$Sr(BF_4)_2$	c	x	1280
$4SrO{\cdot}Al_2O_3$	c	np	789
$SrWO_6{\cdot}2H_2O$	c	n	727
$SrWO_6{\cdot}3H_2O$	c	n	727
$SrWO_8{\cdot}2H_2O$	c	n	727
$SrWO_8{\cdot}3H_2O$	c	n	727
$SrO{\cdot}2CaO{\cdot}3Al_2O_3$	c	np	790
BaO	c	km	695
		mx	793
		z	1466
$BaOH^+$	aq	x	1103
$BaCl_2$	c	q	1509
	liq	x	1048
	aq	v	1509
$BaBr_2$	liq	y	802
$BaSO_4$	c	x	1214
		x	1240
BaSe	c	x	695
$Ba(NO_3)_2$	c	q	875
		mq	1432
		m	1461
$BaCO_3$	c	x	1240
$BaSiO_3$	c	z	1466
$BaSi_2O_5$	c	z	1466
Ba_2SiO_4	c	z	1466
$Ba_2Si_3O_8$	c	z	1466
$Ba(BF_4)_2$	c	x	1280
$BaO{\cdot}Fe_2O_3$	c	np	788
$BaO{\cdot}6Fe_2O_3$	c	np	788
$2BaO{\cdot}Fe_2O_3$	c	np	788
$7BaO{\cdot}2Fe_2O_3$	c	np	788
Ra	g	rs	719
		rstv	996
		rs	1516
Li	c	jm	720
		y	785
		v	1196
Li	liq	rtz	1347
	g	rt	614
		rst	971
		rtz	1347
	non-aq	q	973
LiO	g	rt	614
Li_2O	c	km	690
		z	1466
	g	rt	614
LiH	c	m	795
		m	879
	g	rt	614
LiOH	aq	x	847
LiF	c	km	1173
	g	rt	614
		n	1109
		x	1262
$(LiF)_2$	g	x	1173
LiCl	c	km	1173
	g	rt	614
		rstv	707
		n	1109
		x	1262
	aq	x	847
		v	851
$(LiCl)_2$	g	x	1173
$LiClO_4$	c	npq	1011
	aq	q	1155
		q	1502
LiBr	c	km	1173
	g	n	1109
		rstv	707
		x	1262
	aq	qrsz	1199
$(LiBr)_2$	g	x	1173
LiI	c	k	995
		km	1173
	g	rstv	707
		n	1109
		x	1262
$(LiI)_2$	g	x	995
		x	1173
$(LiI)_3$	g	x	995
$LiSO_4^-$	aq	q	1155
Li_2SO_4	c	m	740
		x	1240
	aq	x	847
$LiNO_3$	liq	q	873
		q	874
		q	1412
	aq	x	847

Substance	State	Prop.	Ref.
Li_2CO_3	c	x	1240
C_2H_5Li	liq	km	1100
$LiCl \cdot 4C_2H_5OH$	c	x	1118
Li_2SiO_3	c	z	1466
$Li_2Si_2O_5$	c	z	1466
	amorph	z	1466
$LiFe_5O_8$	c	v	1436
Li_2UO_4	c	np	939
		v	1044
$3LiF \cdot ThF_4$	c	mr	1013
		amr	1515
	liq	amr	1515
Li_2BeF_4	c	mv	815
$LiMg_x$	c	v	1270
Na	c	jm	720
		v	817
		z	1444
	liq	rtz	1347
		k	1365
		z	1444
	g	rst	971
		rtz	1347
		z	1444
	non-aq	q	973
Na^+	g	rst	529
Na_2O	c	z	1466
	liq	k	1418
		z	1466
	g	rt	614
$Na_2O_2 \cdot 8H_2O$	c	n	794
NaH	g	rt	614
NaOH	c	qrstv	899
	g	rt	614
	aq	x	847
		x	1097
		qx	1219
$NaOH \cdot H_2O$	c	rstvmq	899
NaF	c	mrstvz	1395
	liq	rstvz	1395
	g	rt	614
		n	1109
		x	1262
NaCl	c	n	741
		q	908
		kz	1110
		q	1295
		q	1501
		q	1509
NaCl	g	rt	614
		n	1109
		x	1262
		tx	1463
	aq	y	1105
		v	1127
		v	1509
$(NaCl)_2$	g	tx	1463
NaOCl	c	np	1500
$NaClO_2$	c	q	940
$NaClO_2 \cdot 3H_2O$	c	q	940
$NaClO_3$	c	q	940
$NaClO_4$	c	npq	1011
	aq	q	1155
NaBr	c	q	507
		kz	1110
	liq	y	805
	g	n	1109
		x	1262
		tx	1463
$(NaBr)_2$	g	tx	1463
NaOBr	c	np	1500
NaI	g	n	1109
		x	1262
		tx	1463
$(NaI)_2$	g	tx	1463
$NaSO_4^-$	aq	q	1155
		x	1337
Na_2SO_4	c	mv	588
		x	1240
	liq	k	1418
	aq	x	847
$Na_2S_2O_3 \cdot 5H_2O$	c	q	940
Na_2SeO_4	c	q	651
$Na_2SeO_4 \cdot 10H_2O$	c	q	651
Na_2TeO_4	c	r	881
$NaNO_2$	c	v	1447
$NaNO_3$	liq	q	873
		q	874
		q	875
		q	1412
	aq	x	847
Na_2CO_3	c	x	1240
	liq	k	1418
$CH_3CH_2CH_2COONa$	aq	n	1097
$(CH_3)_2CHCOONa$	aq	n	1097

Substance	State	Prop.	Ref.
NaSCN	c	q	1180
		q	1319
	non-aq	v	1180
$NaSCN \cdot 7/2NH_3$	c	a	1319
Na_2SiO_3	c	rv	556
		z	1466
	liq	z	1466
	amorph	z	1466
$Na_2SiO_3 \cdot nH_2O$	c	v	1195
$Na_2Si_2O_5$	c	z	1466
	liq	z	1466
	amorph	z	1466
$Na_2O \cdot 2PbO \cdot 3SiO_2$	c	rv	556
$Na_2O \cdot 3PbO \cdot 6SiO_2$	c	rv	556
$Na_2O \cdot 3PbO \cdot 7SiO_2$	c	rv	518
$3Na_2O \cdot 3PbO \cdot 11SiO_2$	c	rv	518
$Na_2O \cdot 2B_2O_3$	liq	k	1418
$NaBH_4 \cdot 3NH_3$	c	x	553
$NaBH_4 \cdot 9/2NH_3$	c	x	553
$NaAlF_4$	liq	x	1057
Na_3AlF_6	c	m	752
		np	978
		mrstvz	1395
	liq	x	1057
$NaAlSiO_4$	c	z	1466
$NaAlSi_2O_6$	c	np	1162
		z	1466
$NaAlSi_2O_6 \cdot H_2O$	c	np	1162
$NaAlSi_3O_8$	c	tv	1452
		z	1466
	amorph	z	1466
$NaGa_x$	liq	y	803
Na_2MoO_4	c	mp	908
$Na_2Mo_2O_7$	c	mp	908
$NaF \cdot MoF_6$	c	x	1525
Na_2WO_4	c	mpq	908
$Na_2W_2O_7$	c	mp	908
$Na_2W_4O_{13}$	c	mp	908
$NaVO_3$	c	tv	1453
Na_3VO_4	c	tv	1453
$Na_4V_2O_7$	c	tv	1453
$NaCl \cdot xFeCl_3 \cdot yTaCl_5$	liq	x	1292
$NaCl \cdot xFeCl_3 \cdot yZrCl_4$	liq	x	1292

Substance	State	Prop.	Ref.
Na_2UO_4	c	np	939
		v	1044
$(NaF)_3 \cdot UF_6$	c	x	1525
$Na_2O \cdot 2CaO \cdot 3SiO_2$	liq	k	1418
$2Na_2O \cdot CaO \cdot 3SiO_2$	liq	k	1418
K	c	v	817
	liq	k	523
		rtz	1347
	g	j	523
		rst	971
		rtz	1347
	non-aq	q	973
K_2	liq	k	523
	g	jx	523
		x	747
K_2O	c	z	1466
KOH	aq	x	847
KF	c	z	1466
	liq	z	1466
	g	n	1109
		x	1262
KCl	c	tv	566
		q	623
		q	631
		q	659
		km	696
		kz	1110
	liq	k	1507
	g	n	1109
		x	1262
		tx	1463
	aq	v	708
		x	749
		v	851
		y	1106
$(KCl)_2$	g	tx	1463
		x	1507
$KClO_4$	c	np	575
		np	933
KBr	c	tv	566
		kz	1110
	g	n	1109
		x	1262
KI	g	n	1109
		x	1262
		tx	1463
	aq	x	773
KI_3	aq	n	626
$(KI)_2$	g	tx	1463
$KH(IO_3)_2$	c	np	626

Substance	State	Prop.	Ref.
K_2SO_4	c	q	594
		x	1240
		mrv	1275
	liq	kx	1418
$K_2S_2O_7$	liq	x	1050
$K_2S_2O_8$	c	q	966
KNO_3	c	m	903
		m	1148
		v	1245
	liq	q	873
		q	874
		q	875
		q	1412
	aq	x	847
K_2CO_3	c	q	1168
		x	1240
	liq	k	1418
$K_2Si_2O_5$	c	z	1466
	amorph	z	1466
$K_2Si_4O_9$	c	z	1466
	amorph	z	1466
KPb_x	liq	y	804
KGa_x	liq	y	803
$K_2O{\cdot}2B_2O_3$	liq	k	1418
$KAlSi_2O_6$	c	z	1466
$KAlSi_3O_8$	c	z	1466
$KBr{\cdot}xCdBr_2$	liq	y	1343
$KFeCl_4$	liq	km	892
$K_3Fe(CN)_6$	aq	x	936
$K_4Fe(CN)_6$	aq	x	936
K_2PtCl_4	aq	x	983
K_2PtBr_4	aq	x	983
$KPtNH_3Cl_3$	aq	x	983
K_2ReCl_6	c	mqrstv	1117
$KCrMo(CN)_8$	aq	x	1260
KVO_4	aq	np	631
		n	636
		x	659
K_2TiCl_6	c	x	900
$3KCl{\cdot}NdCl_3$	c	k	837
		pq	838
		x	839
		np	1189
$3KCl{\cdot}2NdCl_3$	c	k	837
		pq	838
		np	1189
		x	839
$2KCl{\cdot}PrCl_3$	c	pq	838
$3KCl{\cdot}PrCl_3$	c	k	837
		pq	838
		x	839
		np	1189
$3KCl{\cdot}2PrCl_3$	c	k	837
		pq	838
		x	839
		np	1189
$KCl{\cdot}3CeCl_3$	c	k	837
		pq	838
		x	839
		np	1189
$3KCl{\cdot}CeCl_3$	c	k	837
		pq	838
		x	839
		np	1189
$3KCl{\cdot}2CeCl_3$	c	k	837
		pq	838
		x	839
		np	1189
$KCl{\cdot}3LaCl_3$	c	k	837
		pq	838
		x	839
		np	1189
$2KCl{\cdot}LaCl_3$	c	k	837
		pq	838
		x	839
		np	1189
K_2UO_4	c	np	939
		v	1044
$KCl{\cdot}xMgCl_2$	liq	x	1507
$KMg_3AlSi_3O_{10}F_2$	c	z	1466
$KNO_2{\cdot}2Ba(NO_2)_2$	c	np	731
$2KNO_2{\cdot}Ba(NO_2)_2$	c	np	731
$NaKSO_4$	c	mrv	1275
$Na_2CO_3{\cdot}K_2CO_3$	liq	x	1418
Rb	c	v	817
	liq	rtz	1347
	g	rst	971
		rtz	1347
RbO_2	c	x	917
Rb_2O	c	x	917
Rb_2O_2	c	x	917
RbF	c	mr	582
	g	n	1109
		x	1262

Substance	State	Prop.	Ref.
RbCl	c	kz	1110
	g	n	1109
		x	1262
		tx	1463
$(RbCl)_2$	g	tx	1463
RbBr	c	kz	1110
	g	n	1109
		x	1262
RbI	g	n	1109
		x	1262
	aq	x	773
$RbNO_3$	c	m	1146
	liq	q	873
		q	874
		q	875
		q	1412
Rb_2UO_4	c	np	939
		v	1044
$RbNO_2 \cdot 2Ba(NO_2)_2$	c	np	731
$2RbNO_2 \cdot Ba(NO_2)_2$	c	np	731
$KBr \cdot RbBr$	c	x	774
Cs	c	v	817
	liq	rtz	1347
	g	rst	971
		rtz	1347
CsF	c	kmrt	603
	g	n	1109
		x	1262
$(CsF)_2$	g	x	1132
CsCl	c	mr	582
		kmrt	603
	liq	k	1507
	g	n	1109
		x	1262
		tx	1463
$(CsCl)_2$	g	x	1132
		tx	1463
		x	1507
CsBr	c	kmrt	603
	g	n	1109
		x	1262
$(CsBr)_2$	g	x	1132
CsI	c	mr	582
		kmrt	603
	g	n	1109
		x	1262
$(CsI)_2$	g	x	1132
$CsNO_3$	liq	q	875
Cs_2UO_4	c	np	939
		v	1044
$CsNO_2 \cdot 2Ba(NO_2)_2$	c	np	731
$2CsNO_2 \cdot Ba(NO_2)_2$	c	np	731
Fr^+	aq	pz	801

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Chapter 7

VAPOR PRESSURE AND HEAT OF SUBLIMATION OF ALUMINUM TRIFLUORIDE BY THE TRANSPIRATION METHOD FROM 1230° TO 1290°K

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A new apparatus has been constructed and tested at the National Bureau of Standards for applying the transpiration or gas-flow method to measure certain solid-gas equilibria involving light elements at elevated temperatures. For the first high-temperature measurements with the apparatus, the determination of the vapor pressure of aluminum fluoride was selected, mainly for the following four considerations.

First, the high stability of anhydrous aluminum fluoride and the ease of obtaining a sample of at least fairly high purity make it suitable for testing the precision of the method and the particular apparatus.

Second, aluminum fluoride is a very important light-element compound. A recent value for the standard heat of formation of the solid was reported as the result of accurate fluorine combustion calorimetry at NBS [1]. Accurate high-temperature vapor pressures give the best way to determine the equally important standard heat of formation of the gas.

Third, there are inconsistencies in the value, a physical constant, for the standard heat of sublimation to form the monomer (AlF_3) at absolute zero, as reported from the measurements of vapor pressure as a function of temperature by several earlier investigators. Both Olbrich [2] and Ruff et al. [3] made measurements from about 1370 to 1550°K. Witt et al. [4, 5], Evseev et al. [6], and Hildenbrand et al. [7] each covered the range from about 970 to 1100°K by the effusion torsion method. Naryshkin [8] and Gross et al. [9] have also reported studies. Different methods in different temperature ranges contribute to varying accuracies. One obvious reason for the apparent discrepancy among the reported standard heat-of-sublimation values calculated by the Third Law method, is the use of different estimations for the entropy (or free energy) of gaseous aluminum fluoride by the respective investigators; namely, one table of thermodynamic functions was used by Witt et al.; another by Evseev et al.; and a third by Hildenbrand et al. and in the analysis of the data of Olbrich and of Ruff et al. by Douglas et al. [10]. But even when the respective, observed vapor-pressure data are compared by use of the NBS Thermodynamic Tables [11], the heat of sublimation values vary as stated in Table 1.

Another source of discrepancy is that the apparent, calculated value, $\Delta_s h^\circ_o(m)$, for the standard heat of sublimation to form one mole of monomer at absolute zero, determined by the Third Law method, assumes that the saturated vapor state of aluminum fluoride is all monomeric over the whole measured temperature range. However, as pointed out by Douglas et al. [10], if the vapor state consisted also of associated molecules such as the dimer (Al_2F_6), then

$$\Delta_s h_o^o(m) \leq \Delta_s H_o^o(m) \qquad (1)$$

where $\Delta_s H_o^o(m)$ is the real standard heat of sublimation to form one mole of monomer at absolute zero.

Fourth, the use of different vapor-pressure methods in different temperature ranges affords some opportunity to evaluate the composition of the saturated vapor. Contrary to an earlier speculation of Douglas et al. [10], a recent mass-spectrographic study [12] has indicated that the saturated vapor state of aluminum fluoride contains a considerable ratio of the dimer (Al_2F_6) to the monomer (AlF_3) in the temperature range of the vapor-pressure measurements made between 965 and 1065°K. Heretofore, this ratio has been assumed as zero by other investigators. At higher temperatures and subsequently higher vapor pressures, even a greater ratio of dimer to monomer would be expected. Finding the best assignment of the monomer-dimer ratio which is consistent with the available data and which gives a non-drifting value for $\Delta_s H_o^o(m)$ as a function of temperature would enable a recalculation of the standard heat of formation of the gaseous monomer. The dimer-monomer ratio is particularly important at high temperatures such as near the sublimation temperature (>1500°K), since the preponderance of dimer in the saturated vapor which appears to exist under such conditions would cause a large error in the free energy of monomer calculated with the neglect of vapor association.

Apparatus and Procedure

The transpiration apparatus used in this work has been briefly described in an earlier NBS Report [13]. Essentially, the method involves the flowing of inert argon gas into the transpiration apparatus, consisting of a vapor-cell chamber to hold the sample of crystalline aluminum fluoride and of a condenser to collect the transpired vapor. The apparatus is contained in a high-temperature furnace whose temperature is measured and controlled with thermocouples, and the flowing argon gas is collected in a "meter-prover."

The one-meter-long cylindrical furnace with an alumina tube of 1.8 cm I.D. along the axis of the furnace is heated with Pt-20% Rh resistance wire wound about another alumina tube of 5.8 cm O.D. concentric to the former. Sandwiched between these alumina tubes in the center of the furnace is a 42 cm-long nickel cylindrical core with 1.1 cm wall thickness to minimize temperature gradients. The gradients over this 42 cm central 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 similar nickel cylinders that are separated by 5 cm-long ceramic spacers from the central core. The nickel is contained in an inert nitrogen gas to prevent corrosion and consequent reduction in thermal conductivity and melting point. The furnace is operated at a given temperature to balance the heat dissipation of the furnace by introducing a continuous flow of electrical energy which is manually adjusted through the use of Pt/Pt-10% Rh differential thermocouples imbedded within the walls of the central nickel core. Furnace temperatures are measured by taking the

mean of two calibrated Pt/Pt-10% Rh absolute thermocouples, referred to an ice-bath reference junction and read to ±0.5 microvolt with a Diesselhorst Type 3589 S potentiometer. One thermocouple is placed through the wall and in the center of the central nickel core and the other, along the axis of the furnace at one end of the housing for the vapor cell and condenser tube.

Having been previously passed through a column of Drierite to remove traces of water vapor, the inert argon gas flow into the transpiration apparatus is monitored at 30 to 40 cc/min by a National Instrument Laboratory Vol-O-Flo meter. The total pressure of the vapor-cell chamber through which the argon is flowing, is taken as the sum of the average barometric pressure and the difference in heights, approximately 5 to 8 mm, of an open-end mercury manometer, connected to the system during the course of the run. After passing through the vapor cell and condenser, the number of moles of the inert gas is determined by collecting it at room temperature in an American Meter Company 60-liter "meter-prover" which measures continuously at barometric pressure the total inert-gas volume with a precision of 0.1% or better for a normal experiment. The volume is corrected for initial and final changes in room temperature and barometric pressure.

The vapor cell and condenser are opposite ends of the same Pt-10% Rh tube with 1.3 cm diameter and 92 cm length as illustrated as item 4 in Figure 1. The sample of aluminum fluoride is contained in Pt-10% Rh boats separated from the tube by the use of a pyrolytic-graphite sled to prevent sticking of metal surfaces at high temperatures. The 20-cm-long vapor cell holding the sample is adjoined to the condenser with a 1 mm I.D. capillary of 10 cm length to minimize vapor transport by diffusion and heat loss out the ends by radiation. The vapor cell-condenser tube is housed in another Pt-10% Rh tube with 1.5 cm diameter and 72.5 cm length, concentric to the former and separated with a pyrolytic-graphite tube. The incoming inert gas passes between the walls of these two concentric tubes on its way to the vapor cell.

The sample of anhydrous aluminum fluoride was obtained through the courtesy of George Long from the Alcoa Research Laboratories, New Kensington, Pa. It had been sublimed at 1050°C in a nickel retort. An NBS spectrographic analysis reported 0.01 to 0.1% magnesium, 0.001 to 0.01% nickel, and lesser traces of other metallic elements. An NBS chemical analysis reported a mean value of 32.15 ± 0.02 percent aluminum, while the theoretical value is 32.130 percent. The degree of saturation of the flowing inert gas with the aluminum fluoride vapor in the vapor cell was indicated by a comparison of the loss of sample from successive boats, the second losing about 4 percent of the first. The amount of aluminum fluoride that transpired during the course of an experiment was measured by taking the difference of the initial and final weighings of the vapor cell-condenser tube, weighing about 160 g. Most of the runs employed a precision analytical balance where the vapor cell—condenser tube was suspended vertically in an enclosed chamber below the balance. However, the last few runs employed a precision analytical Sartorius balance, having a precision of ±0.2 mg. The tube was placed horizontally upon the balance pan and both were encased in a chamber to prevent stray air currents.

Results

The vapor pressure of aluminum fluoride as a function of temperature was computed from the experimental data by assuming that both the inert argon gas and the aluminum fluoride vapor are ideal and that the aluminum fluoride vapor was all monomeric, having a molecular weight of 83.977. Also the flowing inert argon gas is assumed to be saturated with the aluminum fluoride vapor. The total pressure P_t is proportional to the total number of gaseous moles N_t present, and for each component in the gaseous mixture, the partial pressure P_i is proportional to N_i. By Dalton's law,

$$P_t = \Sigma P_i \quad \text{and} \quad N_t = \Sigma N_i \ . \tag{2}$$

Hence, for an inert-gas flow and one vapor species, the observed partial pressure P_{obs} of aluminum fluoride has been derived as

$$P_{obs} = \frac{(\overline{P}_b + \Delta\overline{h})}{1 + \frac{M\overline{P}_b V}{wRT_p}} \ ; \tag{3}$$

where $\overline{P}_b$ = mean barometric pressure during run,

$\Delta\overline{h}$ = mean difference in heights of open-end manometer,

M = molecular weight of aluminum fluoride,

P_b = final barometric pressure,

V = final, corrected volume of argon gas collected in "meter-prover,"

w = mass of condensed aluminum fluoride,

R = universal gas-law constant, and

T_p = final room-temperature of "meter-prover."

The computed values of P_{obs} are reported in Table 2 as a function of temperature and are illustrated as the experimental points on Figure 2.

Assuming that the aluminum fluoride vapor is all monomeric, the standard heat of sublimation, $\Delta_s h_o^o(m)$, of the crystalline form (c) to form one mole of monomer (m) at absolute zero was calculated by the Third Law method using the NBS Thermodynamic Tables [11]. The relationship is given by

$$\Delta_s h_o^o(m)/RT = [-(F^o - H_o^o)/RT]_m - [-(F^o - H_o^o)/RT]_c - \ln P_{obs}(atm) \ . \tag{4}$$

The calculated values of $\Delta_s h_o^o(m)$ for each pressure measurement are reported in Table 2. The mean value of $\Delta_s h_o^o(m)$ was found to be 70.52 kcal/mol with a standard deviation of 0.054. The curve on Figure 2 was determined by recalculating the vapor pressure at each corresponding temperature by the Third-law method from the mean value of $\Delta_s h_o^o(m)$. The precision of the vapor-pressure measurements is stated in the last column of Table 2. By inspection of

Figure 2, the reader will observe no particular and regular drift of the observed points in reference to the calculated curve over the temperature range of this work; hence, the temperature range of this work is too narrow to judge a drifting of the $\Delta_s h_o^o(m)$ values with temperature to account for probable dimerization.

Discussion

When the values, $\Delta_s h_o^o(m)$, (previously defined in this report) as calculated from the data of previous investigators (see Table 1) are compared with the NBS work (see Table 2), they are found to be not in good agreement. Of course, the inconsistencies might be partially brought about by the use of different methods in different temperature ranges. Even the uncertainty of the same method over the same temperature range by different investigators casts suspicion upon the accuracy of the measurements. For example, Witt [4] and Hildenbrand et al. [7] each used the torsion-effusion method to measure the vapor-pressure of aluminum fluoride over the approximately same temperature range, namely, about 960 to 1100°K; yet the mean values of $\Delta_s h_o^o(m)$ were 71.05 kcal/mole for Witt's measurements around 1000°K, and 70.74 kcal/mole for Hildenbrand's measurements around 1050°K.

The mean value of $\Delta_s h_o^o(m)$ determined from the NBS data which gives 70.52 kcal/mole for measurements around 1250°K, is lower than any of those submitted for the lower-temperature measurements. Likewise, the mean values of $\Delta_s h_o^o(m)$ determined by Ruff et al. [3] are lower, namely, 70.37 kcal/mole as the mean for measurements around 1425°K and 69.72 kcal/mole, around 1500°K. We may give lesser weight to his measurements at the lower end of his temperature range because superheating of the solid more likely occurs at lower pressures. We are also considering that the work of Ruff supersedes that of Olbrich [2], and that the works of both Naryshkin [8] and Gross et al. [9] are too aberrant from those of the other investigators to be considered.

The regular decreasing of the value, $\Delta_s h_o^o(m)$, for measurements of the vapor pressure of aluminum fluoride made at increasing temperatures (see column 2 of Table 3) suggests that dimerization of the aluminum fluoride vapor takes place more appreciably at higher temperatures. Considering that $\Delta_s h_o^o(m) \leq \Delta_s H_o^o(m)$ as mentioned earlier in this report, we realize that in the case for aluminum fluoride if we were to correct the vapor pressure measurements at the higher temperatures for dimerization, we could calculate a correspondingly higher value for the heat of sublimation, being a closer approximation to $\Delta_s H_o^o(m)$.

The work of Porter et al. [12] shows that there is a considerable extent of dimerization in the temperature range of the measurements. An equation was derived from the work of Porter et al. to express the equilibrium

constant, K, for the following reaction as a function of temperature.

$$Al_2F_6(g) = 2\ AlF_3(g). \qquad (5)$$

For the basic relationship,

$$\Delta F^\circ = -RT\ \ell n\ Kp = \Delta H^\circ - T\Delta S^\circ, \qquad (6)$$

Porter et al. had given measured values of K from 965 to 1065°K (see points on Figure 3) by using his own mass spectroscopic data and the pressure measurements of Witt et. al. [5]. The value for ΔS° had been estimated by Porter et al. to be 32 ± 3 eu at 1000°K. Assuming that $\Delta Cp = -2R$, corresponding to the change in the equipartitional heat capacity for the reaction in eq. (5), we have

$$-\log K\ (atm) = 10{,}799/T - 13.250 + 2.013 \log T \qquad (7)$$

if $\Delta S^\circ_{1000} = 29$ eu and $K = (1.13)10^{-4}$ atm at 965°K. The expression for the other boundary of K was found to be

$$-\log K\ (atm) = 11{,}599/T - 14.560 + 2.013 \log T \qquad (8)$$

if $\Delta S^\circ_{1000} = 35$ eu and $K = (37.8)10^{-4}$ atm at 1065°K. Equations (7) and (8) were so determined so as to approach a "maximum" and a "minimum" limit respectively for the value of the equilibrium constant by passing them through the mentioned points as illustrated on Figure 3. Note that a Second-law treatment of the work of Porter et al. would give a curve with greater values at higher temperatures than the "maximum" curve.

Referring to the assumption that the vapor was all monomeric for the calculation of the NBS "observed" vapor pressure from eq. (3), the following approximation will be valid in the NBS transpiration study since the moles of argon passed over the crystalline aluminum fluoride is so much greater than that of the transpired vapor.

$$P_{obs} = P_m + 2P_d \qquad (9)$$

where P_m = the partial vapor pressure of the monomer,

and P_d = the partial vapor pressure of the dimer.

However, for the direct pressure measurements of Ruff et al. and the torsion-effusion method of Hildenbrand et al., the following statement holds:

$$P_{obs} = P_m + P_d. \qquad (10)$$

Therefore, realizing that $K = P_m^2/P_d$, the correction of the NBS work for dimerization can be found from

$$P_m = [-K + \sqrt{K (K + 8 P_{obs})}] / 4. \qquad (11)$$

Comparing the mean values of $\Delta_s h^o_o(m)$ from Ruff, et al.; Hildenbrand et al.; and this work, the "maximum" and "minimum" values for $\Delta_s H^o_o(m)$ were computed along with the corresponding mol fraction of dimer, N_d, as stated in Table 3. These respective values for the heat of sublimation, assuming no dimerization, assuming "minimum" dimerization, and assuming "maximum" dimerization are illustrated on Figure 4. The dashed line gives the mean from the work of Hildenbrand et. al. and Witt et al.

The NBS measurements give a value for $\Delta_s H^o_o(m)$ agreeing with lower-temperature torsion-effusion results when correction for dimerization, approximate to what Porter et al. had shown, is applied. The older vapor-pressure measurements at higher temperatures are not in disagreement with this interpretation, but they are not precise enough to give definite information on the extent of dimerization. All results agree, however, in eliminating the possibility of the "maximum" limits of dimerization; but the NBS and lower-temperature results considered together indicate that at least some dimerization occurs.

Table 1

NBS Calculation of the Value, $\Delta_s h^o_o(m)$, for the Heat of Sublimation* of Aluminum Fluoride from the Vapor Pressure Data of Previous Investigators

A. Olbrich [2]

T (°K)	P_{obs} (atm)	$\Delta_s h^o_o(m)$ (kcal/mole)
1371	0.0216	73.22
1396	0.0439	72.49
1417	0.0793	71.84
1454	0.1720	71.34
1491	0.3351	71.03
1519	0.4811	71.16
1548	0.7288	71.12
1556	0.8649	70.93
1567	1.0092	70.89

B. Ruff et al. [3]

T (°K)	P_{obs} (atm)	$\Delta_s h^o_o(m)$ (kcal/mole)
1367	0.0408	71.29
1391	0.0651	71.16
1409	0.1066	70.63
1417	0.1513	70.02
1447	0.2105	70.44
1460	0.263	70.38
1472	0.392	69.74
1492	0.5480	69.61
1524	0.808	69.80

C. Naryshkin [8]

T (°K)	P_{obs} (atm)	$\Delta_s h^o_o(m)$ (kcal/mole)
1108	0.1224	71.37
1188	1.797	69.91
1273	4.034	72.56

D. Gross et al. [9]

T (°K)	$P_{obs}10^3$ (atm)	$\Delta_s h^o_o(m)$ (kcal/mole)
1193	3.22	68.81

E. Witt [4]

T (°K)	$P_{obs}10^6$ (atm)	$\Delta_s h^o_o(m)$ (kcal/mole)
955.2	1.008	71.079
962.7	1.336	71.076
972.5	1.922	71.067
982.4	2.750	71.094
994.7	4.253	71.052
1004.9	6.149	71.013
1062.7	40.18	70.951
Mean		71.05
Std. deviation		0.046

F. Evseev et al. [6]

T (°K)	$P_{obs}10^5$ (atm)	$\Delta_s h^o_o(m)$ (kcal/mole)
980	0.1697	71.84
1000	0.408	71.50
1015	0.760	71.27
1031	1.1507	71.49
1040	1.882	71.07
1053	2.796	71.09
1064	3.825	71.14
1073	5.796	70.82
1088	9.583	70.68
1093	11.07	70.68
1103	15.26	70.59
1123	27.66	70.48
Mean		71.05
Std. deviation		0.40

G. Hildenbrand et al. [7]

T (°K)	$P_{obs}10^5$ (atm)	$\Delta_s h^o_o(m)$ (kcal/mole)
991.7	0.46	70.692
1011.7	0.94	70.621
1034.8	1.87	70.747
1056.8	3.74	70.727
1072.6	5.92	70.756
1087.9	9.11	70.784
1097.8	12.0	70.795
1101.4	13.2	70.807
Mean		70.74
Std. deviation		0.057

*Standard Heat of Sublimation of crystalline aluminum fluoride to form one mole of monomer at absolute zero by the Third-law Method, using the thermodynamic functions from NBS Tables [11], and assuming that the vapor is all monomeric.

Table 2

NBS Observed Vapor Pressure of Aluminum Fluoride and Calculated Values, $\Delta_s h_o^o(m)$, for the Heat of Sublimation *

Date	Flow Rate (cc/min)	V (ℓ)	w (g)	$P_{obs.}$ (mm)	T (°K)	$\Delta_s h_o^o(m)$ (kcal/mole)	** $P_{calc.}$ (mm)	$\frac{P_{obs}-P_{calc}}{P_{calc}}$ (%)
10/31/62	31.4	5.00	0.0635	2.828	1232.8	70.62	2.947	-4.04
1/7/63	31.3	4.91	0.0633	2.897	1232.8	70.56	2.947	-1.70
9/21/62	42.9	4.92	0.0840	3.787	1243.9	70.49	3.752	0.93
9/26/62	26.5	3.98	0.0667	3.706	1244.1	70.56	3.768	-1.65
1/11/63	28.5	4.93	0.0856	3.910	1245.7	70.51	3.899	0.28
11/2/62	31.4	4.07	0.0715	3.909	1246.3	70.54	3.950	-1.04
11/21/62	42.6	2.98	0.0607	4.548	1252.5	70.49	4.509	0.86
9/18/62	39.9	3.99	0.0900	4.986	1256.0	70.45	4.857	2.66
9/20/62	41.6	4.00	0.0917	5.068	1256.9	70.46	4.951	2.36
7/6/62	33.7	5.00	0.1320	5.852	1265.7	70.56	5.950	-1.65
9/14/62	37.1	4.00	0.1092	6.035	1265.7	70.48	5.950	1.43
7/18/62	35.0	3.99	0.1167	6.475	1270.8	70.57	6.617	-2.15
9/13/62	40.0	3.97	0.1183	6.598	1271.6	70.56	6.721	-1.83
9/6/62	36.2	3.98	0.1274	7.105	1272.6	70.43	6.864	3.51
9/12/62	40.2	4.47	0.1541	7.623	1276.1	70.43	7.373	3.39
11/30/62	30.6	2.97	0.1233	9.240	1286.9	70.50	9.177	0.69
11/29/62	31.8	4.97	0.2060	9.209	1288.0	70.56	9.382	-1.84
						Mean = 70.52		
						Standard deviation = 0.054		

* Standard Heat of Sublimation of crystalline aluminum fluoride to form one mole of monomer at absolute zero by the Third-law Method, using the thermodynamic functions from NBS Tables [11], and assuming that the vapor is all monomeric.

** Calculated from the mean value of $\Delta_s h_o^o(m)$.

Table 3

Comparison of the "Maximum" and "Minimum" Limits of $K^{(c)}$ for the Dimerization of Aluminum Fluoride Vapor with the Corresponding Values of $\Delta_s H_0^o(m)^{(d)}$ and the Mol Fraction of Dimer, N_d.

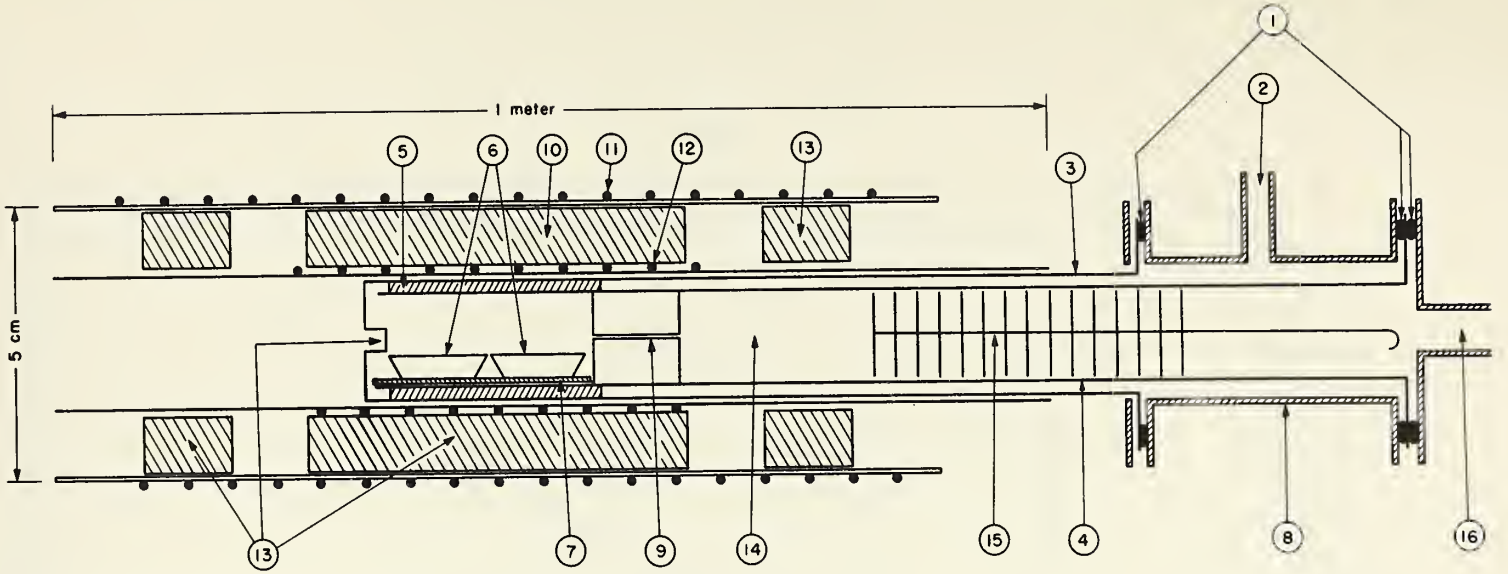
T (°K)	$\Delta_s \bar{h}_0^o(m)^{(a)}$ (kcal/mole)	$P_{obs}^{(b)}$ (atm)	$K^{(c)}$ (atm)	P_m (atm)	$\Delta_s H_0^o(m)^{(d)}$ (kcal/mole)	N_d (%)
1050	70.74	$(3.02)10^{-5}$	$(6.81)10^{-4}$	$(2.90)10^{-5}$	70.82	4.0
1050	70.74	$(3.02)10^{-5}$	$(2.70)10^{-3}$	$(3.00)10^{-5}$	70.75	0.7
1250	70.52	$(5.62)10^{-3}$	0.0238	$(4.16)10^{-3}$	71.27	14.9
1250	70.52	$(5.62)10^{-3}$	0.1115	$(5.14)10^{-3}$	70.74	4.4
1425	70.37	0.1530	0.210	0.1027	71.50	32.9
1425	70.37	0.1530	1.178	0.1370	70.68	10.5
1500	69.72	0.599	0.455	0.342	71.39	42.9
1500	69.72	0.599	2.72	0.504	70.23	15.8

(a) $\Delta_s \bar{h}_0^o(m)$ = mean value for the standard heat of sublimation to form one mole of monomer at absolute zero assuming that the vapor is all monomeric. Values were taken from Ruff and Hildenbrand on Table 1, and the NBS work on Table 2.

(b) Calculated from the corresponding mean values of $\Delta_s \bar{h}_0^o(m)$ by the Third Law method.

(c) K = equilibrium constant for the reaction $Al_2F_6(g) = 2AlF_3(g)$.

(d) $\Delta_s H_0^o(m)$ = standard heat of sublimation to form one mole of monomer at absolute zero, correcting for dimerization.

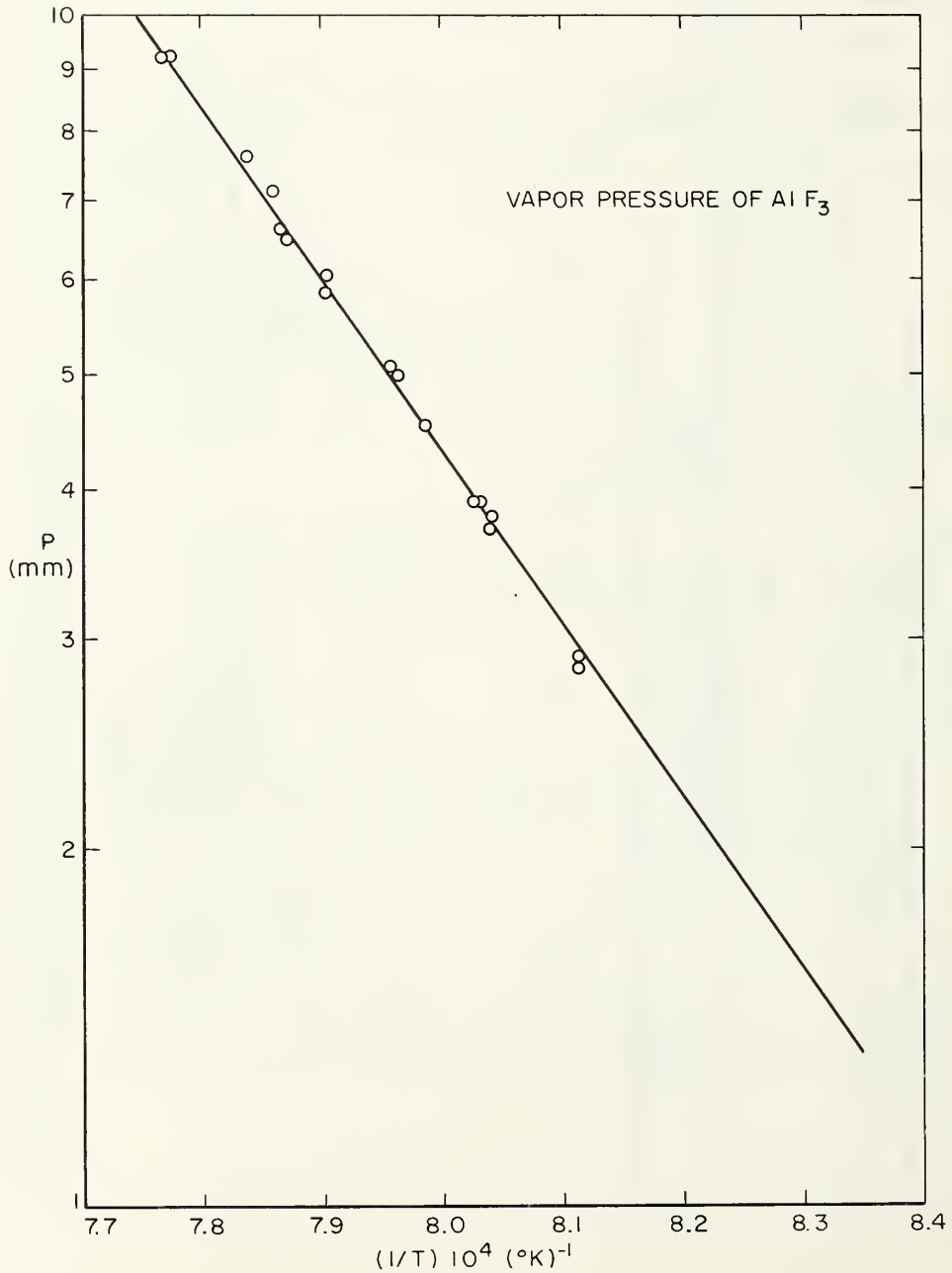


1	O-rings	9	Capillary
2	Inert gas inlet	10	Central Ni cylindrical core
3	Pt-10%Rh outer housing	11	Main heaters
4	Pt-10%Rh vapor cell-condenser	12	Auxillary heater (omitted this work)
5	Pyrolytic graphite cylinder	13	Thermocouple locations
6	Pt-10%Rh sample boats	14	Condenser
7	Pyrolytic graphite sled	15	Condenser baffle
8	Base metal connector	16	Inert gas outlet

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

Figure 1

Figure 2. VAPOR PRESSURE OF AlF_3. The points are NBS observed vapor pressure of aluminum fluoride as a function of temperature. Curve is calculated by Third-law method from the mean value of the standard heat of sublimation to form one mole of monomer at absolute zero, $\Delta_s h^o_o(m)$ = 70.52 kcal/mole, assuming that the vapor is all monomeric.



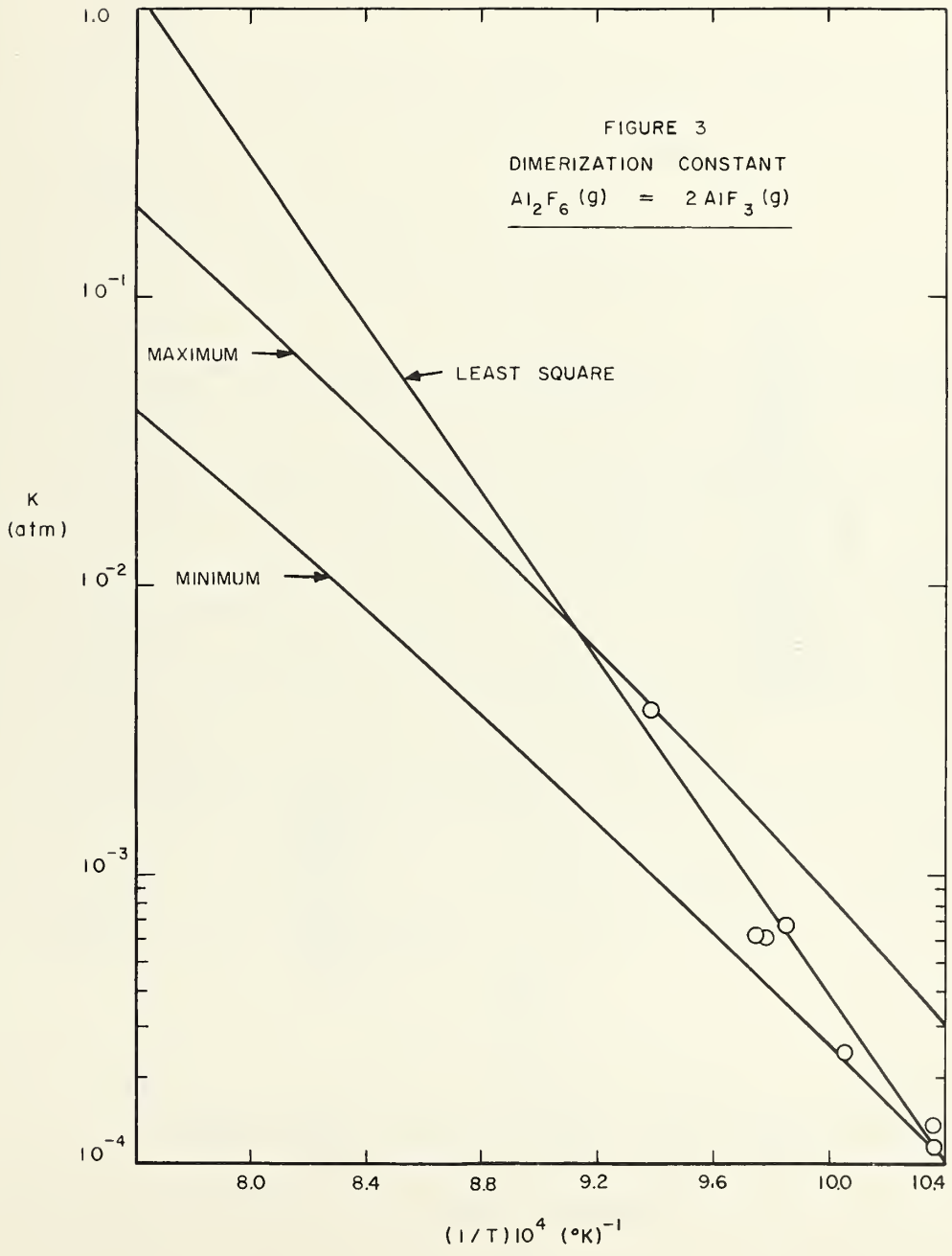


FIGURE 3

DIMERIZATION CONSTANT

Al_2F_6 (g) = 2 AlF_3 (g)

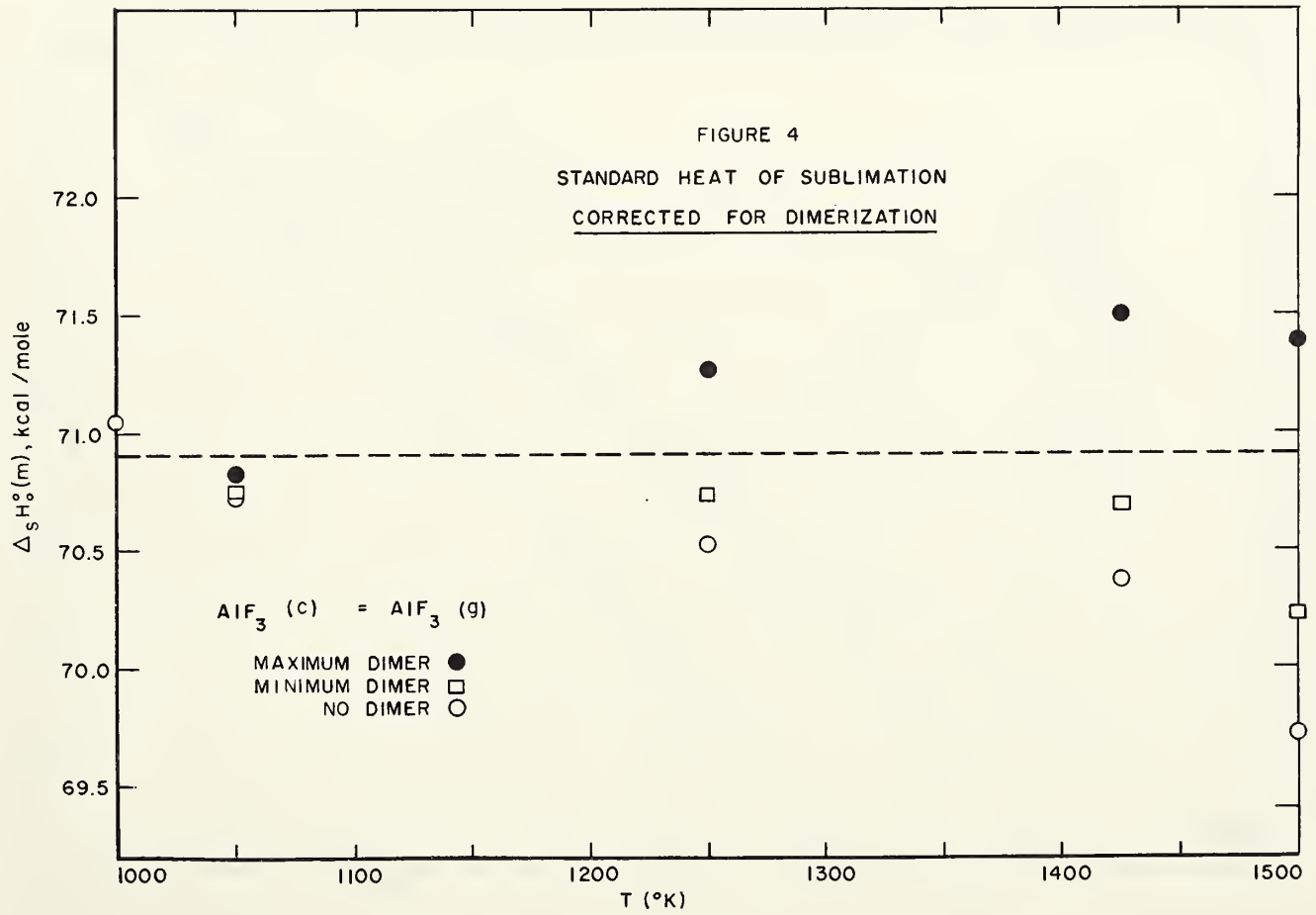


FIGURE 4
STANDARD HEAT OF SUBLIMATION
CORRECTED FOR DIMERIZATION
72.0
71.5
71.0
70.5
70.0
69.5
$\Delta_s H^\circ_o(m)$, kcal / mole
AlF_3 (c) = AlF_3 (g)
MAXIMUM DIMER
MINIMUM DIMER
NO DIMER
1000
1100
1200
1300
1400
1500
T (°K)

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