Thomas K. Fobe Sr.

Technical Note 270-1

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES

PART 1. TABLES FOR THE FIRST TWENTY-THREE ELEMENTS IN THE STANDARD ORDER OF ARRANGEMENT

D. D. WAGMAN, W. H. EVANS, I. HALOW, V. B. PARKER,
S. M. BAILEY, AND R. H. SCHUMM

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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ISSUED OCTOBER 1, 1965

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Institute for Basic Standards
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Washington, D.C.

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Washington, D.C., 20402 - Price 65 cents

FOREWORD

This Technical Note is an advance issue of a revision of the tables of Series I of the National Bureau of Standards Circular 500, Selected Values of Chemical Thermodynamic Properties, by F. D. Rossini, D. D. Wagman, W. H. Evans, S. Levine and I. Jaffe. The revision, prepared in response to the increasing demand and need in the scientific community for a more current, self-consistent set of thermodynamic data for chemical substances, is part of a continuing program of the NBS Thermochemistry Section.

Technical Note 270-1 contains the revised Tables 1-22 and part of Table 23 of Circular 500. As additional revised tables are completed, they will be published as Technical Notes 270-2, 270-3, etc., until the complete revision has been made available. It was decided to issue this Note in parts in order to make the material available as soon after completion as practical. The complete revision of the tables of Series I, including references and discussion of the sources of the values, will be published as a contribution in the National Standard Reference Data Series.

The authors will greatly appreciate receiving comments regarding errors that may have escaped their attention.

Robert D. Huntoon, Director,
Institute for Basic Standards,
National Bureau of Standards.

PREFACE

The preparation of these tables has been the result of the combined efforts of a number of members of the staff of the Thermochemistry Section. Among these are Mrs. Rachel M. Dudley, who is supervisor of the bibliographic and data-abstracting portions of the program and has aided in the final editing of this Note, her assistant Mrs. Joyce J. Grimes, Bernard Bettis and Mrs. Catherine L. Nelson, who have served as abstractors of technical data and have performed many of the calculations. The typing assistance of Mrs. Barbara B. Lineberry and Mrs. Wilma Bell is also gratefully acknowledged.

The Office of Naval Research, U. S. Atomic Energy Commission, and the Office of Standard Reference Data have contributed financial support to this program over the past several years.

Donald D. Wagman, Chief,
Thermochemistry Section.

CONTENTS

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES

by

Donald D. Wagman, William H. Evans, Iva Halow,
Vivian B. Parker, Sylvia M. Bailey, and Richard H. Schumm

INTRODUCTION

Substances and Properties Included in the Tables

The tables contain values where known of the enthalpy and Gibbs energy of formation, enthalpy, entropy and heat capacity at 298.15 °K (25 °C), and the enthalpy of formation at 0 °K, for all inorganic substances and organic molecules containing not more than two carbon atoms. In some instances, such as metal-organic compounds, data are given for substances in which each organic radical contains one or two carbon atoms.

No values are given in these tables for metal alloys or other solid solutions, fused salts, or for substances of undefined chemical composition.

Physical States

The physical state of each substance is indicated in the column headed "State" as crystalline solid (c), liquid (liq), glassy or amorphous (amorp), or gaseous (g). Solutions in water are listed as aqueous (aq).

Definition of Symbols

The symbols used in these tables are defined as follows: P = pressure; V = volume; T = absolute temperature; E = intrinsic or internal energy; S = entropy; H = E + PV = enthalpy (heat content); G = H - TS = Gibbs energy (formerly the free energy); $C_p = (dH/dT)_p$ = heat capacity at constant pressure.

Conventions Regarding Pure Substances

The values of the thermodynamic properties of the pure substances given in these tables are for the substances in their standard states (indicated by the superscript ° on the thermodynamic symbol). These standard states are defined as follows:

For a pure solid or liquid, the standard state is the substance in the condensed phase under a pressure of one atmosphere.

For a gas the standard state is the hypothetical ideal gas at unit fugacity, in which state the enthalpy is that of the real gas at the same temperature and at zero pressure.

The values of Δ Hf° and Δ Gf° given in the tables represent the change in the appropriate thermodynamic quantity when one gram-formula weight of the substance in its standard state is formed, isothermally at the indicated temperature, from the elements, each in its appropriate standard reference state. The standard reference state at 25°C for each element except phosphorus has been chosen to be the standard state that is thermodynamically stable at 25°C and at one atmosphere pressure. For phosphorus the standard reference state is the crystalline white form; the more stable forms have not been well characterized thermochemically. The same reference states have been maintained for the elements at 0°K except for the liquid elements bromine and mercury, for which the reference states have been chosen as the stable crystalline forms. The standard reference states are indicated in the tables by the fact that the values of Δ Hf° and Δ Gf° are exactly zero.

The values of $H^\circ_{298.} - H^\circ_0$ represent the enthalpy difference for the given substance between 298.15°K and 0°K. If the indicated standard state at 25°C is the gas, the corresponding state at 0°K is the hypothetical ideal gas; if the state at 25°C is solid or liquid, the corresponding state at 0°K is the thermodynamically stable crystalline solid, unless otherwise specifically indicated.

The values of S° represent the virtual or "thermal" entropy of the substance in the standard state at 298.15°K, omitting contributions from nuclear spins. Isotope mixing effects, etc., are also excluded except in the case of the hydrogen-deuterium (^1H-^2H) system. Where data have been available only for a particular isotope, they have been corrected when possible to the normal isotopic composition.

The values of the enthalpies of formation of gaseous ionic species are computed on the convention that the value of ΔHf° for the electron is zero. Conversions between 0 and 298.15°K are calculated using the value of $H^\circ_{298} - H^\circ_0$ = 1.481 kcal per mole of electrons, and assuming that the values of $H^\circ_{298} - H^\circ_0$ for the ionized and un-ionized molecules are the same.

Conventions Regarding Solutions

Solutions in water are designated as aqueous (aq); other solvents are designated by name or chemical formula. The concentration of the solution is expressed in terms of the number of moles of solvent associated with one mole of the solute. If no concentration is indicated, the solution is assumed to be "dilute".

The standard state for a solute in aqueous solution is taken as the hypothetical ideal solution of unit molality (indicated as "std. state, m = 1"). In this state the partial molal enthalpy and heat capacity of the solute are the same as in the infinitely dilute real solution. For non-aqueous solutions the standard state of the solute is the hypothetical ideal solution of unit mole fraction of solute ("std. state, $x_2 = 1$").

The value of Δ Hf° given in the tables for a solute in its standard state is the apparent molal enthalpy of formation of the substance in the infinitely dilute real solution. At this dilution the partial molal enthalpy is equal to the apparent molal quantity. At concentrations other than the standard state, the value of Δ Hf° represents the apparent enthalpy of the reaction of formation of the solution from the elements comprising the solute, each in its standard reference state, and the appropriate total number of moles of solvent. In this representation the value of Δ Hf° for the solvent is not required. The experimental value for a heat of dilution is obtained directly as the difference between the two values of Δ Hf° at the corresponding concentrations.

The values of the thermodynamic properties tabulated for the individual ions in aqueous solution are based on the usual convention that the values of ΔHf°, ΔGf°, S° and C_p° for H^+ (aq, std. state, m = 1) are zero. The properties of a neutral electrolyte in aqueous solution in the standard state are equal to the algebraic sum of these values for the appropriate kinds and number of individual ions assumed to constitute the molecule of the given electrolyte. When the undissociated species, rather than the sum of the ions, is meant, the notation "undissociated" or "un-ionized" is used. For an ionic species the properties tabulated refer to that undissociated ion. By adopting the above convention with respect to aqueous H^+, it follows that the thermodynamic relation Δ Gf° = Δ Hf° - T Δ Sf° will not hold for an individual ionic species. However no problem arises when neutral chemical systems are considered.

Unit of Energy and Fundamental Constants

All of the energy values given in these tables are expressed in terms of the thermochemical calorie. This unit, defined as equal to 4.1840 joules, is generally accepted for the presentation of chemical thermodynamic data. Values reported in other units have been converted to calories by means of the conversion factors for molecular energy given in Table A.

The following values of the fundamental physical constants have been used in these calculations:

R = gas constant = 8.3143 ± 0.0012 J/deg mol = 1.98717 ± 0.00029 cal/deg mol

F = Faraday constant = 96487.0 ± 1.6 coulombs/mol = 23060.9 ± 0.4 cal/volt equivalent

Z = Nhc = 11.96258 ± 0.00107 J/cm^{-1} mol = 2.85912 ± 0.00026 cal/cm^{-1} mol

c_2 = second radiation constant = hc/k = 1.43879 ± 0.00015 cm deg

0°C = 273.15°K

These constants are consistent with those given in the Table of General Physical Constants, recommended by the National Academy of Sciences National Research Council[1]. The formula weights in the tables have been calculated for the molecular formula given in the Formula and Description column using the 1961 Table of Relative Atomic Weights based on the atomic mass of ^{12}C = 12 exactly[2].

Internal Consistency of the Tables

All of the values given in these tables have been calculated from the original articles, using consistent values for all subsidiary and auxiliary quantities. The original data were corrected where possible for differences in energy units, molecular weights, temperature scales, etc. Thus we have sought to maintain a uniform scale of energies for all the substances in the tables. In addition the tabulated values of the properties of a substance satisfy all the known physical and thermodynamic relationships among these properties. The quantities Δ Hf°, Δ Gf°, and S° at 298.15°K satisfy the relation:

$$\Delta Gf° = \Delta Hf° - T \Delta Sf°.$$

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[1] NBS Technical News Bulletin, October 1963.

[2] A. E. Cameron and E. Wichers, J. Am. Chem. Soc. 84, 4192 (1962).

Furthermore the calculated value of any thermodynamic quantity for a reaction is independent of the path chosen for the evaluation.

In some cases newer data may have become available on certain substances after the values were selected for these tables. Because of the need to maintain the internal consistency of the tables, it is not always possible to incorporate these newer data into the tables without a detailed analysis of the effect of such a change. Unless great care is used, relatively significant errors in calculated values of $\Delta H°$ or $\Delta G°$ for specific reactions may result from the introduction of such data.

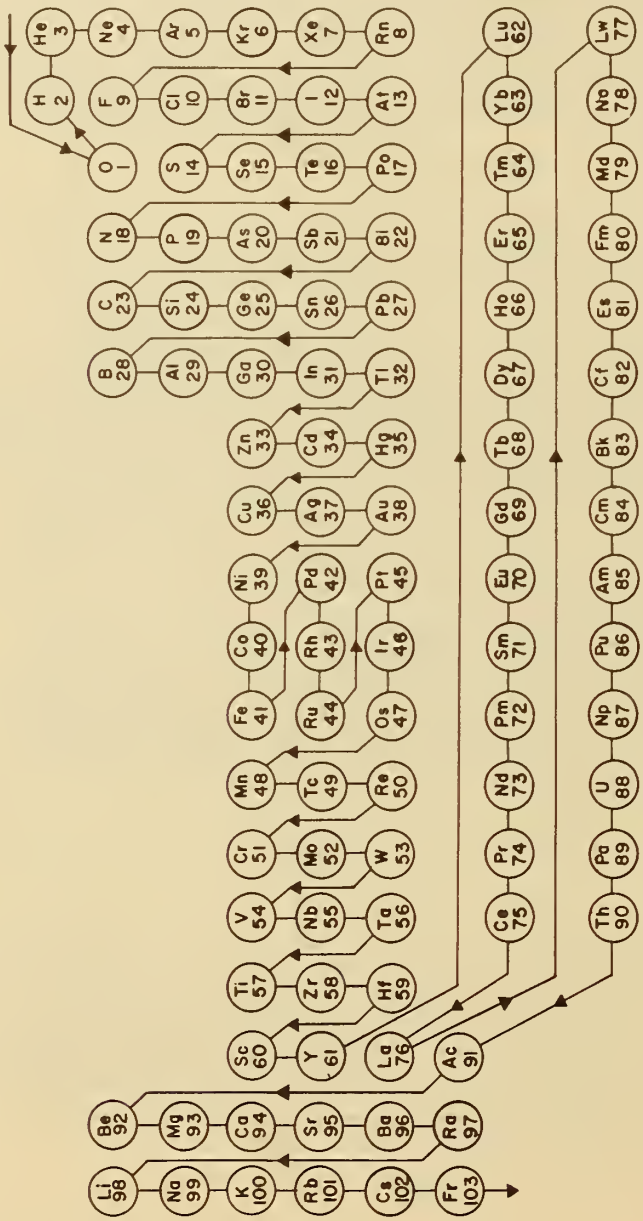
Uncertainties

The uncertainty in any value in the tables depends on the uncertainties of all the determinations in the total chain of reactions used to establish the value.

A discussion of the uncertainties will be included in the final publication of these tables in the National Standard Reference Data System. However we have followed certain rules with respect to significant figures to indicate these uncertainties. Values are tabulated in general such that the overall uncertainty lies between 2 and 20 units of the last figure. On the other hand, values are given so that the experimental data from which they are derived may be recovered with an accuracy equal to that of the original quantities. Thus the number of significant figures for any one value in the tables need not represent the absolute accuracy of that value. For solutions of varying composition values are frequently tabulated to more figures to make possible the recovery of enthalpies of solution and dilution. Similarly values of ΔHf°_{0} and $\Delta Hf^{\circ}_{298.15}$ may be given to different numbers of significant figures. In this instance the quantity with the lesser number of figures is used to represent the uncertainty estimate. The larger number of figures is used for the other quantity to retain the significance of the temperature correction term.

Arrangement of the Tables

The compounds in the tables are entered according to the Standard Order of Arrangement, (see Figure 1), by the principle of latest position. In this scheme, a compound is listed under the element occurring latest in the list; water of hydration is neglected. Within a given element-table will be found all of the compounds of that element with elements occurring earlier in the order; the arrangement within a table follows the same ordering. An exception occurs in the carbon tables (Table 23), which is divided into subgroups consisting of all compounds with one carbon atom, then all with two carbon atoms, etc.



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

Figure 1.

TABLE A

CONVERSION FACTORS FOR UNITS OF MOLECULAR ENERGY

	J/mol	cal/mol	cm^3 atm/mol	kWh/mol	Btu/lb-mol	cm^{-1}/molecule	eV/molecule
1 J/mol =	1	2.390057×10^{-1}	9.86923	2.77778×10^{-7}	0.429923	8.35940×10^{-2}	1.036409×10^{-5}
1 cal/mol =	4.18400	1	41.2929	1.162222×10^{-6}	1.798796	3.49757×10^{-1}	4.33634×10^{-5}
1 cm^3 atm/mol =	0.1013250	2.42173×10^{-2}	1	2.81458×10^{-8}	4.35619×10^{-2}	8.47016×10^{-3}	1.050141×10^{-6}
1 kWh/mol =	3,600,000	860,421	3.55292×10^{7}	1	1,547,721	300,938	37.3107
1 Btu/lb-mol =	2.32600	5.55927×10^{-1}	22.9558	6.46111×10^{-7}	1	1.944396×10^{-1}	2.41069×10^{-5}
1 cm^{-1}/molecule =	11.96258	2.85912	118.0614	3.32294×10^{-6}	5.14299	1	1.239812×10^{-4}
1 eV/molecule =	96487.0	23060.9	952,252	2.68019×10^{-2}	41482.0	8065.73	1

The underlined numbers represent the fundamental values used in deriving this table. The remaining factors were obtained by applying the relationships:

$$n_{ij} = n_{ik} \cdot n_{kj} \qquad n_{ii} = n_{ik} \cdot n_{ki} = 1$$

TABLES OF SELECTED VALUES OF PROPERTIES

SERIES I

Enthalpy of Formation at 0°K

Enthalpy of Formation at 298.15°K

Gibbs Energy of Formation at 298.15°K

Enthalpy at 298.15°K

Entropy at 298.15°K

Heat Capacity at 298.15°K

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 1(1) — OXYGEN — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
O	g	15.9994	58.983	59.553	55.388	1.607	38.467	5.237
O^+	g		373.019	375.070				
O^{2+}	g		1183.73	1187.26				
O^{3+}	g		2450.87	2455.88				
O^{4+}	g		4236.1	4242.6				
O^{5+}	g		6862.8	6870.8				
O^{6+}	g		10048.	10057.				
O^{7+}	g		27097.	27107.				
O^{8+}	g		47191.	47203.				
O^-	g		25.20	24.29				
O_2	g	31.9988	0	0	0	2.0746	48.996	7.016
std. state, m = 1	aq			-2.8	3.9		26.5	
O_2^+	g		280.0	281.48				
O_3	g	47.9982	34.74	34.1	39.0	2.4736	57.08	9.37
	aq			30.1				

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 2(1) HYDROGEN June 1965

Substance			ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
H	g	1.0080	51.626	52.095	48.580	1.481	27.391	4.9679
^1H	g	1.0078	51.626	52.095	48.580	1.481	27.391	4.9679
^2H	g	2.0141	52.524	52.981	49.360	1.481	29.455	4.9679
H^+	g	1.0080	365.211	367.161				
std. state, m = 1	aq			0	0		0	0
H^-	g		34.40	33.38				
H_2	g	2.0159	0	0	0	2.0238	31.208	6.889
$^1H_2$	g	2.0156	0	0	0	2.0238	31.208	6.889
$^2H_2$	g	4.0282	0	0	0	2.0481	34.620	6.978
$^1H^2H$	g	3.0219	0.079	0.076	- 0.350	2.0328	34.343	6.978
H_{2+} std. state, m = 1	aq	2.0159		-1.0	4.2		13.8	
H_2	g		355.74	357.22				
OH	g	17.0074	9.25	9.31	8.18	2.1070	43.890	7.143
O^2H	g	18.0135	8.72	8.81	7.76	2.1509	45.321	7.140
OH^+	g	17.0074	316.	317.5				
OH^-	g		-32.3	-33.67				
std. state, m = 1	aq			-54.970	-37.594		-2.57	-35.5
HO_2	g	33.0068	6.	5.				

National Bureau of Standards — Washington, D. C.

Table 2(2) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity — HYDROGEN — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
HO_2^+		g		272.	271.				
HO_2^-	std. state, m = 1	aq			-38.32	-16.1		5.7	
H_2O		liq	18.0153		-68.315	-56.688		16.71	17.995
^2H_2O		liq	20.0276		-70.411	-58.196		18.15	20.16
$^1H^2HO$		liq	19.0213		-69.285	-57.818		18.95	
H_2O		g	18.0153	-57.102	-57.796	-54.635	2.3667	45.104	8.025
^1H_2O		g	18.0150	-57.102	-57.796	-54.635	2.3667	45.103	8.025
^2H_2O		g	20.0276	-58.855	-59.560	-56.060	2.3801	47.378	8.19
$^1H^2HO$		g	19.0213	-57.927	-58.628	-55.720	2.3721	47.658	8.08
H_2O^+		g	18.0153	233.5	234.2				
H_2O_2		liq	34.0147		-44.88	-28.78		26.2	21.3
		g		-31.07	-32.58	-25.25	2.594	55.6	10.3
	in 0.1 H_2O	aq			-44.965				
	0.5 H_2O	aq			-45.198				
	1 H_2O	aq			-45.365				
	2 H_2O	aq			-45.520				
	3 H_2O	aq			-45.585				
	4 H_2O	aq			-45.620				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 2(3) — HYDROGEN — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
H_2O_2 in 5 H_2O	aq			-45.638				
10 H_2O	aq			-45.670				
15 H_2O	aq			-45.681				
20 H_2O	aq			-45.685				
50 H_2O	aq			-45.687				
∞ H_2O	aq			-45.69				
std. state, m = 1	aq			-45.69	-32.05		34.4	
$H_2O_2^+$	g		220.7	220.7				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 3(1) — HELIUM — June 1965

Substance	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
Formula and Description			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
He	g	4.0026	0	0	0	1.481	30.1244	4.9679
std. state, m = 1	aq			-0.4	4.6		13.3	
He^+	g		566.978	568.459				

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 4(1) — NEON — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
Ne	g	20.183	0	0	0	1.481	34.9471	4.9679
std. state, m = 1	aq			-1.1	4.6		15.8	
Ne^+	g		497.29	498.77				
Ne^{2+}	g		1444.7	1447.6				
Ne^{3+}	g		2915.	2919.				
Ne^{4+}	g		5156.	5162.				
Ne^{5+}	g		8072.	8079.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 5(1) — ARGON — June 1965

Substance			ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
Ar	g	39.948	0	0	0	1.481	36.9822	4.9679
std. state, m = 1	aq			-2.9	3.9		14.2	
Ar^+	g		363.42	364.90				
Ar^{2+}	g		1000.5	1003.5				
Ar^{3+}	g		1943.9	1948.3				
Ar^{4+}	g		3323.	3329.				
Ar^{5+}	g		5053.	5060.				
Ar^{6+}	g		7159.	7168.				
Ar^{7+}	g		10019.	10029.				
Ar^{8+}	g		13328.	13340.				

National Bureau of Standards Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 6(1) KRYPTON June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
Kr	g	83.80	0	0	0	1.481	39.1905	4.9679
std. state, m = 1	aq			-3.7	3.6		14.7	
Kr^+	g		322.84	324.32				
Kr^{2+}	g		889.47	892.43				
Kr^{3+}	g		1741.6	1746.0				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 7(1) — XENON — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
Xe	g	131.30	0	0 .	0	1.481	40.5290	4.9679
std. state, m = 1	aq			-4.2	3.2		15.7	
Xe^+	g		279.72	281.20				
Xe^{2+}	g		768.8	771.8				
Xe^{3+}	g		1509.6	1514.1				

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 8(1) — RADON — June 1965

Substance			ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
Rn	g	222.	0	0	0	1.481	42.09	4.968
Rn^+	g		247.86	249.34				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 9(1) — FLUORINE — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
F	g	18.9984	18.38	18.88	14.72	1.558	37.917	5.436
F^+	g		420.16	422.14				
F^{2+}	g		1226.98	1230.44				
F^{3+}	g		2672.0	2676.9				
F^{4+}	g		4684.2	4690.6				
F^{5+}	g		7318.7	7326.6				
F^{6+}	g		10942.9	10952.3				
F^{7+}	g		15213.4	15224.2				
F^{8+}	g		37209.	37222.				
F^-	g		-63.7	-64.7				
std. state, m = 1	aq			-79.50	-66.64		-3.3	-25.5
F_2	g	37.9968	0	0	0	2.108	48.44	7.48
F_2^+	g		365.1	366.6				
FO	g	34.9978	41.	41.				
F_2O	g	53.9962	-5.7	-5.2	-1.1	2.604	59.11	10.35
F_2O^+	g		310.	311.				
F_2O_2	g	69.9956		4.3				
F_2O_3	g	85.9950		3.8				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 9(2) — FLUORINE — June 1965

Substance			ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
HF	liq	20.0064		71.65			18.02+x	12.35
	g		-64.788	-64.8	-65.3	2.055	41.508	6.963
undissoc.; std. state, m = 1	aq			-76.50	-70.95		21.2	
ionized; std. state, m = 1	aq			-79.50	-66.64		-3.3	-25.5
in 2 H_2O	aq			-75.79				
3 H_2O	aq			-75.98				
4 H_2O	aq			-76.10				
5 H_2O	aq			-76.165				
10 H_2O	aq			-76.235				
15 H_2O	aq			-76.273				
25 H_2O	aq			-76.292				
30 H_2O	aq			-76.300				
40 H_2O	aq			-76.308				
50 H_2O	aq			-76.316				
75 H_2O	aq			-76.333				
100 H_2O	aq			-76.340				
200 H_2O	aq			-76.358				
300 H_2O	aq			-76.374				
400 H_2O	aq			-76.403				
500 H_2O	aq			-76.423				

National Bureau of Standards Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 9(3) FLUORINE June 1965

Substance			ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
HF in 600 H_2O	aq			-76.443				
700 H_2O	aq			-76.463				
800 H_2O	aq			-76.485				
900 H_2O	aq			-76.511				
1,000 H_2O	aq			-76.531				
2,000 H_2O	aq			-76.80				
3,000 H_2O	aq			-76.95				
4,000 H_2O	aq			-77.05				
5,000 H_2O	aq			-77.14				
7,000 H_2O	aq			-77.25				
10,000 H_2O	aq			-77.37				
20,000 H_2O	aq			-77.70				
∞ H_2O	aq			-79.50				
HF_2^- std. state, m = 1	aq	39.0048		-155.34	-138.18		22.1	
XeF_4	c	207.294		-62.5				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 10(1) — CHLORINE — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
Cl		g	35.453	28.68	29.082	25.262	1.499	39.457	5.220
Cl^+		g		328.86	330.74				
Cl^{2+}		g		877.81	881.17				
Cl^{3+}		g		1798.26	1803.10				
Cl^{4+}		g		3031.0	3037.3				
Cl^{5+}		g		4594.9	4602.7				
Cl^{6+}		g		6825.	6835.				
Cl^{7+}		g		9461.	9472.				
Cl^{8+}		g		17495.	17508.				
Cl^{9+}		g		26739.	26753.				
Cl^{10+}		g		37241.	37257.				
Cl^-		g		-57.9	-58.9				
	std. state, m = 1	aq			-39.952	-31.372		13.5	-32.6
Cl_2		g	70.906	0	0	0	2.193	53.288	8.104
	std. state, m = 1	aq			-5.6	1.65		29.	
	in CCl_4; std. state, $x_2 = 1$	aq			-4.44	1.09		34.7	
Cl_2^+		g		264.8	266.3				
Cl_2^{2+}		g		752.	755.				
Cl_3^-	std. state, m = 1	aq	106.359			-20.			
ClO		g	51.4524	24.36	24.34	23.46	2.114	54.14	7.52

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 10(2) — CHLORINE — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
ClO^- std. state, m = 1	aq			-25.6	-8.8		10.	
ClO_2	g	67.4518	25.09	24.5	28.8	2.580	61.36	10.03
std. state, m = 1	aq			17.9	28.1		41.4	
ClO_2^- std. state, m = 1	aq			-15.9	4.1		24.2	
ClO_3	g	83.4512		37.				
ClO_3^- std. state, m = 1	aq			-23.7	-0.8		38.8	
ClO_4^- std. state, m = 1	aq	99.4506		-30.91	-2.06		43.5	
Cl_2O	g	86.9054	19.71	19.2	23.4	2.719	63.60	10.85
in CCl_4; std. state, $x_2 = 1$				12.62	22.98		43.0	
Cl_2O_7	liq	182.9018		56.9				
	g			65.0				
HCl	g	36.4610	-22.020	-22.062	-22.774	2.066	44.646	6.96
std state, m = 1	aq			-39.952	-31.372		13.5	-32.6
in 1 H_2O	aq			-29.05				
1.5 H_2O	aq			-31.71				
2 H_2O	aq			-33.69				
2.5 H_2O	aq			-34.77				
3 H_2O	aq			-35.49				
4 H_2O	aq			-36.548				
4.5 H_2O	aq			-36.927				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 10(3) — CHLORINE — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
HCl	in 5 H_2O	aq			-37.231				
	6 H_2O	aq			-37.687				
	8 H_2O	aq			-38.242				
	10 H_2O	aq			-38.556				
	12 H_2O	aq			-38.762				
	15 H_2O	aq			-38.964				
	20 H_2O	aq			-39 160				
	25 H_2O	aq			-39.278				
	30 H_2O	aq			-39.357				
	40 H_2O	aq			-39.459				
	50 H_2O	aq			-39.521				
	75 H_2O	aq			-39.609				
	100 H_2O	aq			-39.657				
	150 H_2O	aq			-39.700				
	200 H_2O	aq			-39.740				
	300 H_2O	aq			-39.776				
	400 H_2O	aq			-39.796				
	500 H_2O	aq			-39.812				
	600 H_2O	aq			-39.823				
	700 H_2O	aq			-39.832				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 10(4) — CHLORINE — June 1965

Substance	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
Formula and Description			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
HCl in 800 H_2O	aq			-39.839				
900 H_2O	aq			-39.845				
1,000 H_2O	aq			-39.850				
1,500 H_2O	aq			-39.867				
2,000 H_2O	aq			-39.878				
3,000 H_2O	aq			-39.892				
4,000 H_2O	aq			-39.898				
5,000 H_2O	aq			-39.905				
7,000 H_2O	aq			-39.912				
10,000 H_2O	aq			-39.918				
20,000 H_2O	aq			-39.927				
50,000 H_2O	aq			-39.936				
100,000 H_2O	aq			-39.942				
∞ H_2O	aq			-39.952				
in CCl_4; std. state, $x_2 = 1$				-24.7	-20.3		25.2	
$CHCl_3$; std. state, $x_2 = 1$				-25.1	-20.5		24.6	
HClO	g	52.4604				2.440	56.54	8.88
std. state, m = 1	aq			-28.9	-19.1		35.	

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 10(5) CHLORINE June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
HClO in 6 H_2O	aq			-28.42				
7 H_2O	aq			-28.48				
8 H_2O	aq			-28.54				
10 H_2O	aq			-28.62				
12 H_2O	aq			-28.66				
15 H_2O	aq			-28.72				
20 H_2O	aq			-28.77				
25 H_2O	aq			-28.8				
30 H_2O	aq			-28.82				
40 H_2O	aq			-28.85				
50 H_2O	aq			-28.87				
75 H_2O	aq			-28.89				
100 H_2O	aq			-28.90				
200 H_2O	aq			-28.92				
300 H_2O	aq			-28.92				
500 H_2O	aq			-28.92				
1,000 H_2O	aq			-28.93				
$HClO_2$ undissoc.; std. state, m = 1	aq	68.4598		-12.4	6.8		45.0	
$HClO_3$ std. state, m = 1	aq	84.4592		-23.7	-0.8		38.8	
$HClO_4$	liq	100.4586		- 9.70				
std. state, m = 1	aq			-30.91	-2.06		43.5	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 10(6) — CHLORINE — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
$HClO_4$ in 2 H_2O	aq			-25.40				
2.5 H_2O	aq			-26.90				
3 H_2O	aq			-28.02				
4 H_2O	aq			-29.33				
4.5 H_2O	aq			-29.76				
5 H_2O	aq			-30.17				
6 H_2O	aq			-30.55				
8 H_2O	aq			-30.90				
10 H_2O	aq			-31.02				
12 H_2O	aq			-31.07				
15 H_2O	aq			-31.10				
20 H_2O	aq			-31.08				
25 H_2O	aq			-31.06				
30 H_2O	aq			-31.04				
40 H_2O	aq			-30.99				
50 H_2O	aq			-30.96				
75 H_2O	aq			-30.91				
100 H_2O	aq			-30.89				
200 H_2O	aq			-30.85				
500 H_2O	aq			-30.84				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 10(7) — CHLORINE — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$HClO_4$ in 1,000 H_2O	aq			-30.84				
3,000 H_2O	aq			-30.85				
7,000 H_2O	aq			-30.86				
10,000 H_2O	aq			-30.87				
20,000 H_2O	aq			-30.88				
100,000 H_2O	aq			-30.89				
∞ H_2O	aq			-30.91				
$HClO_4 \cdot H_2O$	c	118.4739		-91.35				
$HClO_4 \cdot 2H_2O$	liq	136.4892		-162.04				
ClF	g	54.4514	-11.9	-11.92	-12.28	2.128	52.05	7.66
ClF_3	liq	92.4482		-44.3				
	g		-37.0	-38.0	-28.4	3.262	67.28	15.26
ClF_3^+	g		262.8	263.5				
$(ClF_3)_2$	g	184.8964		-79.9	-54.7		114.	
ClO_3F	g	102.4496	-3.6	-5.7	11.5	3.179	66.65	15.52
$ClF_3 \cdot HF$	g	112.4546		-107.5	-90.8		83.	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 11(1) — BROMINE — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
Br		g	79.909	28.188	26.740	19.700	1.481	41.805	4.968
Br^+		g			301.41				
Br^{2+}		g			800.7				
Br^{3+}		g			1630.0				
Br^{4+}		g			2789.				
Br^-		g			-55.9				
	std. state, m = 1	aq			-29.05	-24.85		19.7	-33.9
Br_2		c	159.818	0					
		liq			0	0	5.859	36.384	18.090
		g		10.921	7.387	0.749	2.324	58.647	8.62
	std. state, m = 1	aq			-0.62	0.94		31.2	
	in CCl_4; std. state, $x_2 = 1$				0.71	0.36		37.6	
	n-C_7F_{16}; std. state, $x_2 = 1$				3.9	-1.8		55.4	
	CS_2				0.01				
	CH_3COOH				-0.25				
	$CHCl_3$				0.65				
Br_2^+		g			253.5				
Br_3^-	std. state, m = 1	aq	239.727		-31.17	-25.59		51.5	
Br_5^-	std. state, m = 1	aq	399.545		-34.0	-24.8		75.7	
BrO		g	95.9084	31.9	30.06	25.87	2.13	56.75	7.67

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 11(2) BROMINE June 1965

Substance				ΔHf_0°	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
Formula and Description		State	Formula Weight	0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
BrO^-	std. state, m = 1	aq	95.9084		-22.5	-8.0		10.	
BrO_2^-		c	111.9078		11.6				
BrO_3^-	std. state, m = 1	aq	127.9072		-20.0	0.4		39.0	
HBr		g	80.9170	-6.825	-8.70	-12.77	2 067	47.463	6.965
	std. state, m = 1	aq			-29.05	-24.85		19.7	-33.9
	in 1 H_2O	aq			-17.38				
	1.5 H_2O	aq			-20.52				
	2 H_2O	aq			-22.40				
	2.5 H_2O	aq			-23.75				
	3 H_2O	aq			-24.68				
	4 H_2O	aq			-25.961				
	4.5 H_2O	aq			-26.395				
	5 H_2O	aq			-26.706				
	6 H_2O	aq			-27.147				
	8 H_2O	aq			-27.649				
	10 H_2O	aq			-27.953				
	12 H_2O	aq			-28.139				
	15 H_2O	aq			-28.307				
	20 H_2O	aq			-28.460				
	25 H_2O	aq			-28.540				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 11(3) — BROMINE — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
HBr in 30 H_2O	aq			-28.595				
40 H_2O	aq			-28.671				
50 H_2O	aq			-28.719				
75 H_2O	aq			-28.780				
100 H_2O	aq			-28.815				
150 H_2O	aq			-28.853				
200 H_2O	aq			-28.874				
300 H_2O	aq			-28.900				
400 H_2O	aq			-28.915				
500 H_2O	aq			-28.926				
600 H_2O	aq			-28.935				
700 H_2O	aq			-28.942				
800 H_2O	aq			-28.948				
900 H_2O	aq			-28.953				
1,000 H_2O	aq			-28.958				
1,500 H_2O	aq			-28.973				
2,000 H_2O	aq			-28.982				
3,000 H_2O	aq			-28.994				
4,000 H_2O	aq			-29.001				
5,000 H_2O	aq			-29.006				
7.000 H_2O	aq			-29.013				

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 11(4) — BROMINE — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
Formula	Description			0°K	298.15°K (25°C)				
				kcal/mol				cal/deg mol	
HBr	10,000 H_2O	aq			-29.019				
	20,000 H_2O	aq			-29.028				
	50,000 H_2O	aq			-29.037				
	100,000 H_2O	aq			-29.041				
	∞ H_2O	aq			-29.05				
	in CCl_4; std. state, $x_2 = 1$				-11.9	-10.9		30.4	
	$CHCl_3$; std. state, $x_2 = 1$				-12.0	-11.0		30.4	
	n-C_4H_{10}; std. state, $x_2 = 1$				-11.8	-10.7		30.2	
	C_6H_6; std. state, $x_2 = 1$				-12.9	-11.2		28.1	
	n-C_6H_{14}; std. state, $x_2 = 1$				-11.4	-10.9		32.1	
	n-C_8H_{18}; std. state, $x_2 = 1$				-11.4	-11.0		32.5	
	n-$C_{10}H_{22}$; std. state, $x_2 = 1$				-11.3	-11.1		33.0	
HBr^+		g			260.7				
HBrO	un-ionized; std. state, m = 1	aq	96.9164		-27.0	-19.7		34.	
$HBrO_3$	std. state, m = 1	aq	128.9152		-20.0	0.4		39.0	
	in 400 H_2O	aq			-19.94				
BrF_3		liq	136.9042		-71.9	-57.5		42.6	29.78
		g		-58.41	-61.09	-54.83	3.416	69.89	15.92
BrF_5		liq	174.9010		-109.6	-84.1		53.8	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 11(5) — BROMINE — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
BrF_5		g		-98.75	-102.5	-83.8	4.452	76.50	23.81
BrCl		g	115.362		3.50				
	in CCl_4				-1.547				
$BrCl^+$		g			261.0				
Br_2Cl^-	std. state, m = 1	aq	195.271		-40.7	-30.7		29.5	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 12(1) — IODINE — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
I	g	126.9044	25.631	25.535	16.798	1.481	43.184	4.968
I^+	g		266.77	268.16				
I^{2+}	g		707.22	710.19				
I^-	g		-45.4	-47.0				
std. state, m = 1	aq			-13.19	-12.33		26.6	-34.0
I_2	c	253.8088	0	0	0	3.154	27.757	13.011
	g		15.659	14.923	4.627	2.418	62.28	
std. state, m = 1	aq			5.4	3.92		32.8	
in CCl_4; std. state, m = 1				6.0	2.66		39.0	
C_6H_6; std. state, $x_2 = 1$				4.3	1.7		36.5	
C_6H_{12}; std. state, $x_2 = 1$				5.8	2.8		37.8	
C_7F_{16}; std. state, $x_2 = 1$				10.3	5.1		45.2	
$CF_3C_6F_{11}$ (perfluoromethyl-cyclohexane); std. state, $x_2 = 1$				5.0	9.5		42.9	
CCl_2FClF_2; std. state, $x_2 = 1$				7.3	3.6		40.2	
$CHBr_3$; std. state, x = 1				5.3	1.6		40.3	
C_6H_5Cl				4.8				
$C_6H_5CH_3$				3.8				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 12(2) — IODINE — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
I_2 in $C_6H_5COOCH_3$				3.9				
CH_3COOCH_3				2.4				
$CH_3COOC_2H_5$				3.1				
CH_3OH				2.1				
1,4 dioxane				1.8				
$(C_2H_5)_2O$				1.8				
$C_6H_5NO_2$				1.7				
C_2H_5OH				1.7				
pyridine				4.0				
CS_2				5.2				
$CHCl_3$				5.3				
I_2^+	g		230.5	231.2				
I_3^- std. state, m = 1	aq	380.7132		-12.3	-12.3		57.2	
IO^- std. state, m = 1	aq	142.9038		-25.7	-9.2		-1.3	
IO_3^- std. state, m = 1	aq	174.9026		-52.9	-30.6		28.3	
IO_4^{2-}	aq	190.9020		-35.2				
I_2O^{2-} std. state, m = 1	aq	269.8082			-19.7			
I_2O_5	c	333.8058		-37.78				
HI	g	127.9124	6.50	6.33	0.51	2.069	49.351	6.969
std. state, m = 1	aq			-13.19	-12.33		26.6	-34.0

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 12(3) — IODINE — June 1965

Substance	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
HI in 3 H_2O	aq			-8.56				
4 H_2O	aq			-10.23				
4.5 H_2O	aq			-10.73				
5 H_2O	aq			-11.09				
6 H_2O	aq			-11.560				
8 H_2O	aq			-12.075				
10 H_2O	aq			-12.335				
12 H_2O	aq			-12.490				
15 H_2O	aq			-12.654				
20 H_2O	aq			-12.794				
25 H_2O	aq			-12.854				
30 H_2O	aq			-12.889				
40 H_2O	aq			-12.930				
50 H_2O	aq			-12.956				
75 H_2O	aq			-12.996				
100 H_2O	aq			-13.014				
200 H_2O	aq			-13.050				
300 H_2O	aq			-13.065				
400 H_2O	aq			-13.074				
500 H_2O	aq			-13.082				

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 12(4) IODINE June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
HI in 600 H_2O	aq			-13.088				
800 H_2O	aq			-13.098				
1,000 H_2O	aq			-13.106				
2,000 H_2O	aq			-13.127				
3,000 H_2O	aq			-13.138				
4,000 H_2O	aq			-13.144				
5,000 H_2O	aq			-13.149				
7,000 H_2O	aq			-13.156				
10,000 H_2O	aq			-13.161				
20,000 H_2O	aq			-13.170				
50,000 H_2O	aq			-13.178				
100,000 H_2O	aq			-13.181				
∞ H_2O	aq			-13.19				
HIO undissoc.; std. state, m = 1	aq	143.9118		-33.0	-23.7		22.8	
HIO_3	c	175.9106		-55.0				
un-ionized, std. state, m = 1	aq			-50.5	-31.7		39.9	
in 100 H_2O	aq			-51.7				
200 H_2O	aq			-51.8				
400 H_2O	aq			-52.0				
800 H_2O	aq			-52.2				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 12(5) — IODINE — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
H_2OI^+	std. state, m = 1	aq	144.9197			-25.5			
$H_3IO_6^{2-}$		aq	225.9247		-179.6				
$H_4IO_6^-$		aq	226.9327		-180.4				
H_5IO_6		aq	227.9406		-180.4				
I_2OH^-	std. state, m = 1	aq	270.8162			-55.0			
$I_2O_5 \cdot HIO_3$		c	509.7164		-92.2				
IF		g	145.9028	-1.64	-2.10	-7.56	2.174	56.42	7.99
IF_5		liq	221.8964		-206.7				
		g		-194.29	-196.58	-179.68	4.565	78.3	23.7
IF_5^+		g		117.0	116.20				
IF_7		g	259.8932	-222.4	-225.6	-195.6	5.752	82.8	32.6
ICl		c,α	162.3574		-8.4				
		liq			-5.71	-3.25		32.3	
		g		4.64	4.25	-1.30	2.282	59.140	8.50
	std. state, m = 1	aq				-4.1			
	in CCl_4; std. state, $x_2 = 1$				-3.3	-2.1		36.5	
ICl^+		g			243.5				
ICl_2^-	std. state, m = 1	aq	197.8104			-38.5			
ICl_3		c	233.2634		-21.4	-5.34		40.0	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 12(6) — IODINE — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
I_2Cl^- std. state, m = 1	aq	289.2618			-31.7			
IBr	c	206.8134		-2.5				
	g		11.90	9.76	0.89	2.367	61.822	8.71
std. state, m = 1	aq				-1.0			
in CCl_4; std. state, $x_2 = 1$				1.62	-0.4		39.	
IBr^+	g		242.	241.3				
IBr_2^- std. state, m = 1	aq	286.7224			-29.4			
BrI_2^- std. state, m = 1	aq	333.7178		-30.6	-26.3		47.2	
$HBrI_2$ std. state, m = 1	aq	334.7258		-30.6	-26.3		47.2	
$IBrCl^-$ std. state, m = 1	aq	242.2664			-35.0			

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 13(1) — ASTATINE — June 1965

Substance			ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
At	c		0	0	0			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(1) — SULFUR — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
S rhombic	c	32.064	0	0	0	1.054	7.60	5.41
monoclinic	c			0.08				
	g		66.1	66.636	56.949	1.591	40.094	5.658
in $6CS_2$				0.405				
$2CS_2$				0.402				
CCl_4				0.62				
C_6H_6				0.69				
$(C_2H_5)_2O$				1.5				
$CHCl_3$				0.70				
S^+	g		304.95	306.97				
S^{2+}	g		844.8	848.2				
S^{3+}	g		1653.0	1657.9				
S^{4+}	g		2743.6	2750.0				
S^{5+}	g		4415.	4422.				
S^{6+}	g		6445.	6654.				
S^{7+}	g		12925.	12935.				
S^{8+}	g		20508.	20520.				
S^{9+}	g		29247.	29260.				
S^-	g		18.36	17.42				
S^{2-} std. state, m = 1	aq			7.9	20.5		-3.5	

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(2) — SULFUR — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
S_2		g	64.128	30.647	30.68	18.90	2.141	54.51	7.76
S_2^+		g		254.	255.5				
S_2^{2-}	std. state, m = 1	aq			7.2	19.0		6.8	
S_3		g	96.192		31.7				
S_3^+		g			344.				
S_3^{2-}	std. state, m = 1	aq			6.2	17.6		15.8	
S_4		g	128.256		32.7				
S_4^+		g			334.				
S_4^{2-}	std. state, m = 1	aq			5.5	16.5		24.7	
S_5		g	160.320		29.6				
S_5^+		g			259.				
S_5^{2-}	std. state, m = 1	aq			5.1	15.7		33.6	
S_6		g	192.384		24.5				
S_6^+		g			247.				
S_7		g	224.448		27.1				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(3) — SULFUR — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
S_7^+	g			248.				
S_8	g	256.512	25.35	24.45	11.87	7.531	102.98	37.39
S_8^+	g		247.	247.				
SO	g	48.0634	1.5	1.496	-4.742	2.087	53.02	7.21
SO_2	liq	64.0628		-76.6				
	g		-70.336	-70.944	-71.749	2.521	59.30	9.53
un-ionized; std. state, m = 1	aq			-77.194	-71.872		38.7	
in 100 H_2O	aq			-78.054				
150 H_2O	aq			-78.226				
200 H_2O	aq			-78.355				
250 H_2O	aq			-78.458				
300 H_2O	aq			-78.547				
400 H_2O	aq			-78.691				
500 H_2O	aq			-78.811				
750 H_2O	aq			-79.139				

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(4) — SULFUR — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
SO_2 in 1,000 H_2O	aq			-79.201				
1,500 H_2O	aq			-79.461				
2,000 H_2O	aq			-79.642				
2,500 H_2O	aq			-79.776				
3,000 H_2O	aq			-79.891				
3,500 H_2O	aq			-79.989				
4,000 H_2O	aq			-80.068				
5,000 H_2O	aq			-80.209				
7,500 H_2O	aq			-80.443				
10,000 H_2O	aq			-80.584				
in dimethylaniline				-81.2				
SO_2^+	g		214.2	215.1				
SO_3 I, β	c	80.0622		-108.63	-88.19		12.5	
	liq			-105.41	-88.04		22.85	
	g		-93.21	-94.58	-88.69	2.796	61.34	12.11

National Bureau of Standards Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(5) SULFUR June 1965

Substance	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
SO_3^{2-} std. state, m = 1	aq			-151.9	-116.3		-7.	
SO_4^{2-} std. state, m = 1	aq	96.0616		-217.32	-177.97		4.8	-70.
$S_2O_3^{2-}$	aq	112.1262		-155.9				
$S_2O_4^{2-}$ std. state, m = 1	aq	128.1256		-180.1	-143.5		22.	
$S_2O_6^{2-}$	aq	160.1244		-286.4				
$S_2O_7^{2-}$	aq	176.1238		-334.9				
$S_2O_8^{2-}$ std. state, m = 1	aq	192.1232		-320.0	-265.4		59.3	
$S_3O_6^{2-}$	aq	192.1884		-286.7				
$S_4O_6^{2-}$	aq	224.2524		-292.58				
$S_5O_6^{2-}$	aq	256.3164		-295.5				
HS	g	33.0720	34.	34.10	27.08	2.171	46.74	7.72
HS^- std. state, m = 1	aq			-4.2	-2.88		15.0	
H_2S	g	34.0799	-4.381	-4.93	-8.02	2.379	49.16	8.18
std. state, m = 1	aq			-9.5	-6.66		29.	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(6) — SULFUR — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
H_2S^+		g			237.8				
H_2S_2		liq	66.1439		-5.51				20.1
		g			2.53				12.3
$H_2S_2^+$		g			239.				
H_2S_3		liq	98.2079		-7.27				
		g			3.59				
H_2S_4		liq	130.2719		-7.85				
		g			5.71				
H_2S_5		liq	162.3359		-8.35				
		g			7.98				
H_2S_6		liq	194.3999		-8.85				
HSO_3^-	undissoc.; std. state, m = 1	aq	81.0702		-149.67	-126.15		33.4	
HSO_4^-	std. state, m = 1	aq	97.0696		-212.08	-180.69		31.5	-20.
H_2SO_3	un-ionized, std. state, m = 1	aq	82.0781		-145.51	-128.56		55.5	
	in 100 H_2O	aq			-146.369				
	150 H_2O	aq			-146.541				
	200 H_2O	aq			-146.670				
	250 H_2O	aq			-146.773				
	300 H_2O	aq			-146.862				
	400 H_2O	aq			-147.006				
	500 H_2O	aq			-147.126				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(7) — SULFUR — June 1965

Substance	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
H_2SO_3 in 750 H_2O	aq			-147.454				
1,000 H_2O	aq			-147.516				
1,500 H_2O	aq			-147.776				
2,000 H_2O	aq			-147.957				
2,500 H_2O	aq			-148.091				
3,000 H_2O	aq			-148.206				
3,500 H_2O	aq			-148.304				
4,000 H_2O	aq			-148.383				
5,000 H_2O	aq			-148.524				
7,500 H_2O	aq			-148.758				
10,000 H_2O	aq			-148.899				
H_2SO_4	c	98.0775	-194.019					
	liq			-194.548	-164.942	6.748	37.501	33.20
std. state, m = 1	aq			-217.32	-177.97		4.8	-70.
in 1.0 H_2O	aq			-201.193				
1.5 H_2O	aq			-203.128				
2.0 H_2O	aq			-204.455				
2.5 H_2O	aq			-205.452				
3.0 H_2O	aq			-206.241				
3.5 H_2O	aq			-206.886				
4.0 H_2O	aq			-207.428				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(8) — SULFUR — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
H_2SO_4 in 4.5 H_2O	aq			-207.889				
5.0 H_2O	aq			-208.288				
5.5 H_2O	aq			-208.637				
6 H_2O	aq			-208.944				
7 H_2O	aq			-209.458				
8 H_2O	aq			-209.865				
9 H_2O	aq			-210.190				
10 H_2O	aq			-210.451				
12 H_2O	aq			-210.835				
15 H_2O	aq			-211.191				
20 H_2O	aq			-211.500				
25 H_2O	aq			-211.660				
30 H_2O	aq			-211.755				
40 H_2O	aq			-211.869				
50 H_2O	aq			-211.944				
75 H_2O	aq			-212.068				
100 H_2O	aq			-212.150				
115 H_2O	aq			-212.192				
150 H_2O	aq			-212.282				
200 H_2O	aq			-212.387				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(9) — SULFUR — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
H_2SO_4 in 300 H_2O	aq			-212.565				
400 H_2O	aq			-212.709				
500 H_2O	aq			-212.833				
600 H_2O	aq			-212.950				
700 H_2O	aq			-213.040				
800 H_2O	aq			-213.128				
900 H_2O	aq			-213.205				
1,000 H_2O	aq			-213.275				
1,500 H_2O	aq			-213.552				
2,000 H_2O	aq			-213.740				
3,000 H_2O	aq			-214.015				
4,000 H_2O	aq			-214.220				
5,000 H_2O	aq			-214.390				
7,000 H_2O	aq			-214.675				
10,000 H_2O	aq			-215.060				
15,000 H_2O	aq			-215.553				
20,000 H_2O	aq			-215.880				
30,000 H_2O	aq			-216.232				
50,000 H_2O	aq			-216.545				
70,000 H_2O	aq			-216.706				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(10) — SULFUR — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0°K	298.15°K (25°C)				
				kcal/mol				cal/deg mol	
H_2SO_4	in 100,000 H_2O	aq			-216.855				
	150,000 H_2O	aq			-216.971				
	200,000 H_2O	aq			-217.042				
	300,000 H_2O	aq			-217.120				
	500,000 H_2O	aq			-217.187				
	700,000 H_2O	aq			-217.221				
	1,000,000 H_2O	aq			-217.246				
	2,000,000 H_2O	aq			-217.277				
	∞ H_2O	aq			-217.32				
	in 10 C_2H_5OH				-209.55				
	15 C_2H_5OH				-210.30				
	20 C_2H_5OH				-210.95				
	25 C_2H_5OH				-211.35				
	49 C_2H_5OH				-212.05				
	in 5 $(C_2H_5)_2O$				-205.93				
	10 $(C_2H_5)_2O$				-207.15				
	15 $(C_2H_5)_2O$				-208.15				
	20 $(C_2H_5)_2O$				-208.91				
	25 $(C_2H_5)_2O$				-209.51				
	in CH_2ClCH_2Cl				-190.2				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(11) — SULFUR — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
in 5 $(CH_3)_2SO_4$				-197.00				
10 $(CH_3)_2SO_4$				-197.45				
15 $(CH_3)_2SO_4$				-197.60				
20 $(CH_3)_2SO_4$				-197.80				
25 $(CH_3)_2SO_4$				-197.90				
in 5 $C_6H_5NO_2$				-195.75				
10 $C_6H_5NO_2$				-196.05				
15 $C_6H_5NO_2$				-196.25				
20 $C_6H_5NO_2$				-196.43				
25 $C_6H_5NO_2$				-196.55				
49 $C_6H_5NO_2$				-196.84				
$H_2SO_4 \cdot 1H_2O$	liq	116.0929		-269.508	-227.186		50.56	51.35
$H_2SO_4 \cdot 2H_2O$	liq	134.1082		-341.085	-286.777		66.06	62.34
$H_2SO_4 \cdot 3H_2O$	liq	152.1236		-411.186	-345.185		82.55	76.23
$H_2SO_4 \cdot 4H_2O$	liq	170.1389		-480.688	-403.011		99.09	91.35
$H_2SO_4 \cdot 6.5\ H_2O$	liq	215.1772		-653.264	-546.413		140.51	136.30
$HS_2O_4^-$ std. state, m = 1	aq	129.1336			-146.9			
$H_2S_2O_4$ std. state, m = 1	aq	130.1415			-147.4			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(12) — SULFUR — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
$H_2S_2O_6$		aq	162.1403		-286.4				
$H_2S_2O_7$		c	178.1397		-304.4				27.
$H_2S_2O_8$	std. state, m = 1	aq	194.1391		-320.0	-265.4		59.3	
SF_4		g	108.0576	-183.4	-185.2	-174.8	3.482	69.77	17.45
SF_6		g	146.0544	-285.7	-289.	-264.1	4.056	69.72	23.25
	std. state, m = 1	aq			-293.0	-259.2		39.8	
SO_3F^-		aq	99.0606		-193.0				
SOF_2		g	86.0602				2.997	66.58	13.58
SO_2F_2		g	102.0596				3.241	67.86	15.78
$HF \cdot SO_2$		g	84.0692		-139.2				
HSO_3F		liq	100.0686		-186.				
		aq			-191.9				
SCl_2		liq	102.970		-12.				
		g			-4.7				
S_2Cl_2		liq	135.034		-14.2				
		g		-4.18	-4.4	-7.6	4.082	79.2	17.6
S_3Cl_2		liq	167.098		-12.4				

National Bureau of Standards Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 14(13) SULFUR June 1965

Substance	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
S_4Cl_2	liq	199.162		-10.2				
S_5Cl_2	liq	231.226		-8.8				
$SOCl_2$	liq	118.9694		-58.7				29.
	g		-50.07	-50.8	-47.4	3.559	74.01	15.9
in C_6H_6				-59.7				
SO_2Cl_2	liq	134.9688		-94.2				32.
	g		-85.50	-87.0	-76.5	3.825	74.53	18.4
in C_6H_6				-94.2				
$S_2O_5Cl_2$	liq	215.0310		-168.7				56.
	g			-153.2				
$SO_2 \cdot HCl$	g	100.5238		-96.5				
HSO_3Cl	liq	116.5232		-143.7				
SF_5Cl	liq	162.5090		-254.7				
	g		-247.48	-250.5	-226.9	4.396	76.26	24.9
S_2Br_2	liq	223.946		-3.				
$SOBr_2$	g	207.8814		-17.7				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 15(1) SELENIUM June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
Se	hexagonal, black	c	78.96	0	0	0	1.319	10.144	6.062
	monoclinic, red	c			1.6				
		g		49.	49.16	39.60	1.4827	42.22	5.020
	glassy	amorp			1.2				
Se^{2-}	std. state, m = 1	aq				30.9			
Se_2		g	157.92		34.9				
Se_6		g	473.76		48.7				
SeO_2		c	110.959		-53.86				
		aq			-52.97				
SeO_3		c	126.958		-39.9				
SeO_3^{2-}	std. state, m = 1	aq			-121.7	-88.4		3.	
SeO_4^{2-}	std. state, m = 1	aq	142.958		-143.2	-105.5		12.9	
Se_2O_5		c	237.917		-97.6				
HSe^-	std. state, m = 1	aq	79.968		3.8	10.5		19.	
H_2Se		g	80.976	8.05	7.1	3.8	2.391	52.32	8.30
	std. state, m = 1	aq			4.6	5.3		39.1	
$HSeO_3^-$	std. state, m = 1	aq	127.966		-122.98	-98.36		33.1	
$HSeO_4^-$	std. state, m = 1	aq	143.966		-139.0	-108.1		35.7	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 15(2) — SELENIUM — June 1965

Substance	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
H_2SeO_3	c	128.974		-125.35				
un-ionized; std. state, m = 1	aq			-121.29	-101.87		49.7	
	aq			-121.24				
H_2SeO_4	c	144.974		-126.7				
in 7.85 H_2O				-134.4				
500 H_2O				-140.1				
1,200 H_2O				-140.3				
$H_2SeO_4 \cdot H_2O$	c	162.989		-200.9				
	liq			-196.1				
SeF_6	g	192.950	-264.1	-267.	-243.	4.740	74.99	26.4
$SeCl_2$	g	149.866		-7.6				
$SeCl_4$	c	220.772		-43.8				
Se_2Cl_2	liq	228.826		-19.7				
	g			4.				
$SeOCl_2$	g	165.865		-6.				
$Se(OH)_3 \cdot ClO_4$	c	229.433		-147.4				
$SeBr_2$	g	238.778		-5.				
Se_2Br_2	g	317.738		7.				
$SeO_2 \cdot SO_3$	c	191.021		-164.7				

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 16(1) — TELLURIUM — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
Te		c	127.60	0	0	0	1.463	11.88	6.15
		g		45.5	45.52	36.05	1.481	43.65	4.968
		amorp			2.7				
Te^{+}		g		253.26	254.76				
Te^{2+}		g		682.	685.				
Te^{3+}		g		1388.	1393.				
Te^{4+}		g		2260.	2266.				
Te^{5+}		g		3650.	3658.				
Te^{6+}		g		5318.	5327.				
Te^{7+}		g		8483.	8494.				
Te_2		g	255.20	40.7	40.2				
TeO		g	143.599	41.6					
TeO_2^{2-}		c	159.599		-77.1	-64.6		19.0	
TeO_3^{2-}		aq	175.598		-142.6				
H_2Te		g	129.616		23.8				
H_2TeO_3	std. state, m = 1	aq	177.614			-76.2			
$Te(OH)_3^{+}$	std. state, m = 1	aq	178.622		-145.4	-118.6		26.7	
$H_4TeO_6^{2-}$		aq	227.628		-292.1				
$H_5TeO_6^{-}$		aq	228.636		-301.5				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 16(2) — TELLURIUM — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
H_6TeO_6	c	229.644		-310.4				
	aq			-307.				
TeF_6	g	241.590		-315.				
$TeCl_4$	c	269.412		-78.0				33.1
$TeBr_4$	c	447.236		-45.5				
$2TeO_2 \cdot SO_3$	c	399.260		-314.9				
TeSe	g	206.56		41.6				

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 17(1) — POLONIUM — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
Po	c		0	0	0			
Po^{2+} std. state, m = 1	aq				17.			
Po^{4+} std. state, m = 1	aq				70.			
$Po(OH)_2^{4+}$ std. state, m = 1	aq				-113.			
$Po(OH)_4$	c				-130.			
$PoCl_6^{2-}$ std. state, m = 1	aq				-138.			
PoS	c				52.			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(1) — NITROGEN — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
N		g	14.0067	112.534	112.979	108.883	1.481	36.622	4.968
N^+		g		447.663	449.589				
N^{2+}		g		1130.55	1133.96				
N^{3+}		g		2224.52	2229.41				
N^{4+}		g		4011.04	4017.41				
N^{5+}		g		6268.41	6276.26				
N^{6+}		g		18999.5	19008.9				
N^{7+}		g		34381.1	34392.0				
N_2		g	28.0134	0	0	0	2.072	45.77	6.961
N_3^+		g	42.0201	389.	390.2				
N_3^-		g		45.	43.2				
	std. state, m = 1	aq			65.76	83.2		25.8	
NO		g	30.0061	21.45	21.57	20.69		50.347	
NO^+		g		234.8	236.4				
NO_2		g	46.0055	8.60	7.93	12.26	2.438	57.35	8.89
NO_2^+		g		276.6	277.4				
NO_2^-	std. state, m = 1	aq			-25.0	-8.9		33.5	-23.3
NO_3^-	nitrate; std. state, m = 1	aq	62.0049		-49.56	-26.61		35.0	-20.7
	peroxynitrite	aq			-10.7				

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(2) NITROGEN June 1965

Substance			ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
N_2O	g	44.0128	20.435	19.61	24.90	2.284	52.52	9.19
	aq			13.4				
$N_2O_2^{2-}$ hyponitrite	aq	60.0122		-4.1				
N_2O_3	liq	76.0116		12.02				
	g		21.628	20.01	33.32	3.566	74.61	15.68
N_2O_4	liq	92.0110		-4.66	23.29		50.0	34.1
	g		4.49	2.19	23.38	3.918	72.70	18.47
N_2O_5	c	108.0104		-10.3	27.2		42.6	34.2
	g		5.7	2.7	27.5	4.237	85.0	20.2
NH	g	15.0147	79.	80.				
NH_2	g	16.0226		41.				
NH_3	g	17.0306	-9.34	-11.02	-3.94	2.388	45.97	8.38
un-ionized, std. state, m = 1	aq			-19.19	-6.35		26.6	
equilibrium								
in 1 H_2O	aq			-18.011				
2 H_2O	aq			-18.560				
5 H_2O	aq			-18.945				
10 H_2O	aq			-19.074				
20 H_2O	aq			-19.125				
50 H_2O	aq			-19.156				
100 H_2O	aq			-19.167				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(3) — NITROGEN — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
NH_3 in 500 H_2O	aq			-19.173				
1,000 H_2O	aq			-19.171				
5,000 H_2O	aq			-19.154				
10,000 H_2O	aq			-19.140				
50,000 H_2O	aq			-19.086				
100,000 H_2O	aq			-19.047				
in $(C_2H_5)_2O$				-4.0				
NH_3^+	g		224.7	224.53				
NH_4^+ std. state, m = 1	aq	18.0386		-31.67	-18.97		27.1	19.1
N_2H_4	liq	32.0453		12.10	35.67		28.97	23.63
	g		26.18	22.80	38.07	2.743	56.97	11.85
undissoc.; std. state, m = 1	aq			8.20	30.6		33.	
$N_2H_5^+$ std. state, m = 1	aq	33.0532		-1.8	19.7		36.	16.8
HN_3	liq	43.0281		63.1	78.2		33.6	
	g		71.82	70.3	78.4	2.599	57.09	10.44
undissoc.; std. state, m = 1	aq			62.16	76.9		34.9	
HN_3^+	g		309.	309.0				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(4) — NITROGEN — June 1965

Substance	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
NH_4N_3	c	60.0587		27.6	65.5		26.9	
std. state, m = 1	aq			34.1	64.3		52.7	
HNO_2 cis	g	47.0135	-17.12	-18.64	-10.27	2.608	59.43	10.70
trans	g		-17.68	-19.15	-10.82	2.652	59.54	11.01
cis-trans mixture	g			-19.0	-11.0		60.7	10.9
undissoc.; std. state, m = 1	aq			-28.5	-13.3		36.5	
HNO_3	liq	63.0129		-41.61	-19.31		37.19	26.26
	g		-29.94	-32.28	-17.87	2.815	63.64	12.75
std. state, m = 1	aq			-49.56	-26.61		35.0	-20.7
in 1 H_2O	aq			-44.845				
2 H_2O	aq			-46.500				
3 H_2O	aq			-47.459				
4 H_2O	aq			-48.065				
5 H_2O	aq			-48.462				
7 H_2O	aq			-48.899				
10 H_2O	aq			-49.192				
15 H_2O	aq			-49.357				
25 H_2O	aq			-49.430				
50 H_2O	aq			-49.439				
100 H_2O	aq			-49.440				

National Bureau of Standards — Washington, D. C.

Table 18(5) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity — NITROGEN — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
HNO_3 in 500 H_2O	aq			-49.468				
1,000 H_2O	aq			-49.484				
2,000 H_2O	aq			-49.501				
5,000 H_2O	aq			-49.518				
10,000 H_2O	aq			-49.529				
50,000 H_2O	aq			-49.545				
∞ H_2O	aq			-49.56				
$HNO_3 \cdot H_2O$	liq	81.0282		-113.16	-78.61		51.84	43.61
$HNO_3 \cdot 3H_2O$	liq	117.0589		-252.40	-193.91		82.93	77.71
NH_2OH	c	33.0300		-27.3				
	aq			-23.5				
$NH_2OH_2^+$	aq	34.0380		-32.8				
NH_4OH	liq	35.0460		-86.33	-60.74		39.57	37.02
undissoc.; std. state, m = 1	aq			-87.505	-63.04		43.3	
ionized; std. state, m = 1	aq			-86.64	-56.56		24.5	-16.4
in 1 H_2O	aq			-86.875				
1.5 H_2O	aq			-86.998				
2 H_2O	aq			-87.078				
2.5 H_2O	aq			-87.138				
3 H_2O	aq			-87.188				

National Bureau of Standards Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(6) NITROGEN June 1965

Substance	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
NH_4OH in 3.5 H_2O	aq			-87.228				
4 H_2O	aq			-87.260				
4.5 H_2O	aq			-87.286				
5 H_2O	aq			-87.307				
6 H_2O	aq			-87.338				
8 H_2O	aq			-87.377				
10 H_2O	aq			-87.396				
12 H_2O	aq			-87.412				
15 H_2O	aq			-87.427				
20 H_2O	aq			-87.443				
25 H_2O	aq			-87.454				
30 H_2O	aq			-87.458				
40 H_2O	aq			-87.470				
50 H_2O	aq			-87.474				
75 H_2O	aq			-87.480				
100 H_2O	aq			-87.483				
200 H_2O	aq			-87.486				
400 H_2O	aq			-87.489				
500 H_2O	aq			-87.488				
1,000 H_2O	aq			-87.486				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(7) — NITROGEN — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
NH_4OH in 2,000 H_2O	aq			-87.481				
3,000 H_2O	aq			-87.478				
4,000 H_2O	aq			-87.473				
5,000 H_2O	aq			-87.469				
7,000 H_2O	aq			-87.464				
10,000 H_2O	aq			-87.455				
20,000 H_2O	aq			-87.440				
50,000 H_2O	aq			-87.401				
100,000 H_2O	aq			-87.362				
∞ H_2O	aq			-86.64				
NH_4HO_2 std. state, m = 1	aq	51.0454		-69.99	-35.1		32.8	
$HN_2O_2^-$ hyponitrite ion	aq	61.0202		-12.4				
$H_2N_2O_2$ hyponitrous acid	aq	62.0281		-15.4				
NH_2NO_2 nitramide	c	62.0281		-48.2				
NH_4NO_2	c	64.0441		-61.3				
std. state, m = 1	aq			-56.7	-27.9		60.6	-4.2
NH_4NO_3	c	80.0435		-87.37	-43.98		36.11	33.3
std. state, m = 1	aq			-81.23	-45.58		62.1	-1.6

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(8) — NITROGEN — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
NH_4NO_3	in 3 H_2O	aq			-83.485				
	4 H_2O	aq			-83.218				
	5 H_2O	aq			-83.050				
	7 H_2O	aq			-82.775				
	10 H_2O	aq			-82.470				
	15 H_2O	aq			-82.180				
	25 H_2O	aq			-81.866				
	50 H_2O	aq			-81.538				
	75 H_2O	aq			-81.412				
	100 H_2O	aq			-81.318				
	150 H_2O	aq			-81.266				
	200 H_2O	aq			-81.232				
	300 H_2O	aq			-81.203				
	500 H_2O	aq			-81.183				
	1,000 H_2O	aq			-81.177				
	2,000 H_2O	aq			-81.182				
	5,000 H_2O	aq			-81.194				
	10,000 H_2O	aq			-81.202				
	50,000 H_2O	aq			-81.216				
	∞ H_2O	aq			-81.23				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(9) — NITROGEN — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
NH_4ONO_2	ammonium peroxynitrite	aq	80.0435		-42.4				
$NH_2OH \cdot HNO_3$		c	96.0429		-87.6				
		aq			-82.4				
N_2H_5OH		liq	50.0606		-58.01				
		g			-49.0	-18.9		63.	
	undissoc.; std. state, m = 1	aq			-60.11	-26.1		49.7	17.5
	in 75 H_2O	aq			-60.089				
	100 H_2O	aq			-60.095				
	150 H_2O	aq			-60.101				
	200 H_2O	aq			-60.105				
	500 H_2O	aq			-60.107				
	∞ H_2O	aq			-60.11				
$(NH_4)_2O$		liq	52.0766		-102.94	-63.84		63.94	59.08
$NH_4HN_2O_2$		aq	79.0588		-44.1				
$N_2H_5NO_3$		c	95.0582		-60.13				
	std. state, m = 1	aq			-51.41	-6.91		71.	
$(NH_4)_2N_2O_2$		aq	96.0894		-67.4				
NF_2		g	52.0035	9.68	10.3	13.9	2.527	59.71	9.80
NF_2^+		g		282.	284.				
NF_3		g	71.0019	-28.43	-29.8	-20.0	2.827	62.29	12.7

National Bureau of Standards — Washington, D. C.

N_2F_2 18

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(10) — NITROGEN — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
N_2F_2 cis, active	g	66.0102		16.6				
trans	g			19.6				
N_2F_4	g	104.0070	0.88	-1.7	19.4	3.710	71.96	18.9
NOF	g	49.0045	-15.33	-15.9	-12.2	2.557	59.27	9.88
NO_2F	g	65.0039				2.755	62.2	11.9
NH_4F	c	37.0370	-107.41	-110.89	-83.36	2.655	17.20	15.60
std. state, m = 1	aq			-111.17	-85.61		23.8	-6.4
$NH_4F \cdot H_2O$	c	55.0523				6.146	34.92	37.22
NF_2H	g	53.0115				2.582	60.40	10.37
NH_4HF_2	c	57.0434	-187.94	-191.9	-155.6	4.243	27.61	25.50
std. state, m = 1	aq			-187.01	-157.15		49.2	
in 4.54 H_2O; saturated	aq			-186.8				
600 H_2O	aq			-187.1				
$NH_4H_3F_4$	liq	97.0561		-336.8				
NCl_3	liq	120.3657		55.				
in CCl_4				55.0				
NOCl	g	65.4591	12.82	12.36	15.78	2.716	62.52	10.68
std. state, m = 1	aq				16.04			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(11) — NITROGEN — June 1965

Substance			ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
NO_2Cl	g	81.4585	4.29	3.0	13.0	2.915	65.02	12.71
$NOClO_4$	c	129.4567		-36.9				
NO_2ClO_4	c	145.4561		8.7				
NH_4Cl	c	53.4916		-75.15	-48.51		22.6	20.1
std. state, m = 1	aq			-71.62	-50.34		40.6	-13.5
in 8 H_2O	aq			-71.590				
10 H_2O	aq			-71.567				
12 H_2O	aq			-71.551				
15 H_2O	aq			-71.531				
20 H_2O	aq			-71.512				
25 H_2O	aq			-71.500				
30 H_2O	aq			-71.492				
40 H_2O	aq			-71.486				
50 H_2O	aq			-71.484				
100 H_2O	aq			-71.487				
150 H_2O	aq			-71.496				
200 H_2O	aq			-71.503				
300 H_2O	aq			-71.515				
400 H_2O	aq			-71.522				
500 H_2O	aq			-71.528				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(12) — NITROGEN — June 1965

Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
NH_4Cl in 600 H_2O	aq			-71.533				
700 H_2O	aq			-71.538				
800 H_2O	aq			-71.541				
900 H_2O	aq			-71.544				
1,000 H_2O	aq			-71.547				
1,500 H_2O	aq			-71.557				
2,000 H_2O	aq			-71.563				
3,000 H_2O	aq			-71.572				
4,000 H_2O	aq			-71.576				
5,000 H_2O	aq			-71.580				
7,000 H_2O	aq			-71.586				
10,000 H_2O	aq			-71.591				
20,000 H_2O	aq			-71.598				
50,000 H_2O	aq			-71.606				
100,000 H_2O	aq			-71.610				
∞ H_2O	aq			-71.62				
NH_4Cl_3 std. state, m = 1	aq				-39.			
N_2H_5Cl	c	68.5062		-47.0				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(13) — NITROGEN — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
N_2H_5Cl std. state, m = 1	aq			-41.8	-11.7		49.5	-15.8
in 50 H_2O	aq			-41.868				
75 H_2O	aq			-41.835				
100 H_2O	aq			-41.822				
200 H_2O	aq			-41.807				
500 H_2O	aq			-41.802				
∞ H_2O	aq			-41.8				
$N_2H_5Cl \cdot HCl$	c	104.9672		-87.8				
$NH_2OH \cdot HCl$	c	69.4910		-75.9				22.2
	aq			-72.6				
NH_4ClO std. state, m = 1	aq	69.4910		-57.3	-27.8		37.	
NH_4ClO_2 std. state, m = 1	aq	85.4904		-47.6	-14.9		51.3	
NH_4ClO_3 std. state, m = 1	aq	101.4898		-55.4	-19.8		65.9	
NH_4ClO_4	c	117.4892		-70.58	-21.25		44.5	
std. state, m = 1	aq			-62.58	-21.03		70.6	
$N_2H_5ClO_4$	c	132.5038		-42.2				
std. state, m = 1	aq			-32.7	17.6		79.7	

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(14) NITROGEN June 1965

Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
$N_2H_5ClO_4$ in 50 H_2O	aq			-33.775				
100 H_2O	aq			-33.330				
200 H_2O	aq			-33.052				
300 H_2O	aq			-32.960				
500 H_2O	aq			-32.880				
1,000 H_2O	aq			-32.815				
∞ H_2O	aq			-32.7				
$N_2H_5ClO_4 \cdot 1/2\ H_2O$	c	141.5115		-78.18				
NOBr	g	109.9151	21.83	19.64	19.70	2.785	65.38	10.87
NH_4Br	c	94.9237		-64.73	-41.9		27.	23.
std. state, m = 1	aq			-60.72	-43.69		46.8	-14.8
in 100 H_2O	aq			-60.614				
150 H_2O	aq			-60.615				
200 H_2O	aq			-60.620				
300 H_2O	aq			-60.625				
400 H_2O	aq			-60.630				
500 H_2O	aq			-60.634				
600 H_2O	aq			-60.640				
700 H_2O	aq			-60.644				
800 H_2O	aq			-60.646				
1000 H_2O	aq			-60.650				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(15) — NITROGEN — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
NH_4Br in 1,500 H_2O	aq			-60.659				
2,000 H_2O	aq			-60.665				
3,000 H_2O	aq			-60.674				
4,000 H_2O	aq			-60.677				
5,000 H_2O	aq			-60.681				
7,000 H_2O	aq			-60.687				
10,000 H_2O	aq			-60.691				
20,000 H_2O	aq			-60.698				
50,000 H_2O	aq			-60.706				
100,000 H_2O	aq			-60.710				
∞ H_2O	aq			-60.72				
NH_4Br_3	c	254.7417		-67.5	-45.1		65.	
std. state, m = 1	aq			-62.84	-44.56		78.6	
NH_4Br_5 std. state, m = 1	aq	414.5597		-65.7	-43.8		102.8	
N_2H_5Br	c	109.9383		-37.2				
std. state, m = 1	aq			-30.8	-5.2		55.7	-17.1
in 50 H_2O	aq			-31.010				
100 H_2O	aq			-30.885				
200 H_2O	aq			-30.825				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(16) — NITROGEN — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
N_2H_5Br in 500 H_2O	aq			-30.809				
1,000 H_2O	aq			-30.805				
∞ H_2O	aq			-30.8				
$N_2H_5Br \cdot HBr$	c	190.8553		-64.8				
$N_2H_5Br \cdot HBr \cdot 2H_2O$	c	226.8860		-206.6				
$NH_4Br \cdot 1.5NH_3$	c	123.4935		-93.9	-47.0		51.	
NH_4BrO std. state, m = 1	aq	113.9470		-54.2	-27.0		37.	
NH_4BrO_3 std. state, m = 1	aq	145.9458		-51.7	-18.6		66.1	
NH_4Br_2Cl std. state, m = 1	aq	213.3096		-72.4	-49.7		56.6	
NH_4I	c	144.9430		-48.14	-26.9		28.	
std. state, m = 1	aq			-44.86	-31.30		53.7	-14.9
in 100 H_2O	aq			-44.784				
150 H_2O	aq			-44.782				
200 H_2O	aq			-44.780				
300 H_2O	aq			-44.775				
400 H_2O	aq			-44.778				
500 H_2O	aq			-44.780				
600 H_2O	aq			-44.786				
800 H_2O	aq			-44.788				
1,000 H_2O	aq			-44.792				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(17) — NITROGEN — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
NH_4I in 1,500 H_2O	aq			-44.801				
2,000 H_2O	aq			-44.807				
4,000 H_2O	aq			-44.818				
5,000 H_2O	aq			-44.822				
7,000 H_2O	aq			-44.828				
10,000 H_2O	aq			-44.832				
20,000 H_2O	aq			-44.839				
50,000 H_2O	aq			-44.847				
100,000 H_2O	aq			-44.850				
∞ H_2O	aq			-44.86				
NH_4I_3	c	398.7518		-49.7	-28.6		56.1	
std. state, m = 1	aq			-44.0	-31.3		84.3	
$NH_4I \cdot NH_3$	c	161.9736		-69.0	-31.5		43.1	
NH_3NI_3	c	411.7505		36.9				
$NH_4I \cdot 2NH_3$	c	179.0042		-89.6	-35.0		55.5	
NH_4IO std. state, m = 1	aq	160.9424		-57.4	-28.2		25.8	
NH_4IO_3	c	192.9412		-92.2				
std. state, m = 1	aq			-84.6	-49.6		55.4	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(18) — NITROGEN — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
NH_4IO_4		aq	208.9406		-66.9				
$NH_4H_4IO_6$		aq	244.9713		-212.1				
NH_4I_2OH	std. state, m = 1	aq	288.8548			-74.0			
$(NH_4)_2H_3IO_6$		aq	262.0019		-242.9				
$(NH_4)_2I_2O$	std. state, m = 1	aq	305.8854			-57.6			
NH_4ICl_2		c	215.8490			-55.5			
	std. state, m = 1	aq				-57.5			
NH_4ICl_4		c	286.7550			-59.2			
NH_4I_2Cl	std. state, m = 1	aq	307.3004			-50.7			
NH_4IBr_2		c	304.7610		-70.8	-46.9		55.4	
	std. state, m = 1	aq				-48.4			
NH_4BrI_2	std. state, m = 1	aq	351.7564		-62.3	-45.3		74.3	
NH_4IBrCl		c	260.3050			-52.0			
	std. state, m = 1	aq				-54.0			
N_4S_4		c	184.2868		128.0				
$N_2O_3(SO_3)_2$		c	236.1380		-253.				
NH_4HS		c	51.1106		-37.5	-12.1		23.3	
	std. state, m = 1	aq			-35.9	-16.09		42.1	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(19) — NITROGEN — June 1965

Substance				ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description		State	Formula Weight	0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
NH_4HS	in 200 H_2O	aq			-34.8				
S_7NH		c	239.4627		-67.4				
$(NH_4)_2S$	std. state, m = 1	aq	68.1412		-55.4	-17.4		50.7	
$(NH_4)_2S_2$	std. state, m = 1	aq	100.2052		-56.1	-18.9		61.0	
$(NH_4)_2S_3$	std. state, m = 1	aq	132.2692		-57.1	-20.3		70.0	
$(NH_4)_2S_4$		c	164.3332		-65.2				
	std. state, m = 1	aq			-57.8	-21.4		78.9	
$(NH_4)_2S_5$		c	196.3972		-65.6				
	std. state, m = 1	aq			-58.2	-22.2		87.8	
$(NH_4)_2S_8$		c	292.5892		-66.0				
H_2NSO_3H	sulfamic acid	c	97.0928		-161.3				
		aq			-156.3				
NH_4HSO_3		c	99.1088		-183.7				
	std. state, m = 1	aq			-181.34	-145.12		60.5	
	in 300 H_2O	aq			-181.3				
NH_4HSO_4		c	115.1082		-245.45				
	std. state, m = 1	aq			-243.75	-199.66		58.6	-0.9
	in 200 H_2O	aq			-245.65				
$NH_2OH \cdot H_2SO_4$		aq	131.1076		-246.7				
$NH_4HS_2O_4$	std. state, m = 1	aq	147.1722			-165.9			

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(20) NITROGEN June 1965

Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
$SO_2(NH_2)_2$ sulfamide	c	96.1081		-129.3				
$(NH_4)_2SO_3$	c	116.1394		-211.6				
std. state, m = 1	aq			-215.2	-154.2		47.2	
in 400 H_2O	aq			-211.0				
$(NH_4)_2SO_3 \cdot H_2O$	c	134.1547		-283.8				
$(NH_4)_2SO_4$	c	132.1388		-282.23	-215.56		52.6	44.81
std. state, m = 1	aq			-280.66	-215.77		58.6	-31.8
in 10 H_2O	aq			-280.72				
30 H_2O	aq			-280.58				
50 H_2O	aq			-280.51				
100 H_2O	aq			-280.407				
200 H_2O	aq			-280.321				
400 H_2O	aq			-280.25				
500 H_2O	aq			-280.242				
1,000 H_2O	aq			-280.217				
2,000 H_2O	aq			-280.217				
∞ H_2O	aq			-280.66				
$(NH_2OH)_2 \cdot H_2SO_4$	aq	164.1376		-281.3				
$(NH_4)_2S_2O_3$	aq	148.2034		-219.2				
$(NH_4)_2S_2O_4$ std. state, m = 1	aq	164.2028		-243.4	-181.4		76.	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(21) — NITROGEN — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$(NH_4)_2S_2O_6$	aq	196.2016		-349.7				
$(NH_4)_2S_2O_7$	aq	212.2010		-398.2				
$(NH_4)_2S_2O_8$	c	228.2004		-392.5				
std. state, m = 1	aq			-383.3	-303.3		113.5	
$(NH_4)_2S_3O_6$	aq	228.2656		-350.0				
$(NH_4)_2S_4O_6$	aq	260.3296		-355.92				
$(NH_4)_2S_5O_6$	aq	292.3936		-358.8				
$(N_2H_5)_2SO_4$	c	162.1681		-229.2				
std. state, m = 1	aq			-221.0	-138.6		77.	-36.
$(N_2H_5)_2SO_4 \cdot H_2O$	c	180.1834		-291.3				
$(NH_4)_2SO_4 \cdot 3NH_3$	c	183.2306		-341.7	-223.7		89.5	
NSF	g	65.0691				2.678	62.07	10.55
NSF_3	g	103.0659				3.471	68.48	17.18
NH_4SO_3F	aq	117.0992		-224.7				
$NH_4I \cdot 3SO_2$	c	337.1314		-289.2	-238.9		100.3	
NSe	c	92.967		42.3				
NH_4HSe	c	98.006		-31.8	=5.6		23.1	
std. state, m = 1	aq			-27.9	-8.5		46.	
	aq			-28.2				

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 18(22) NITROGEN June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description				0°K	298.15°K (25°C)				
				kcal/mol				cal/deg mol	
$(NH_4)_2Se$	std. state, m = 1	aq	115.037			-7.0			
NH_4HSeO_3	std. state, m = 1	aq	146.005		-154.65	-117.33		60.2	
NH_4HSeO_4	std. state, m = 1	aq	162.004		-170.7	-127.1		62.8	
$(NH_4)_2SeO_3$	std. state, m = 1	aq	163.035		-185.0	-126.3		57.3	
$(NH_4)_2SeO_4$		c	179.035		-209.0				
	std. state, m = 1	aq			-206.5	-143.4		67.1	
NH_4HTe		c	146.646		0.3				
$NH_4H_5TeO_6$		aq	246.675		-333.2				
$(NH_4)_2TeO_3$		aq	211.675		-205.9				
$(NH_4)_2H_4TeO_6$		aq	263.705		-355.4				
$(NH_4)_2PoCl_6$	std. state, m = 1	aq				-176.			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(1) — PHOSPHORUS — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
P α, white	c	30.9738	0	0	0	1.281[a]	9.82	5.698
red, triclinic	c		-3.78	-4.2	-2.9		5.45	5.07
black	c			-9.4				
red	amorp			-1.8				
	g					1.481	38.978	4.968
in CS_2				0.5				
P_2	g	61.9476		34.5	24.8		52.108	
P_4	g	123.8952	15.83	14.08	5.85	3.378	66.89	16.05
PO	g	46.9732					53.221	
PO_3^-	aq	78.9720		-233.5				
PO_4^{3-} std. state, m = 1	aq	94.9714		-305.9	-244.0		-53.	
$P_2O_7^{4-}$ std. state, m = 1	aq	173.9434		-542.8	-459.8		-25.	
P_4O_6	c	219.8916		-392.0				
P_4O_{10} hexagonal	c	283.8892	-705.82	-713.2	-644.8	8.117	54.70	50.60
	amorp			-727.				
PH_3	g	33.9977	3.20	1.3	3.2	2.420	50.22	8.87
std. state, m = 1	aq			-2.16	0.35		48.2	
PH_3^+	g		243.	242.6				
PH_4^+ std. state, m = 1	aq	35.0057			16.2			

[a] Relative to P, α, white

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(2) — PHOSPHORUS — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
P_2H_4	liq	65.9795		-1.2				
	g			5.0				
HPO_3	c	79.9800		-226.7				
	aq			-233.5				
HPO_3^{2-}	aq			-231.6				
HPO_4^{2-} std. state, m = 1	aq	95.9794		-309.37	-260.91		-8.0	
$H_2PO_2^-$	aq	64.9885		-146.7				
$H_2PO_3^-$	aq	80.9879		-231.7				
$H_2PO_4^-$ std. state, m = 1	aq	96.9873		-310.38	-270.73		21.6	
H_3PO_2	c	65.9965		-144.5				
	liq			-142.3				
in 50 H_2O	aq			-143.6				
100 H_2O	aq			-144.0				
200 H_2O	aq			-144.4				
400 H_2O	aq			-144.7				
H_3PO_3	c	81.9959		-230.5				
	aq			-230.6				
H_3PO_4	c	97.9953	-301.29	-305.7	-267.5	4.059	26.41	25.35
	liq			-302.8				
std. state, m = 1	aq			-307.92	-273.10		37.8	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(3) — PHOSPHORUS — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
H_3PO_4 in 0.75 H_2O	aq			-303.96				
1.0 H_2O	aq			-304.69				
1.5 H_2O	aq			-305.26				
2.0 H_2O	aq			-305.60				
2.5 H_2O	aq			-305.98				
3 H_2O	aq			-306.23				
3.5 H_2O	aq			-306.43				
4 H_2O	aq			-306.60				
4.5 H_2O	aq			-306.75				
5 H_2O	aq			-306.87				
5.5 H_2O	aq			-306.97				
6 H_2O	aq			-307.05				
7 H_2O	aq			-307.20				
8 H_2O	aq			-307.31				
9 H_2O	aq			-307.40				
10 H_2O	aq			-307.48				
12 H_2O	aq			-307.594				
15 H_2O	aq			-307.715				
18 H_2O	aq			-307.793				
20 H_2O	aq			-307.831				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(4) — PHOSPHORUS — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
H_3PO_4 1n 25 H_2O	aq			-307.907				
30 H_2O	aq			-307.955				
40 H_2O	aq			-308.032				
50 H_2O	aq			-308.067				
75 H_2O	aq			-308.138				
100 H_2O	aq			-308.176				
150 H_2O	aq			-308.237				
200 H_2O	aq			-308.276				
250 H_2O	aq			-308.302				
300 H_2O	aq			-308.326				
350 H_2O	aq			-308.35				
400 H_2O	aq			-308.368				
500 H_2O	aq			-308.403				
750 H_2O	aq			-308.473				
1,000 H_2O	aq			-308.532				
1,500 H_2O	aq			-308.622				
2,000 H_2O	aq			-308.696				
2,500 H_2O	aq			-308.762				
3,000 H_2O	aq			-308.818				
4,000 H_2O	aq			-308.931				

National Bureau of Standards Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(5) PHOSPHORUS June 1965

Substance			Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description		State		0°K	298.15°K (25°C)				
				kcal/mol				cal/deg mol	
H_3PO_4	in 5,000 H_2O	aq			-308.982				
	10,000 H_2O	aq			-309.197				
$H_3PO_4 \cdot 0.5\ H_2O$		c	107.0030	-336.899	-342.1	-296.9	4.785	30.87	20.12
$H_3PO_4 \cdot H_2O$		c	116.0106		-374.96				
PH_4OH	std. state, m = 1	aq	52.0130		-70.48	-56.34		65.	
$HP_2O_7^{3-}$	std. state, m = 1	aq	174.9514		-543.7	-472.5		15.	
$H_2P_2O_7^{2-}$	std. state, m = 1	aq	175.9593		-544.6	-481.6		42.	
$H_3P_2O_7^-$	std. state, m = 1	aq	176.9673		-544.1	-484.7		54.	
$H_4P_2O_5$		aq	145.9765		-393.6				
$H_4P_2O_7$		c	177.9753		-535.6				
	supercooled	liq			-533.4				
	std. state, m = 1	aq			-542.2	-486.8		68.	
	in 500 H_2O	aq			-543.0				
$H_4P_2O_7 \cdot 3/2\ H_2O$		c	204.9983		-640.9				
		liq			-637.3				
PF_3		g	87.9690	-218.25	-219.6	-214.5	3.092	65.28	14.03
PF_5		g	125.9658		-381.4				
PO_3F^{2-}	std. state, m = 1	aq	97.9704			-280.8			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(6) — PHOSPHORUS — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
POF_3		g	103.9684	-287.39	-289.5	-277.9	3.369	68.11	16.41
HPO_3F^-	std. state, m = 1	aq	98.9784			-286.4			
H_2PO_3F	std. state, m = 1	aq	99.9863			-287.5			
PCl_3		liq	137.3328		-76.4	-65.1		51.9	
		g		-67.85	-68.6	-64.0	3.817	74.49	17:17
PCl_3^+		g		180.	181.				
PCl_5		c	208.2388		-106.0				
		g		-88.33	-89.6	-73.0	5.499	87.11	26.96
$POCl_3$		c	153.3322	-145.81					
		liq			-142.7	-124.5	8.720	53.17	33.17
		g			-133.48	-122.60	4.273	77.76	20.30
	in $CHCl_3$				-143.6				
PH_4Cl		c	70.4587		-34.7				
$H_3PO_4 \cdot HClO_4$		c	198.4539		-325.3				
PBr_3		liq	270.7008		-44.1	-42.0		57.4	
		g		-27.47	-33.3	-38.9	4.240	83.17	18.16
	in CS_2				-43.0				
PBr_5		c	430.5188		-64.5				
$POBr_3$		c	286.7002		-109.6				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(7) — PHOSPHORUS — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$POBr_3$	g					4.744	85.97	21.48
PH_4Br	c	114.9147		-30.5	-11.4		26.3	
PI_3	c	411.6870		-10.9				
	g					4.542	89.45	18.73
in CS_2				-7.6				
PH_4I	c	161.9101		-16.7	0.2		29.4	26.2
P_2S_3	c	158.1396		-19.2				
$PSCl_3$	g	169.3968				4.522	80.47	21.39
$PSBr_3$	c	302.7648					55.2	
	g						89.07	22.69
PN	g	44.9805					50.437	
$1/n\ (PN)_n$	c			-15.				
P_3N_5	c	162.9549		-71.4				36.
NH_4PO_3	aq	97.0106		-265.2				
$NH_4H_2PO_2$	c	83.0271		-180.0				

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(8) PHOSPHORUS June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$NH_4H_2PO_2$ in 100 H_2O	aq			-178.00				
200 H_2O	aq			-178.16				
300 H_2O	aq			-178.22				
400 H_2O	aq			-178.28				
800 H_2O	aq			-178.32				
1,000 H_2O	aq			-178.34				
1,400 H_2O	aq			-178.38				
1,600 H_2O	aq			-178.39				
∞ H_2O	aq			-178.4				
$NH_4H_2PO_3$	aq	99.0265		-263.4				
$NH_4H_2PO_4$	c	115.0259		-345.94	-289.89		36.32	34.00
std. state, m = 1	aq			-342.05	-289.70		48.7	
in 15 H_2O	aq			-342.157				
20 H_2O	aq			-342.155				
25 H_2O	aq			-342.149				
40 H_2O	aq			-342.128				
50 H_2O	aq			-342.113				
75 H_2O	aq			-342.099				
100 H_2O	aq			-342.088				
200 H_2O	aq			-342.071				
500 H_2O	aq			-342.057				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(9) — PHOSPHORUS — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
$NH_4H_2PO_4$ in 1,000 H_2O	aq			-342.055				
5,000 H_2O	aq			-342.051				
∞ H_2O	aq			-342.05				
$(NH_4)_2HPO_3$	aq	116.0571		-249.9				
$(NH_4)_2HPO_4$	c	132.0565		-347.50				45.
std. state, m = 1	aq			-372.71	-298.85		46.2	
in 11 H_2O	aq			-370.35				
15 H_2O	aq			-370.40				
20 H_2O	aq			-370.48				
25 H_2O	aq			-370.56				
30 H_2O	aq			-370.62				
50 H_2O	aq			-370.85				
75 H_2O	aq			-371.00				
100 H_2O	aq			-371.22				
200 H_2O	aq			-371.29				
300 H_2O	aq			-371.35				
500 H_2O	aq			-371.4				
1,000 H_2O	aq			-371.44				
$(NH_4)_3PO_4$	c	149.0871		-399.6				
std. state, m = 1	aq			-400.9	-300.9		28.	

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 19(10) — PHOSPHORUS — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
$(NH_4)_3PO_4$ in 600 H_2O	aq	149.0871		-391.3				
$(NH_4)_3PO_4 \cdot 3H_2O$	c	203.1332		-610.8				
$NH_4H_3P_2O_7$ std. state, m = 1	aq	195.0059		-575.8	-503.7		81.	
$(NH_4)_2H_2P_2O_7$ std. state, m = 1	aq	212.0365		-607.9	-519.5		96.	
$(NH_4)_3HP_2O_7$ std. state, m = 1	aq	229.0671		-638.7	-529.4		96.	
$(NH_4)_4P_2O_7$ std. state, m = 1	aq	246.0977		-669.5	-535.7		83.	
NH_4PF_6	c	163.0028					60.49	40.33
$NH_4PF_6 \cdot NH_3$	c	180.0334					79.8	
NH_4HPO_3F std. state, m = 1	aq	117.0170			-305.4			
$(NH_4)_2PO_3F$ std. state, m = 1	aq	134.0476			-318.7			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 20(1) — ARSENIC — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
As α, gray, metallic	c	74.9216	0	0	0	1.226	8.4	5.89
γ, yellow, cubic	c			3.5				
β	amorp			1.0				
	g		72.04	72.3	62.4	1.481	41.61	4.968
As^+	g		298.38	300.12				
As^{2+}	g		764.42	767.64				
As^{3+}	g		1417.44	1422.14				
As^{4+}	g		2573.58	2579.76				
As^{5+}	g		4017.82	4025.48				
As^{6+}	g		6959.28	6968.42				
As_2	g	149.8432	53.30	53.1	41.1	2.251	57.2	8.366
As_4	g	299.6864		34.4	22.1		75.	
AsO	g	90.9210	16.88	16.72		2.101		
AsO^+ un-ionized, std. state, m = 1	aq				-39.15			
AsO_2^- std. state, m = 1	aq	106.9204		-102.54	-83.66		9.9	
AsO_4^{3-} std. state, m = 1	aq	138.9192		-212.27	-155.00		-38.9	
As_2O_4	c	213.8408		-189.72				
As_2O_5	c	229.8402		-221.05	-187.0		25.2	27.85
	aq			-227.4				
$As_2O_5 \cdot 4H_2O$	c	301.9016		-503.0				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 20(2) — ARSENIC — June 1965

Substance: Formula and Description		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
As_4O_6	octahedral	c	395.6828		-314.04	-275.46		51.2	45.72
	monoclinic	c			-313.0	-275.82		56.	
		g			-289.0	-262.4		91.	
		aq			-299.6				
$3As_2O_5 \cdot 5H_2O$		c	779.5973		-1015.4				
AsH_3		g	77.9455	17.70	15.88	16.47	2.438	53.22	9.10
$HAsO_2$	un-ionized; std. state, m = 1	aq	107.9284		-109.1	-96.25		30.1	
$HAsO_4^{2-}$	undissoc.; std. state, m = 1	aq	139.9272		-216.62	-170.82		-0.4	
$H_2AsO_3^-$	undissoc.; std. state, m = 1	aq	124.9357		-170.84	-140.35		26.4	
$H_2AsO_4^-$	undissoc.; std. state, m = 1	aq	140.9351		-217.39	-180.04		28.	
H_3AsO_3	un-ionized; std. state, m = 1	aq	125.9437		-177.4	-152.94		46.6	
		aq			-177.4				
H_3AsO_4		c	141.9431		-216.6				
		aq			-216.2				
	un-ionized; std. state, m = 1	aq			-215.7	-183.11		44.	
AsF_3		liq	131.9168		-228.55	-217.29		43.31	30.25
		g		-218.68	-220.04	-216.46	3.413	69.07	15.68
AsO_3F^{2-}	undissoc.; std. state, m = 1	aq	141.9182			-245.59			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 20(3) — ARSENIC — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
$HAsO_3F^-$	un-ionized; std. state, m = 1	aq	142.9262		.	-253.60			
$AsCl_2$		g	145.8276	16.	16.				
$AsCl_3$		liq	181.2806		-72.9	-61.37		49.6	
		g		-61.42	-61.80	-58.77	4.137	78.17	18.10
$AsBr_3$		c	314.6486		-47.2				
		g		-25.55	-31.	-28.	4.569	86.94	18.92
AsI_3		c	455.6348	-13.91	-13.9	-14.2	5.964	50.92	25.28
		g					4.834	92.79	19.27
As_2S_2		c	213.9712		-34.1				
As_2S_3		c	246.0352		-40.4	-40.3		39.1	27.8
$As_2O_3 \cdot SO_3$		c	277.9036		-285.45				
AsN		g	88.9283	47.	46.91	40.15	2.169	53.9	7.27
NH_4AsO_2	std. state, m = 1	aq	124.9590		-134.21	-102.63		37.0	
$NH_4H_2AsO_3$	std. state, m = 1	aq	143.9743		-202.51	-159.32		53.5	
$NH_4H_2AsO_4$		c	158.9737		-253.3	-199.1		41.12	36.13
	std. state, m = 1	aq			-249.06	-199.01		55.1	
	in 660 H_2O	aq			-249.1				
$(NH_4)_2HAsO_4$		c	176.0043		-282.4				
	std. state, m = 1	aq			-279.9	-208.7		53.8	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 20(4) — ARSENIC — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
$(NH_4)_2HAsO_4$ in 660 H_2O	aq			-279.8				
$(NH_4)_3AsO_4$	c	193.0349		-307.4				
std. state, m = 1	aq			-307.28	-211.91		42.4	
$(NH_4)_3AsO_4 \cdot 3H_2O$	c	247.0810		-517.9				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 21(1) — ANTIMONY — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
Sb	III	c	121.75	0	0	0	1.410	10.92	6.03
	IV, explosive	amorp			2.54				
		g		62.63	62.7	53.1	1.481	43.06	4.97
Sb^+		g		261.91	263.46				
Sb^{2+}		g		643.1	646.1				
Sb^{3+}		g		1227.1	1231.6				
Sb^{4+}		g		2245.4	2251.4				
Sb^{5+}		g		3530.	3537.				
Sb^{6+}		g		6012.	6021.				
Sb_2		g	243.500	56.76	56.3	44.7	2.360	60.90	8.70
Sb_4		g	487.000	50.2	49.0	33.8	4.40	84.	
SbO		g	137.749	48.	47.67		2.122		
SbO^+	std. state, m = 1	aq				-42.33			
SbO_2^-	std. state, m = 1	aq	153.749			-81.32			
Sb_2O_3		aq	291.498		-164.9				
Sb_2O_4		c	307.498		-216.9	-190.2		30.4	27.39
Sb_2O_5		c	323.497		-232.3	-198.2		29.9	
		aq			-228.7				
Sb_4O_6	II, cubic	c	582.996		-344.3	-303.1		52.8	

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 21(2) — ANTIMONY — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula	Description			0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
Sb_4O_6	I, orthorhombic	c			-338.7	-299.5		58.8	48.46
Sb_6O_{13}		c	938.492		-670.6				
SbH_3		g	124.774	36.625	34.681	35.31	2.502	55.61	9.81
$HSbO_2$	un-ionized; std. state, m = 1	aq	154.757		-116.6	-97.4		11.1	
$Sb(OH)_3$		c	172.772			-163.8			
	un-ionized; std. state, m = 1	aq			-184.9	-154.1		27.8	
H_3SbO_4		aq	188.772		-216.8				
$HSb(OH)_6$		aq	224.802		-353.4				
SbF		g	140.748	-11.	-11.29		2.171		
SbF_3		c	178.745		-218.8				
	in 200 H_2O	aq			-217.7				
SbOF	un-ionized; std. state, m = 1	aq	156.748			-116.5			
H_3SbF_6		aq	238.764		-448.4				
$Sb(OH)_2F$	un-ionized; std. state, m = 1	aq	174.763			-173.2			
SbCl		g	157.203	-6.	-6.22		2.289		
$SbCl_2$		g	192.656	-18.	-18.5				
$SbCl_3$		c	228.109		-91.34	-77.37		44.0	25.8

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 21(3) — ANTIMONY — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C°_p
Formula and Description				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
$SbCl_3$		g		-74.57	-75.0	-72.0	4.269	80.71	18.33
$SbCl_5$		liq	299.015		-105.2	-83.7		72.	
		g		-93.70	-94.25	-79.91	6.341	96.04	28.95
	in nitrobenzene				-115.6				
SbOCl		c	173.202		-89.4				
		g		-25.	-25.5				
$Sb_4O_5Cl_2$		c	637.903		-346.9				
$SbBr_3$		c	361.477		-62.0	-57.2		49.5	
		g		-41.03	-46.5	-53.5	4.727	89.09	19.17
	in CS_2				-58.4				
SbI_3		c	502.463		-24.0				
		aq			-23.6				
Sb_2S_3	black	c	339.692		-41.8	-41.5		43.5	28.65
	orange	amorp			-35.2				
$Sb_2S_4^{2-}$	std. state, m = 1	aq	461.442		-52.4	-23.8		-12.5	
$Sb_2(SO_4)_3$		c	621.371		-574.2				
Sb_2Te_3		c	626.30		-13.5	-13.2		56.	
SbN		g	135.757	64.	63.66		2.104		

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 21(4) — ANTIMONY — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
NH_4SbO_2 std. state, m = 1	aq	171.787			-100.29			
$SbF_3 \cdot NH_3$	c	195.776		-243.5				
$SbF_3 \cdot 2NH_3$	c	212.806		-266.6				
$SbF_3 \cdot 3NH_3$	c	229.837		-286.9				
$SbF_3 \cdot 4NH_3$	c	246.868		-305.5				
$SbF_3 \cdot 6NH_3$	c	280.929		-342.5				
$(NH_4)_2Sb_2S_4$ std. state, m = 1	aq	407.833		-115.7	-61.7		41.7	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 22(1) — BISMUTH — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
Bi	c	208.980	0	0	0	1.536	13.56	6.10
	g		49.56	49.5	40.2	1.481	44.669	4.968
Bi^+	g		217.65	219.13				
Bi^{2+}	g		602.5	605.4				
Bi^{3+}	g		1192.0	1196.4				
std. state, m = 1	aq				19.8			
Bi^{4+}	g		2237.0	2242.9				
Bi^{5+}	g		3528.5	3535.9				
Bi^{6+}	g		5565.	5574.				
Bi_2	g	417.960		52.5				
BiO^+ std. state, m = 1	aq	224.9794			-35.0			
Bi_2O_3	c	465.9582		-137.16	-118.0		36.2	27.13
$Bi_6O_6^{6+}$ std. state, m = 1	aq	1349.8764			-220.6			
$BiOH^{2+}$ std. state, m = 1	aq	225.9874			-35.0			
BiO·OH	c	241.9868			-88.0			
$Bi(OH)_3$	c	260.0021		-170.0				
$Bi_6O_6(OH)_3^{3+}$ std. state, m = 1	aq	1400.8985			-379.6			
$Bi_6(OH)_{12}^{6+}$ std. state, m = 1	aq	1457.9684			-561.9			
$Bi_9(OH)_{20}^{7+}$ std. state, m = 1	aq	2220.9674			-951.5			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 22(2) — BISMUTH — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$Bi_9(OH)_{21}^{6+}$ std. state, m = 1	aq	2237.9748			-1003.8			
$Bi_9(OH)_{22}^{5+}$ std. state, m = 1	aq	2254.9821			-1056.9			
BiCl	c	244.433		-31.2	-25.9		22.6	
$BiCl^{2+}$ std. state, m = 1	aq				-14.64			
$BiCl_2^+$ std. state, m = 1	aq	279.886			-49.1			
$BiCl_3$	c	315.339		-90.6	-75.3		42.3	25.
	g		-63.32	-63.5	-61.2	4.642	85.74	19.04
in 2N HCl	aq			-101.7				
$BiCl_4^-$ std. state, m = 1	aq	350.792			-115.1			
$BiCl_6^{3-}$ std. state, m = 1	aq	421.698			-178.51			
BiOCl	c	260.4324		-87.7	-77.0		28.8	
$Bi(OH)_2Cl$	c	278.4477			-128.71			
$BiBr^{2+}$ std. state, m = 1	aq	288.889			-8.1			
$BiBr_2^+$ std. state, m = 1	aq	368.798			-35.9			
$BiBr_3$	c	448.707						26.
std. state, m = 1	aq	448.707			-63.3			
$BiBr_4^-$ std. state, m = 1	aq				-90.2			
BiOBr	c	304.8884			-71.0			
BiI^{2+} std. state, m = 1	aq	335.8844			3.8			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 22(3) — BISMUTH — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
BiI_3	c	589.6932			-41.9			
BiI_4^- std. state, m = 1	aq	716.5976			-49.9			
BiS	g	241.044		43.	29.		68.	
BiS^+	g			229.				
Bi_2S_3	c	514.152		-34.2	-33.6		47.9	29.2
$Bi_2(SO_4)_3$	c	706.1448		-608.1				
BiSe	g	287.940		42.0				
Bi_2Se_3	c	654.840						
BiTe	g	336.580		42.8				
Bi_2Te_3	c	703.480		-18.5	-18.4	7.387	62.36	28.8
$BiONO_3$	c	286.9843			-67.0			
NH_4BiCl_4 std. state, m = 1	aq	368.8306			-134.1			
$NH_4BiCl_6^{2-}$ std. state, m = 1	aq	439.7366			-197.6			
$(NH_4)_3BiCl_6$ std. state, m = 1	aq	475.8137			-235.42			
NH_4BiBr_4 std. state, m = 1	aq	546.6546			-109.2			
NH_4BiI_4 std. state, m = 1	aq	734.6362			-68.9			
$BiAsO_4$	c	347.8992			-148.			

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(1) CARBON June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0°K	298.15°K (25°C)				
				kcal/mol				cal/deg mol	
C	graphite	c	12.0112	0	0	0	0.251	1.372	2.038
	diamond	c		0.5797	0.4533	0.6930	0.125[a]	0.568	1.4615
		g		169.98	171.291	160.442	1.562	37.7597	4.9805
C^+		g		429.628	432.420				
C^{2+}		g		991.900	996.173				
C^{3+}		g		2095.98	2101.73				
C^{4+}		g		3583.23	3590.46				
C^{5+}		g		12625.1	12633.8				
C^{6+}		g		23924.	23934.				
CO		g	28.0106	-27.199	-26.416	-32.781	2.0716	47.219	6.959
	std. state, m = 1	aq			-28.91	-28.66		25.0	
	in CH_3COOH				-26.416	-28.15		31.7	
CO^+		g		295.9	298.16				
CO^{2+}		g		942.	945.5				
CO_2		g	44.0100	-93.964	-94.051	-94.258	2.2378	51.06	8.87
	undissoc.; std. state, m = 1	aq			-98.90	-92.26		28.1	
	in CH_3OH				-97.57				
	in abs. C_2H_5OH;								
	std. state, $x_2 = 1$				-96.85	-91.32		31.8	
	in CCl_4				-98.39				

[a] Relative to C, diamond

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(2) — CARBON — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
CO_2 in acetone; std. state, $x_2 = 1$				-98.37	-91.91		28.7	
CO_2 in benzene				-95.16				
CO_2^+	g		223.8	225.23				
CO_3^{2-} std. state, m = 1	aq	60.0094		-161.84	-126.17		-13.6	
CH	g	13.0191	141.6	142.4				
CH^+	g		398.1	400.4				
CH_2	g	14.0271	93.9	93.7				
CH_2^+	g		333.6	334.9				
CH_3	g	15.0351	34.0	33.2				
CH_3^+	g		261.0	261.7				
CH_4	g	16.0430	-15.970	-17.88	-12.13	2.388	44.492	8.439
std. state, m = 1	aq			-21.28	-8.22		20.0	
CH_4^+	g		277.1	276.7				
HCO	g	29.0185				2.386	53.68	8.26
$HCOO^-$ std. state, m = 1	aq	45.0180		-101.71	-83.87		22.	-21.0
HCO_3^- std. state, m = 1	aq	61.0174		-165.39	-140.26		21.8	
HCHO	g	30.0265	-27.1	-28.	-27.	2.394	52.26	8.46
unhydrolyzed	aq			-35.9				
in 60 H_2O	aq			-42.8				

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES - SERIES I

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(3) — CARBON — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
HCHO in 40 CH_3OH				-43.0				
HCOOH	liq	46.0259		-101.51	-86.38		30.82	23.67
	g			-90.48				
un-ionized, std. state, m = 1	aq			-101.68	-88.98		39.	
ionized; std. state, m = 1	aq			-101.71	-83.87		22.	-21.0
in 0.5 H_2O	aq			-101.633				
1 H_2O	aq			-101.699				
2 H_2O	aq			-101.715				
3 H_2O	aq			-101.697				
4 H_2O	aq			-101.681				
5 H_2O	aq			-101.667				
6 H_2O	aq			-101.657				
8 H_2O	aq			-101.645				
10 H_2O	aq			-101.642				
15 H_2O	aq			-101.641				
25 H_2O	aq			-101.643				
50 H_2O	aq			-101.654				
75 H_2O	aq			-101.661				
100 H_2O	aq			-101.666				
200 H_2O	aq			-101.674				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(4) — CARBON — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$HCOOH$ in 500 H_2O	aq			-101.678				
1,000 H_2O	aq			-101.681				
10,000 H_2O	aq			-101.685				
20,000 H_2O	aq			-101.687				
50,000 H_2O	aq			-101.690				
100,000 H_2O	aq			-101.697				
∞ H_2O	aq			-101.71				
$HCOOH^+$	g			165.80				
H_2CO_3 std. state, m = 1	aq	62.0253		-167.22	-148.94		44.8	
CH_3OH	liq	32.0424		-57.04	-39.76		30.3	19.5
	g		-45.355	-47.96	-38.72	2.731	57.29	10.49
in 0.25 H_2O	aq			-57.179				
0.5 H_2O	aq			-57.273				
1.0 H_2O	aq			-57.425				
1.5 H_2O	aq			-57.555				
2.0 H_2O	aq			-57.675				
2.5 H_2O	aq			-57.780				
3.0 H_2O	aq			-57.872				
3.5 H_2O	aq			-57.954				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(5) — CARBON — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
CH_3OH in 4.0 H_2O	aq			-58.026				
4.5 H_2O	aq			-58.089				
5.0 H_2O	aq			-58.145				
5.5 H_2O	aq			-58.194				
6 H_2O	aq			-58.236				
7 H_2O	aq			-58.307				
8 H_2O	aq			-58.362				
9 H_2O	aq			-58.407				
10 H_2O	aq			-58.439				
12 H_2O	aq			-58.498				
15 H_2O	aq			-58.553				
20 H_2O	aq			-58.609				
25 H_2O	aq			-58.642				
30 H_2O	aq			-58.665				
40 H_2O	aq			-58.693				
50 H_2O	aq			-58.710				
75 H_2O	aq			-58.733				
100 H_2O	aq			-58.744				
150 H_2O	aq			-58.756				
200 H_2O	aq			-58.762				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(6) — CARBON — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
CH_3OH in 300 H_2O	aq			-58.767				
400 H_2O	aq			-58.770				
500 H_2O	aq			-58.772				
1,000 H_2O	aq			-58.776				
∞ H_2O	aq			-58.779				
in 0.1 C_6H_6				-57.004				
0.15 C_6H_6				-56.986				
0.2 C_6H_6				-56.969				
0.25 C_6H_6				-56.952				
0.5 C_6H_6				-56.875				
1.0 C_6H_6				-56.742				
1.5 C_6H_6				-56.634				
2.0 C_6H_6				-56.532				
2.5 C_6H_6				-56.441				
3.0 C_6H_6				-56.359				
3.5 C_6H_6				-56.282				
4.0 C_6H_6				-56.208				
4.5 C_6H_6				-56.139				
5.0 C_6H_6				-56.074				
5.5 C_6H_6				-56.010				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(7) — CARBON — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
CH_3OH in 6 C_6H_6				-55.950				
7 C_6H_6				-55.839				
8 C_6H_6				-55.738				
9 C_6H_6				-55.648				
10 C_6H_6				-55.562				
12 C_6H_6				-55.408				
15 C_6H_6				-55.212				
20 C_5H_6				-54.950				
$CH_2(OH)_2$	g	48.0418		-98.				
	aq			-111.1				
CF_4	g	88.0048	-219.6	-221.	-210.	3.043	62.50	14.60
in C_7F_{14}; std. state, $x_2 = 1$				-222.7	-207.3		47.6	
COF_2	g	66.0074	-150.95	-151.7	-148.0	2.642	61.78	11.19
CH_3F	g	34.0335				2.422	53.25	8.96
CH_2F_2	g	52.0239	-104.97	-106.8	-100.2	2.555	58.94	10.25
CHF_3	g	70.0143	-162.84	-164.5	-156.3	2.764	62.04	12.20
CHOF	g	48.0169				2.486	58.92	9.54
CCl_4	liq	153.8232		-32.37	-15.60		51.72	31.49
	g		-24.08	-24.6	-14.49	4.117	74.03	19.91

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(8) — CARBON — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$COCl_2$	g	98.9166	-51.89	-52.3	-48.9	3.067	67.74	13.78
CH_3Cl	g	50.4881	-17.426	-19.32	-13.72	2.489	56.04	9.74
std. state, m = 1	aq			-24.3	-12.3		34.6	
CH_2Cl_2	liq	84.9331		-29.03	-16.09		42.5	23.9
	g		-20.462	-22.10	-15.75	2.830	64.56	12.18
$CHCl_3$	liq	119.3781		-32.14	-17.62		48.2	27.2
	g		-23.486	-24.65	-16.82	3.389	70.65	15.70
CF_3Cl	g	104.4594	-164.8	-166.	-156.	3.293	68.16	15.98
CF_2Cl_2	g	120.9140	-113.0	-114.	-105.	3.543	71.86	17.27
$CFCl_3$	liq	137.3686		-72.02	-56.61		53.86	29.05
	g		-65.2	-66.	-57.	3.843	74.05	18.66
CH_2ClF	g	68.4785				2.689	63.17	11.24
$CHClF_2$	g	86.4689				2.955	67.11	13.35
$CHCl_2F$	g	102.9235				3.170	70.02	14.56
CBr_4	g	331.6472	26.10	19.	16.	4.873	85.55	21.79
$COBr_2$	liq	187.8286		-30.4				
	g			-23.0				
CH_3Br	g	94.9441	-4.72	-8.4	-6.2	2.536	58.86	10.14
CH_2Br_2	g	173.8451				3.020	70.06	13.07

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(9) CARBON June 1965

Substance			ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
Formula and Description	State	Formula Weight	0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$CHBr_3$	liq	252.7461		-6.8	-1.2		52.8	31.
	g		10.24	4.	2.	3.811	79.07	17.02
CF_3Br	g	148.9154	-151.21	-153.6	-147.3	3.457	71.14	16.57
CF_2Br_2	g	209.8260				3.892	77.71	18.41
$CFBr_3$	g	270.7366				4.364	82.64	20.17
CH_2BrF	g	112.9345				2.781	66.0	11.76
$CHBrF_2$	g	130.9249				3.147	70.5	14.04
$CHFBr_2$	g	191.8355				3.439	75.7	15.56
CCl_3Br	g	198.2792	-8.81	-11.0	-5.1	4.285	79.55	20.38
CBr_2Cl_2	g	242.7352				4.467	83.1	20.81
$CClBr_3$	g	287.1912				4.679	85.5	21.36
CH_2ClBr	g	129.3891				2.919	68.7	12.60
$CHBrCl_2$	g	163.8341				3.520	75.6	16.11
$CHBr_2Cl$	g	208.2901				3.655	78.3	16.53
CF_2ClBr	g	165.3700				3.708	76.1	17.82
$CFBrCl_2$	g	181.8246				3.994	79.0	19.13
CI_4	g	519.6288				5.343	93.65	22.91
CH_3I	liq	141.9395		-3.7	3.2		39.0	30.
	g		5.38	3.1	3.5	2.585	60.71	10.54

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Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(10) — CARBON — June 1965

Substance		State	Formula Weight	ΔHf°_0	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
CH_2I_2		liq	267.8359		16.0	21.6		41.6	32.
		g		29.26	27.0	22.9	3.172	74.0	13.79
CHI_3		c	393.7323		33.7				
		g					4.106	85.1	17.92
CH_3I_3	in n-heptane		395.7483		-4.2				
CF_3I		g	195.9108				3.579	73.44	16.94
CH_2ClI		g	176.3845				3.002	70.7	13.02
CH_2IBr		g	220.8405				3.102	73.5	13.46
CS_2		liq	76.1392		21.44	15.60		36.17	18.1
		g		27.86	28.05	16.05	2.547	56.82	10.85
COS		g	60.0746	-33.990	-33.96	-40.47	2.373	55.32	9.92
CH_3SH		liq	48.1070		-11.08	-1.85		40.44	21.64
		g		-2.885	-5.34	-2.23	2.898	60.96	12.01
$SC(SH)_2$	trithiocarbonic acid	liq	110.2191		6.0	7.0		52.	35.8
CH_2SO_4	methylene sulfate	c	110.0887		-164.6				
HF·COS		g	80.0809		-102.6				
CSe_2		liq	169.9312		39.4				
CN^-	std. state, m = 1	aq	26.0178		36.0	41.2		22.5	

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(11) CARBON June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0°K	298.15°K (25°C)				
				kcal/mol				cal/deg mol	
N_3CN	cyanogen azide	c	68.0380		92.6				
$1/n\ (N_3CN)_n$	polymeric	c			82.2				
CNO^-	std. state, m = 1	aq	42.0172		-34.9	-23.3		25.5	
$C(NO_2)_4$		liq	196.0332		8.8				
HCN		liq	27.0258		26.02	29.86		26.97	16.88
		g		32.39	32.3	29.8	2.208	48.20	8.57
	std. state, m = 1	aq			36.0	41.2		22.5	
	un-ionized; std. state, m = 1	aq			25.6	28.6		29.8	
CH_3NH_2	methylamine	liq	31.0577		-11.3	8.5		35.90	
		g			-5.49	7.67		58.15	12.7
	un-ionized; std. state, m = 1	aq			-16.77	4.94		29.5	
	in 300 H_2O	aq			-16.57				
	400 H_2O	aq			-16.62				
	500 H_2O	aq			-16.65				
	600 H_2O	aq			-16.67				
	700 H_2O	aq			-16.70				
	800 H_2O	aq			-16.73				
	900 H_2O	aq			-16.76				
	1,000 H_2O	aq			-16.78				
$CH_3NH_3^+$	std. state, m = 1	aq	32.0657		-29.87	-9.55		34.1	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(12) — CARBON — June 1965

Substance: Formula and Description		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H^\circ_{298} - H^\circ_0$	S°	C_p°
				0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
CH_2N_2	diazirine	g	42.0405					56.87	10.19
CH_2N_2	diazomethane	g						58.02	12.55
NH_2CN	cyanamide	c			14.1				
	in 600 H_2O	aq			17.8				
NH_4CN		c	44.0564		0.10				32.
		aq			7.7				
	std. state, m = 1	aq			4.3	22.2		49.6	
CH_3NHNH_2		liq	46.0724		12.9	36.2		39.66	32.25
		g		27.507	22.55	44.66	3.438	66.61	17.0
$C{=}NH(NH_2)_2$	guanidine	c	59.0711		-18.1				
CH_2N_4	tetrazole	c	70.0539		56.7				
	in 700 acetone				59.74				
CH_3N_5	5-aminotetrazole	c	85.0686		49.7				
HNCO	isocyanic acid	g	43.0252				2.615	56.85	10.72
HCNO	cyanic acid								
	ionized; std. state, m = 1	aq			-34.9	-23.3		25.5	
	un-ionized; std. state, m = 1	aq			-36.90	-28.0		33.9	
$CH_2NO_2^-$	nitromethane ion of nitro form	aq	60.0326		-20.3				
$HCONH_2$		liq	45.0412		-60.7				
		g						59.41	10.84

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(13) — CARBON — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$HCONH_2$ in 200 H_2O	aq			-59.2				
CH_3NO_2 nitromethane	liq	61.0406		-27.03	-3.47		41.05	25.33
	g			-17.86	-1.65	3.083	65.69	13.70
in 600 H_2O	aq			-26.4				
CH_3ONO methyl nitrite	g	61.0406		-16.5				
CH_3NO_3	liq	77.0400		-38.0				
	g			-29.8				
$HCOONH_4$	c	63.0565		-135.63				
std. state, m = 1	aq			-133.38	-102.84		49.	-1.9
in 200 H_2O	aq			-133.15				
NH_4HCO_3	c	79.0559		-203.0	-159.2		28.9	
	aq			-196.4				
std. state, m = 1	aq			-197.06	-159.23		48.9	
CH_3NH_3OH std. state, m = 1	aq	49.0730		-84.83	-47.14		31.5	
un-ionized; std. state, m = 1	aq			-85.08	-51.75		46.2	
NH_4CNO	c	60.0558		-72.75				
std. state, m = 1	aq			-66.6	-42.3		52.6	
$CO(NH_2)_2$ urea	c	60.0558		-79.56	-47.04		25.00	22.26

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(14) — CARBON — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$CO(NH_2)_2$ in 5 H_2O	aq			-75.606				
7 H_2O	aq			-75.695				
10 H_2O	aq			-75.786				
15 H_2O	aq			-75.872				
20 H_2O	aq			-75.923				
25 H_2O	aq			-75.958				
50 H_2O	aq			-76.035				
100 H_2O	aq			-76.08				
200 H_2O	aq			-76.097				
400 H_2O	aq			-76.106				
∞ H_2O	aq			-76.117				
in 125 CH_3OH				-77.37				
85 C_2H_5OH				-76.50				
65 C_3H_7OH				-76.82				
NH_2COONH_4 ammonium carbamate	c	78.0712		-154.17	-107.09		31.9	
	aq			-150.4				
$CH_3NH_2 \cdot HNO_3$	c	94.0706		-84.7				
in 500 H_2O	aq			-79.3				
$(NH_4)_2CO_3$ std. state, m = 1	aq	96.0865		-225.18	-164.11		40.6	
in 400 H_2O	aq			-218.3				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(15) — CARBON — June 1965

Substance: Formula and Description	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
			0 °K	298.15 °K (25 °C)				
			kcal/mol				cal/deg mol	
$CH(NO_2)_3$	liq	151.0356		-5.1				
$NH_2CONHNO_2$ nitrourea	c	105.0534		-67.5				
$NH_2CONHNH_2$ semicarbazide;								
std. state, m = 1	aq	75.0705		-39.9	-9.7		71.2	
$CO(NH_2)_2 \cdot HNO_3$								
urea nitrate	c	123.0687		-134.8				
in 400 H_2O	aq			-124.3				
CH_2N_4O 5-hydroxytetrazole	c	86.0533		1.5				
$CH_4N_4O_2$ nitroguanidine	c	104.0686		-22.13				
$C{=}NH(NH_2)_2 \cdot HNO_3$								
guanidine nitrate	c	122.0840		-92.5				
in 1,600 H_2O	aq			-83.0				
$CH_5N_5O_2$ nitroaminoguanidine	c	119.0833		5.3				
$CH_2N_6O_2$ nitroguanylazide	c	130.0661		71.3				
$CH_4N_6O_3$ 5-aminotetrazole nitrate	c	148.0814		-6.6				
$CH_4N_6O_3$ guanylazide nitrate	c			3.8				
$CH_8N_6O_3$ diaminoguanidine nitrate	c	152.1133		-37.6				
CNCl	liq	61.4708		26.79				
	g		32.804	32.97	31.32	2.550	56.42	10.75
$CCl(NO_2)_3$ trinitrochloromethane	liq	185.4806		-5.6				39.0

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(16) — CARBON — June 1965

Substance	State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description			0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
$CH_3NH_2 \cdot HCl$ methylamine hydrochloride	c	67.5187		-71.20	-37.99		33.13	21.72
std. state, m = 1	aq			-69.82	-40.92		47.6	
in 50 H_2O	aq			-69.650				
100 H_2O	aq			-69.674				
150 H_2O	aq			-69.686				
200 H_2O	aq			-69.694				
300 H_2O	aq			-69.704				
400 H_2O	aq			-69.712				
500 H_2O	aq			-69.72				
600 H_2O	aq			-69.724				
700 H_2O	aq			-69.728				
800 H_2O	aq			-69.732				
900 H_2O	aq			-69.735				
1,000 H_2O	aq			-69.738				
1,500 H_2O	aq			-69.749				
2,000 H_2O	aq			-69.756				
3,000 H_2O	aq			-69.767				
4,000 H_2O	aq			-69.772				
5,000 H_2O	aq			-69.776				
7,000 H_2O	aq			-69.781				
10,000 H_2O	aq			-69.787				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(17) — CARBON — June 1965

Substance			ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description	State	Formula Weight	0°K	298.15°K (25°C)				
			kcal/mol				cal/deg mol	
$CH_3NH_2 \cdot HCl$ in 20,000 H_2O	aq			-69.794				
50,000 H_2O	aq			-69.803				
100,000 H_2O	aq			-69.807				
∞ H_2O	aq			-69.82				
$NH_2CONHNH_2 \cdot HCl$								
semicarbazide hydrochloride	c	111.5315						34.
$C(=NH)(NH_2)_2 \cdot HClO_4$								
guanidine perchlorate	c	159.5297		-74.8				
	aq			-64.4				
CNBr	c	105.9268		33.58				
	g		46.07	44.5	39.5	2.648	59.32	11.22
CNI	c	152.9222		39.71	44.22		23.0	
	g		54.04	53.9	47.0	2.724	61.35	11.54
std. state, m = 1	aq			42.5	44.95		29.9	
in CCl_4; std. state, m = 1					46.24			
I_2CN^- std. state, m = 1	aq	279.8266			32.53			
CNS^- thiocyanate ion;								
std. state, m = 1	aq	58.0818		18.27	22.15		34.5	-9.6
HNCS isothiocyanic acid	g	59.0898		30.5	27.0		59.2	11.2

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 23(18) — CARBON — June 1965

Substance		State	Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description				0°K	298.15°K (25°C)				
				kcal/mol				cal/deg mol	
HCNS	thiocyanic acid								
	undissoc.; std. state, m = 1	aq				23.31			
	ionized; std. state, m = 1	aq			18.27	22.15		34.5	-9.6
	in 100 H_2O	aq			18.4				
NH_4CNS	ammonium thiocyanate	c	76.1204		-18.8				
	std. state, m = 1	aq			-13.40	3.18		61.6	9.5
	in 200 H_2O	aq			-13.4				
$CS(NH_2)_2$	thiourea	c	76.1204		-21.1				
	in 100 H_2O	aq			-15.6				
$CS(NH_2)_2 \cdot HNO_3$	thiourea nitrate	c	139.1333		-73.1				
$[C(=NH)(NH_2)_2]_2 \cdot H_2SO_4$	guanidine sulfate	c	216.2197		-288.0				
		aq			-281.2				

$[C(=NH)(NH_2)_2]_2 \cdot H_2SO_4$ 23

APPENDIX

The order in which the tables of Series I of National Bureau of Standards Circular 500 are revised follows the Standard Order of Arrangement. However it has been necessary to evaluate the data on certain additional substances in order to complete the calculations for the tables given in this part. The values obtained for some of these compounds are given in the following Table B.

National Bureau of Standards Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table B BASIC AUXILIARY COMPOUNDS

Substance			Formula Weight	ΔHf_0°	ΔHf°	ΔGf°	$H_{298}^\circ - H_0^\circ$	S°	C_p°
Formula and Description		State		0 °K	298.15 °K (25 °C)				
				kcal/mol				cal/deg mol	
Ag		c	107.870	0	0	0		10.20	6.10
Ag^+	std. state, m = 1	aq			25.234	18.433		17.40	
Ag_2O		c	231.7394		-7.42	-2.68		29.0	
AgCl		c	143.323		-30.370	-26.244		23.0	
AgBr		c	187.779		-23.99	-23.16		25.6	
AgI		c	234.7744		-14.78	-15.82		27.6	13.58
Hg		liq	200.59		0	0		18.17	
Hg_2Cl_2		c	472.086		-63.39	-50.377		46.0	
Hg_2Br_2		c	560.998			-43.278			
Hg_2I_2		c	654.989			-26.53			
Hg_2SO_4		c	497.242		-177.61	-149.589		47.96	31.54
Na		c	22.9898	0	0	0		12.24	6.75
Na^+	std. state, m = 1	aq			-57.39	-62.593		14.1	11.1
NaOH		c	56.1094		-101.72				
	std. state, m = 1	aq			-112.36	-100.189		11.5	-24.4
K		c	39.102	0	0	0	1.695	15.34	7.07
K^+	std. state, m = 1	aq			-60.32	-67.70		24.5	5.2
KOH		c	39.9972		-101.52				
	std. state, m = 1	aq			-115.29	-105.30		21.9	-30.3

Index of Contents by Chemical Symbols

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