NBS TECHNICAL NOTE 270-7

Selected Values of Chemical Thermodynamic Properties

Tables for the Lanthanide (Rare Earth) Elements

(Elements 62 through 76 in the Standard Order of Arrangement)

U.S. DEPARTMENT OF COMMERCE
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Selected Values of Chemical Thermodynamic Properties

Tables for the Lanthanide (Rare Earth) Elements (Elements 62 through 76 in the Standard Order of Arrangement)

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Abstract

Contains tables of values for the standard heats and Gibbs (free) energies of formation, entropies and enthalpies at 298.15 K and heats of formation at 0 K for compounds of the rare-earth elements (the lanthanides; lutetium through lanthanum; elements 62 through 76 in the Standard Order of Arrangement). These tables are a continuation of the comprehensive revision of NBS Circular 500.

Key words: Cerium compounds; dysprosium compounds; enthalpy; entropy; erbium compounds; europium compounds; gadolinium compounds; Gibbs energy of formation; holium compounds; lanthanides; lanthanum compounds; lutetium compounds; neodymium compounds; praseodymium compounds; promethium; rare-earth elememts; samarium compounds; terbium compounds; thulium compounds; ytterbium compounds.

PREFACE

Technical Note 270-7 is the seventh part of a series of Notes containing the tables of numerical material prepared as a revision of Series I of 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. This Note contains data for the compounds of 15 elements, numbered 62 through 76 in the Standard Order of Arrangement. In addition there is an Appendix which contains a list of all the corrections and misprints which have been detected in the previous Notes of this Series.

The continued encouragement and support of the Office of Standard Reference Data of the National Bureau of Standards is gratefully acknowledged.

Contents

SELECTED VALUES OF CHEMICAL THERMODYNAMIC PROPERTIES

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). For non-aqueous systems the physical state is that normal for the indicated solvent at 298.15 K.

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 non-dissociated solute in aqueous solution is taken as the hypothetical ideal solution of unit molality, which has been designated as "std. state, m = 1". For strong electrolytes in aqueous solution the conventional standard state is the ideal solution of unit activity (unit mean molality). For nonaqueous 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 $\Delta Hf°$ given 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 $\Delta Hf°$ 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 $\Delta Hf°$ 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 $\Delta Hf°$ 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 $\Delta Hf°$, $\Delta Gf°$, $S°$ 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 $\Delta Gf° = \Delta Hf° - T\,\Delta Sf°$ 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.

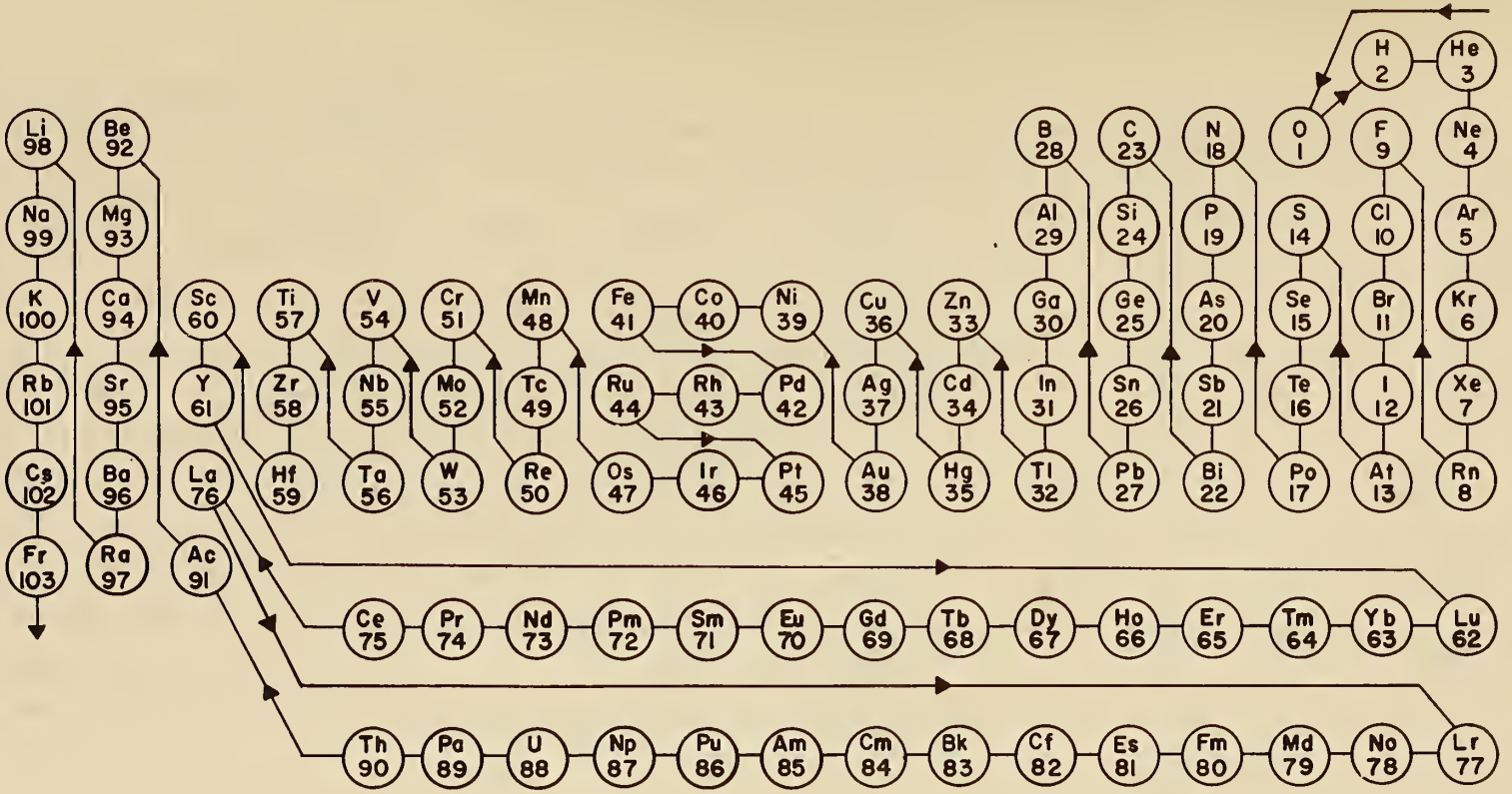
Uncertainties

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

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Table 62(1) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Lutetium

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	
Lu		c	174.97	0	0	0	1.524	12.18	6.42
		g		102.242	102.2	96.7	1.482	44.142	4.986
Lu^+		g		227.36	228.80				
Lu^{2+}		g		547.	549.9				
Lu^{3+}	std. state, m=1	aq			-159.	-150.		-63.	6.
LuO	$^2\Sigma$	g	190.969	-3.	-3.5	-9.8	2.116	57.83	7.548
Lu_2O_3		c	397.938	-446.93	-448.9	-427.6	4.192	26.28	24.32
LuH	$^1\Sigma$	g	175.978				2.074	51.00	7.040
LuF^{2+}	std. state, m=1	aq	193.968			-222.6			
$LuCl_3$		c	281.329		-226.0				
		g			-155.				
	std. state, m=1	aq			-279.	-244.		-23.	-92.
$LuCl_3 \cdot 6H_2O$		c	389.421	-667.41	-676.6	-576.3	13.96	89.9	82.0
LuOCl		c	226.422		-227.				

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Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 62(2) — Lutetium

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	
$Lu(BrO_3)_3$	in 24.0 H_2O (satd)	aq	558.692		-220.0				
	5,500 H_2O	aq			-218.40				
$Lu(BrO_3)_3 \cdot 9H_2O$		c	720.830		-845.7				
LuI_3		c	555.683		-131.				
$Lu(IO_3)_3$		c	699.678		320.				
LuS		g	207.034	48.					
$LuSO_4^+$	std. state, m=1	aq	271.032		-373.	-333.		-31.	
$Lu(SO_4)_2^-$	std. state, m=1	aq	367.093		-589.	-513.		-14.	
$Lu(NO_3)_3$	in 900 H_2O	aq	360.985		-307.05				
$Lu(NO_3)_3 \cdot 5H_2O$		c	451.061		-646.26				
$Lu_2P_2O_7^{2-}$	std. state, m=1	aq	523.883			-789.			
LuAs		c	249.892		-75.				

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Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 62(3) — Lutetium

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	
$LuC_2O_4^+$	std. state, m=1	aq	262.990			-325.0			
$Lu(HCOO)^{2+}$	std. state, m=1	aq	219.988			-235.2			
$Lu(HCOO)_2^+$	std. state, m=1	aq	265.006			-320.6			
$Lu(CH_2OHCOO)^{2+}$	std. state, m=1	aq	250.014		-315.6				
$Lu(CH_2OHCOO)_2^+$	std. state, m=1	aq	325.059		-472.1				
LuAu		g	371.937	116.					
LuPt		g	370.06	138.					
$Lu(MoO_4)^+$	std. state, m=1	aq	334.91			-355.7			

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Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 63(1) Ytterbium

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	
Yb		c	173.04	0	0	0	1.604	14.31	6.39
		g		36.479	36.4	28.3	1.481	41.352	4.968
Yb^+		g		180.70	182.05				
Yb^{2+}		g		462.	464.8				
	std. state, m=1	aq				-126.			
Yb^{3+}		g		1043.	1047.3				
	std. state, m=1	aq			-161.2	-153.9		-57.	6.
Yb_2O_3		c	394.078	-432.08	-433.7	-412.7	4.69	31.8	27.57
YbH		g	174.048				2.083	52.66	7.178
Yb^2H		g	175.054				2.114	54.16	7.534
YbH_2		c	175.056		-42.1				
YbF^{2+}	std. state, m=1	aq	192.038			-226.6			
$YbCl_2$		c	243.946		-191.1				
$YbCl_3$		c	279.399		-229.4				
	std. state, m=1	aq			-281.1	-248.0		-17.	-92.

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Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 63(2) — Ytterbium

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	
$YbCl_3$ in 13.86 H_2O (satd.)	aq			-272.720				
15 H_2O	aq			-273.376				
20 H_2O	aq			-275.293				
25 H_2O	aq			-276.330				
30 H_2O	aq			-276.970				
40 H_2O	aq			-277.702				
50 H_2O	aq			-278.122				
75 H_2O	aq			-278.671				
100 H_2O	aq			-278.954				
150 H_2O	aq			-279.261				
200 H_2O	aq			-279.443				
300 H_2O	aq			-279.640				
400 H_2O	aq			-279.765				
500 H_2O	aq			-279.854				
600 H_2O	aq			-279.923				
700 H_2O	aq			-279.977				
800 H_2O	aq			-280.023				

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Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 63(3) Ytterbium

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	
$YbCl_3$ in 900 H_2O	aq			-280.061				
1,000 H_2O	aq			-280.093				
1,500 H_2O	aq			-280.212				
2,000 H_2O	aq			-280.296				
3,000 H_2O	aq			-280.405				
4,000 H_2O	aq			-280.477				
5,000 H_2O	aq			-280.528				
7,000 H_2O	aq			-280.599				
10,000 H_2O	aq			-280.667				
15,000 H_2O	aq			-280.735				
20,000 H_2O	aq			-280.777				
50,000 H_2O	aq			-280.886				
100,000 H_2O	aq			-280.945				
∞ H_2O	aq			-281.1				
in 40,000 dimethylsulfoxide	nonaq			-286.				
$YbCl_3 \cdot 6H_2O$	c	387.491		-680.2	-580.6		94.6	81.6
YbOCl	c	224.492		-229.9				

National Bureau of Standards — Washington, D. C.

Table 63(4) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Ytterbium

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	
$Yb(BrO_3)_3$	in 25.9 H_2O (satd.)	aq	556.762		-221.2				
	5,500 H_2O	aq			-220.13				
$Yb(BrO_3)_3 \cdot 9H_2O$		c	718.900		-847.7				
$Yb(IO_3)_3$		c	697.748		-322.				
$YbSO_4^+$	std. state, m=1	aq	269.102		-374.9	-336.4		-25.	
$Yb(SO_4)_2^-$	std. state, m=1	aq	365.163		-591.3	-516.7		-9.	
$Yb(NO_3)_3$	in 200 H_2O	aq	359.055		-308.997				
	500 H_2O	aq			-309.161				
	1,000 H_2O	aq			-309.294				
	2,000 H_2O	aq			-309.423				
	5,000 H_2O	aq			-309.569				
	10,000 H_2O	aq			-309.654				
	20,000 H_2O	aq			-309.747				
	50,000 H_2O	aq			-309.835				
	100,000 H_2O	aq			-309.872				
	200,000 H_2O	aq			-309.89				
	250,000 H_2O	aq			-309.89				
	∞ H_2O	aq			-309.9				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 63(5) Ytterbium

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	
YbC_2		c	197.062		-17.9	-18.5		19.	
$Yb(C_2O_4)_2^-$	std. state, m=1	aq	349.080			-492.			
Yb_2OC		c	374.091		-169.	-163.		35.	
$Yb_2(C_2O_4)_3 \cdot 5H_2O$		c	700.216			-1113.			
$Yb(C_2H_3O_2)^{2+}$	std. state, m=1	aq	232.085		-273.85	-244.49		-16.8	
$Yb(CH_2OHCOO)^{2+}$	std. state, m=1	aq	248.084		-317.40				
$Yb(C_2H_3O_2)_2^+$	std. state, m=1	aq	291.130		-387.46	-334.45		18.1	
$Yb(CH_2OHCOO)_2^+$	std. state, m=1	aq	323.129		-473.90				
$Yb(C_2H_3O_2)_3$	undissoc., std state, m=1	aq	350.175		-503.1	-423.72		43.8	
$Yb(CH_2OHCOO)_3$	undissoc., std state, m=1	aq	398.173		-630.6				
$Yb(CH_2OHCOO)_4^-$	std. state, m=1	aq	473.218		-785.4				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 64(1) — Thulium

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	
Tm	c	168.934	0	0	0	1.767	17.69	6.46
	g		55.786	55.5	47.2	1.481	45.412	4.968
Tm^+	g		198.3	199.5				
Tm^{2+}	g		476.	479.				
Tm^{3+}	g		1023.	1027.				
std. state, m=1	aq			-166.8	-158.2		-58.	6.
TmO	g	184.933	-19.					
Tm_2O_3	c	385.866	-449.75	-451.4	-428.9	4.99	33.4	27.9
$TmCl_3$	c	275.293		-235.8				
	g			-166.				
std. state, m=1	aq			-286.6	-252.3		-18.	-92.

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 64(2) — Thulium

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	
$TmCl_3$ in 200 H_2O	aq			-284.947				
300 H_2O	aq			-285.145				
400 H_2O	aq			-285.269				
500 H_2O	aq			-285.358				
600 H_2O	aq			-285.428				
700 H_2O	aq			-285.485				
800 H_2O	aq			-285.530				
900 H_2O	aq			-285.566				
1,000 H_2O	aq			-285.598				
1,500 H_2O	aq			-285.717				
2,000 H_2O	aq			-285.798				
3,000 H_2O	aq			-285.908				
4,000 H_2O	aq			-285.982				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 64(3) — Thulium

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	
$TmCl_3$ in 5,000 H_2O	aq			-286.032				
7,000 H_2O	aq			-286.104				
10,000 H_2O	aq			-286.172				
15,000 H_2O	aq			-286.238				
20,000 H_2O	aq			-286.279				
50,000 H_2O	aq			-286.387				
100,000 H_2O	aq			-286.446				
∞ H_2O	aq			-286.6				
$TmCl_3 \cdot 6H_2O$	c	383.385					95.5	
TmOCl	c	220.386		-236.0				
TmI_3	c	549.647		-143.8				
$Tm(IO_3)_3$	c	693.642		-328.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 64(4) Thulium

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	
$TmSO_4^+$	std. state, m=1	aq	264.996		-380.5	-340.8		-26.	
$Tm(SO_4)_2^-$	std. state, m=1	aq	361.057		-596.9	-521.2		-10.	
TmC_2		c	192.956		-22.				
		g		134.	134.2	121.5	2.47	63.	10.5
$Tm(CH_2OHCOO)^{2+}$	std. state, m=1	aq	243.978		-322.99				
$Tm(CH_2OHCOO)_2^+$	std. state, m=1	aq	319.023		-479.46				
$Tm(CH_2OHCOO)_3$	undissoc., std state, m=1	aq	394.067		-636.2				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 65(1) — Erbium

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	
Er		c	167.26	0	0	0	1.765	17.49	6.72
		g		76.08	75.8	67.2	1.48	46.72	4.97
Er^+		g		216.8	218.0				
Er^{2+}		g		492.	495.				
Er^{3+}	std. state, m=1	aq			-168.6	-159.9		-58.4	5.
ErO		g	183.259	-13.					
Er_2O_3		c	382.518	-451.69	-453.6	-432.3	4.78	37.2	25.93
ErH_2		c	169.276		-49.0				
Er^2H_2		c	171.288		-49.3				
ErH_3		c	170.284		-58.				
ErF		g	186.258		-45.				
ErF^{2+}	std. state, m=1	aq				-232.6			
ErF_2		g	205.257		-164.				
ErF_3		c	224.255		-409.				
		g			-294.				
$ErCl_3$		c	273.619		-238.7				24.

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 65(2) — Erbium

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	
$ErCl_3$	g			-167.				
std. state, m=1	aq			-288.5	-254.0		-18.0	-93.
in 300 H_2O	aq			-287.07				
400 H_2O	aq			-287.18				
500 H_2O	aq			-287.27				
600 H_2O	aq			-287.34				
700 H_2O	aq			-287.39				
800 H_2O	aq			-287.44				
900 H_2O	aq			-287.48				
1,000 H_2O	aq			-287.51				
1,500 H_2O	aq			-287.64				
in 40,000 dimethylsulfoxide	nonaq			-294.				
$ErCl_3 \cdot 6H_2O$	c	381.711	-677.92	-687.0	-586.6	14.39	95.3	82.0
ErOCl	c	218.712		-237.9				
$Er(BrO_3)_3$ in 27.2 H_2O (satd)	aq	550.982		-229.4				
5,500 H_2O	aq			-228.02				
$Er(BrO_3)_3 \cdot 9H_2O$	c	713.120		-856.8				

National Bureau of Standards — Washington, D. C.

Table 65(3) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Erbium

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	
ErI_3		c	547.973		-146.5				
$Er(IO_3)_3$		c	691.968		-330.				
$ErSO_4^+$	std. state, m=1	aq	263.322		-382.3	-342.6		-26.	
$Er(SO_4)_2^-$	std. state, m=1	aq	359.383		-598.3	-523.0		-8.	
ErC_2		g	191.282	138.	138.2	125.4	2.47	63.	10.5
$ErC_2O_4^+$	std. state, m=1	aq	255.280			-327.6			
$Er(C_2O_4)_2^-$	std. state, m=1	aq	343.300						
$Er(C_2O_4)_3^{3-}$	std. state, m=1	aq	431.320			-657.			
$Er_2(C_2O_4)_3 \cdot 6H_2O$		c	706.672			-1183.			
$Er(C_2H_3O_2)^{2+}$	std. state, m=1	aq	226.305		-281.48	-250.43		-19.2	
$Er(CH_2OHCOO)^{2+}$	std. state, m=1	aq	242.304		-324.65				
$Er(C_2H_3O_2)_2^+$	std. state, m=1	aq	285.350		-395.41	-340.44		14.8	
$Er(CH_2OHCOO)_2^+$	std. state, m=1	aq	317.349		-480.95				
$Er(C_2H_3O_2)_3$	undissoc., std state, m=1	aq	344.395		-511.91	-429.84		38.0	
$Er(CH_2OHCOO)_3$	undissoc., std state, m=1	aq	392.393		-637.6				
$Er(CH_2OHCOO)_4^-$	std. state, m=1	aq	467.438		-793.6				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 66(1) — Holmium

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	
Ho		c	164.930	0	0	0	1.91	18.0	6.49
		g		72.33	71.9	63.3	1.48	46.72	4.97
Ho^+		g		211.1	212.2				
Ho^{2+}		g		483.	486.				
Ho^{3+}	std. state, m=1	aq			-168.5	-161.0		-54.2	4.
Ho_2		g	329.860	126.	124.67		2.49		8.87
HoO		g	180.929	-22.					
Ho_2O_3		c	377.858	-447.59	-449.5	-428.1	5.02	37.8	27.48
HoH_2		c	166.946		-51.7				
Ho^2H_2		c	168.958		-49.5				
HoF		g	183.928		-43.				
HoF_2		g	202.927		-163.				
HoF_3		c	221.925		-408.				
		g			-294.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 66(2) — Holmium

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	
$HoCl_3$	c	271.289		-240.3				21.
	g			-168.				
std. state, m=1	aq			-288.4	-255.1		-13.8	-94.
in 14.84 H_2O (satd.)	aq			-280.23				
15 H_2O	aq			-280.311				
20 H_2O	aq			-282.340				
25 H_2O	aq			-283.448				
30 H_2O	aq			-284.123				
40 H_2O	aq			-284.898				
50 H_2O	aq			-285.342				
75 H_2O	aq			-285.919				
100 H_2O	aq			-286.221				
150 H_2O	aq			-286.542				
200 H_2O	aq			-286.719				
300 H_2O	aq			-286.924				
400 H_2O	aq			-287.050				
500 H_2O	aq			-287.139				

National Bureau of Standards — Washington, D. C.

Table 66(3) Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Holmium

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	
$HoCl_3$	in	600 H_2O	aq			-287.210				
		700 H_2O	aq			-287.266				
		800 H_2O	aq			-287.314				
		900 H_2O	aq			-287.354				
		1,000 H_2O	aq			-287.389				
		2,000 H_2O	aq			-287.598				
		3,000 H_2O	aq			-287.701				
		4,000 H_2O	aq			-287.767				
		5,000 H_2O	aq			-287.816				
		7,000 H_2O	aq			-287.887				
		10,000 H_2O	aq			-287.956				
		15,000 H_2O	aq			-288.027				
		20,000 H_2O	aq			-288.071				
		50,000 H_2O	aq			-288.184				
		100,000 H_2O	aq			-288.244				
		∞ H_2O	aq			-288.4				

National Bureau of Standards — Washington, D. C.

Table 66(4) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Holmium

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	
$HoCl_3$ in 40,000 dimethylsulfoxide	nonaq			-293.				
$HoCl_3 \cdot 6H_2O$	c	379.381	-678.80	-687.9	-588.0	14.49	97.08	83.0
HoOCl	c	216.382		-239.2				
$Ho(BrO_3)_3$ in 5,500 H_2O	aq	548.652		-227.9				
$Ho(BrO_3)_3 \cdot 9H_2O$	c	710.790		-857.5				
HoI_3	c	545.643		-149.0				
$Ho(IO_3)_3$	c	689.638		-330.				
HoS	g	196.994	43.					
$HoSO_4^+$ std. state, m=1	aq	260.992		-382.2	-343.5		-22.	
$Ho(SO_4)_2^-$ std. state, m=1	aq	357.053		-597.9	-523.7		-4.	
$Ho_2P_2O_7^{2+}$ std. state, m=1	aq	503.803			-809.2			
HoAs	c	239.852		-72.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 66(5) Holmium

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	
HoC_2		c	188.952		-26.	-26.7		23.	
		g		135.	135.1		2.47		10.5
HoC_4		g	212.975	165.					
Ho_2C_3		c	365.893		-56.				
$Ho(HCOO)^{2+}$	std. state, m=1	aq	209.948			-246.4			
$Ho(HCOO)_2^+$	std. state, m=1	aq	254.966			-331.5			
$Ho(C_2H_3O_2)^{2+}$	std. state, m=1	aq	223.975		-281.49	-251.57		-15.2	
$Ho(CH_2OHCOO)^{2+}$	std. state, m=1	aq	239.974		-324.48				
$Ho(C_2H_3O_2)_2^+$	std. state, m=1	aq	283.020		-395.81	-341.57		17.4	
$Ho(CH_2OHCOO)_2^+$	std. state, m=1	aq	315.019		-480.78				
$Ho(C_2H_3O_2)_3$	undissoc., std state, m=1	aq	342.065		-512.45	-431.06		40.5	
$Ho(CH_2OHCOO)_3$	undissoc., std state, m=1	aq	390.063		-639.1				
HoAg		g	272.800	112.	111.14		2.42		8.79
HoAu		g	361.897	100.	99.06		2.41		8.77
$Ho(MoO_4)^+$	std. state, m=1	aq	324.868			-366.8			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 67(1) — Dysprosium

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	
Dy		c	162.50	0	0	0	1.91	18.0	6.49
		g		70.04	69.4	60.8	1.48	46.97	4.97
Dy^+		g		206.8	207.8				
Dy^{2+}		g		476.	477.0				
Dy^{3+}	std. state, m=1	aq			-167.	-159.		-55.2	5.
DyO		g	178.499	-19.					
Dy_2O_3		c	372.998	-443.02	-445.3	-423.4	5.04	35.8	27.79
DyF		g	181.498		-43.				
DyF^{2+}	std. state, m=1	aq				-231.7			
$DyCl_3$	β	c	268.859		-239.				
	γ	c			-236.				
	std. state, m=1	aq			-286.	-253.		-14.8	-93.

National Bureau of Standards — Washington, D. C.

Table 67(2) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Dysprosium

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	
$DyCl_3$	in	300 H_2O	aq			-284.517				
		400 H_2O	aq			-284.637				
		500 H_2O	aq			-284.725				
		600 H_2O	aq			-284.794				
		700 H_2O	aq			-284.850				
		800 H_2O	aq			-284.898				
		900 H_2O	aq			-284.939				
		1,000 H_2O	aq			-284.974				
		1,500 H_2O	aq			-285.105				
		2,000 H_2O	aq			-285.193				
		3,000 H_2O	aq			-285.307				
		4,000 H_2O	aq			-285.380				
		5,000 H_2O	aq			-285.432				
		7,000 H_2O	aq			-285.505				
		10,000 H_2O	aq			-285.573				
		15,000 H_2O	aq			-285.639				
		20,000 H_2O	aq			-285.680				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 67(3) — Dysprosium

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	
$DyCl_3$ in 50,000 H_2O	aq			-285.787				
100,000 H_2O	aq			-285.846				
∞ H_2O	aq			-286.				
in 40,000 dimethylsulfoxide	nonaq			-289.				
$DyCl_3 \cdot 6H_2O$	c	376.951	-676.83	-686.	-586.	14.42	96.00	82.7
DyOCl	c	213.952		-236.				
$Dy(BrO_3)_3$ in 36.0 H_2O (satd)	aq	546.222		-227.6				
5,500 H_2O	aq			-226.50				
$Dy(BrO_3)_3 \cdot 9H_2O$	c	708.360		-856.1				
DyI_3	c	543.213		-145.				
$Dy(IO_3)_3$	c	687.208		-329.				
$DySO_4^+$ std. state, m=1	aq	258.562		-380.	-341.		-22.	
$Dy(SO_4)_2^-$ std. state, m=1	aq	354.623		-596.	-522.		-5.	
$Dy_2(P_2O_7)^{2+}$ std. state, m=1	aq	498.943			-804.8			
DyAs	c	237.422		-78.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 67(4) — Dysprosium

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	
DyC_2	g	186.522	206.	206.1	193.2	2.47	64.	10.5
$Dy_2O_3 \cdot CO_2$	c	417.008		-553.				
$Dy_2(C_2O_4)_3 \cdot 10H_2O$	c	769.213			-1408.			
$Dy(C_2H_3O_2)^{2+}$ std. state, m=1	aq	221.545		-280.23	-249.62		-16.9	
$Dy(CH_2OHCOO)^{2+}$ std. state, m=1	aq	237.544		-323.02				
$Dy(C_2H_3O_2)_2^{+}$ std. state, m=1	aq	280.590		-394.88	-339.71		14.9	
$Dy(CH_2OHCOO)_2^{+}$ std. state, m=1	aq	312.589		-479.41				
$Dy(C_2H_3O_2)_3$	c	339.635		-476.				
$Dy(C_2H_3O_2)_3$ undissoc., std state, m=1	aq			-511.17	-429.11		38.9	
$Dy(CH_2OHCOO)_3$ undissoc., std state, m=1	aq	387.633		-636.44				
$Dy(CH_2OHCOO)_4^{-}$ std. state, m=1	aq	462.678		-793.2				
$DyCo_5$	c	457.166				8.010	55.63	38.54

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 68(1) — Terbium

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	
Tb		c	158.924	0	0	0	2.250	17.50	6.91
		g		93.36	92.9	83.6	1.79	48.63	5.87
Tb^+		g		228.3	229.3				
Tb^{2+}		g		494.	496.				
Tb^{3+}	std. state, m=1	aq			-163.2	-155.8		-54.	4.
TbO		g	174.923	-19.					
TbO_2		c	190.923		-232.2				
Tb_2O_3		c	365.846		-445.8				27.7
Tb_7O_{12}		c	1304.461		-1596.0				98.7
$Tb_{11}O_{20}$		c	2068.152		-2524.5				153.
$TbCl_3$		c	265.283		-238.3				
	std. state, m=1	aq			-283.0	-249.9		-14.	-94.

National Bureau of Standards — Washington, D. C.

Table 68(2) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Terbium

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	
$TbCl_3$ in 15.50 H_2O (satd)	aq			-275.12				
20 H_2O	aq			-276.892				
25 H_2O	aq			-278.003				
30 H_2O	aq			-278.685				
40 H_2O	aq			-279.474				
50 H_2O	aq			-279.917				
75 H_2O	aq			-280.504				
100 H_2O	aq			-280.811				
150 H_2O	aq			-281.128				
200 H_2O	aq			-281.305				
300 H_2O	aq			-281.512				
400 H_2O	aq			-281.640				
500 H_2O	aq			-281.732				
600 H_2O	aq			-281.800				
700 H_2O	aq			-281.856				

National Bureau of Standards — Washington, D. C.

Table 68(3) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Terbium

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	
$TbCl_3$ in 800 H_2O	aq			-281.902				
900 H_2O	aq			-281.943				
1,000 H_2O	aq			-281.976				
1,500 H_2O	aq			-282.098				
2,000 H_2O	aq			-282.182				
3,000 H_2O	aq			-282.293				
4,000 H_2O	aq			-282.367				
5,000 H_2O	aq			-282.420				
7,000 H_2O	aq			-282.495				
10,000 H_2O	aq			-282.563				
15,000 H_2O	aq			-282.633				
20,000 H_2O	aq			-282.676				
50,000 H_2O	aq			-282.785				
100,000 H_2O	aq			-282.845				
∞ H_2O	aq			-283.0				
$TbCl_3 \cdot 6H_2O$	c	373.375		-683.4	-583.4		96.4	
TbOCl	c	210.377		-233.				

National Bureau of Standards — Washington, D. C.

Table 68(4) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Terbium

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	
$Tb(BrO_3)_3$	in 39.1 H_2O (satd)	aq	542.646		-226.0				
	5,500 H_2O	aq			-222.62				
$Tb(BrO_3)_3 \cdot 9H_2O$		c	704.784		-853.3				
$Tb(IO_3)_3$		c	683.632		-326.				
$TbSO_4^+$	std. state, m=1	aq	254.986		-376.9	-338.5		-21.	
$Tb(SO_4)_2^-$	std. state, m=1	aq	351.047		-593.4	-519.1		-5.	
$Tb(NO_3)^{2+}$	std. state, m=1	aq	220.929			-183.7			
$Tb_2P_2O_7^{2+}$	std. state, m=1	aq	491.791			-798.3			
TbAs		c	233.846		-75.				
TbC_2		g	182.946	212.	211.7	198.7	2.47	64.	10.5
$Tb_2(CO_3)_3$		c	497.876		-795.7				
$Tb_2(C_2O_4)_3 \cdot 10H_2O$		c	762.061			-1402.			
$Tb(CH_2OHCOO)^{2+}$	std. state, m=1	aq	233.968		-319.19				
$Tb(CH_2OHCOO)_2^+$	std. state, m=1	aq	309.013		-475.92				
$Tb(MoO_4)^+$	std. state, m=1	aq	318.862			-361.8			

National Bureau of Standards — Washington, D. C.

Table 69(1) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Gadolinium

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	
Gd		c	157.25	0	0	0	2.178	16.27	8.85
		g		95.353	95.0	86.0	1.825	46.416	6.584
Gd^+		g		237.0	238.1				
Gd^{2+}		g		517.	519.				
Gd^{3+}	std. state, m=1	aq			-164.	-158.		-49.2	0.
GdO		g	173.249	-17.					
Gd_2O_3	monoclinic	c	362.498		-434.9				25.5
	cubic	c					4.45	36.0	25.22
GdH_2		c	159.266		-45.5				
GdF		g	176.248		-41.				
GdF^{+2}	std. state, m=1	aq				-230.4			
GdF_2		g	195.247		-169.				
GdF_3		g	214.245		-310.				
$GdF_3 \cdot \frac{1}{2}H_2O$		c	223.253		-433.				
$GdCl_3$		c	263.609		-241.				21.
	std. state, m=1	aq			-284.	-253.		-8.8	-98.

National Bureau of Standards — Washington, D. C.

Table 69(2) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity — Gadolinium

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	
$GdCl_3$ in 300 H_2O	aq			-282.528				
400 H_2O	aq			-282.654				
500 H_2O	aq			-282.744				
600 H_2O	aq			-282.813				
700 H_2O	aq			-282.870				
800 H_2O	aq			-282.917				
900 H_2O	aq			-282.957				
1,000 H_2O	aq			-282.990				
1,500 H_2O	aq			-283.109				
2,000 H_2O	aq			-283.190				
3,000 H_2O	aq			-283.298				
4,000 H_2O	aq			-283.371				
5,000 H_2O	aq			-283.422				
7,000 H_2O	aq			-283.494				
10,000 H_2O	aq			-283.572				
15,000 H_2O	aq			-283.631				
20,000 H_2O	aq			-283.674				
50,000 H_2O	aq			-283.785				
100,000 H_2O	aq			-283.845				
∞ H_2O	aq			-284.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 69(3) — Gadolinium

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	
$GdCl_3$ in 40,000 dimethylsulfoxide	nonaq			-293.				
in 5,000 N,N-dimethylformamide	nonaq			-278.				
50,000 N,N-dimethylformamide	nonaq			-287.4				
$GdCl_3 \cdot 6H_2O$	c	371.701	-675.66	-685.	-586.	14.43	97.56	83.0
GdOCl	c	208.702		-234.				
$Gd(OH)_{2.5}Cl_{0.5}$	c	217.495			-299.2			
$Gd(BrO_3)_3$ in 44.3 H_2O (satd.)	aq	540.972		-226.7				
5,500 H_2O	aq			-223.44				
$Gd(BrO_3)_3 \cdot 9H_2O$	c	703.110		-854.8				
GdI_3	c	537.963		-142.				
$Gd(IO_3)_3$	c	681.958		-327.				
GdS	g	189.314	38.					
$GdSO_4^+$ std. state, m=1	aq	253.312		-377.	-341.		-16.	
$Gd(SO_4)_2^-$ std. state, m=1	aq	349.373		-593.	-521.		1.	
$Gd_2(SO_4)_3 \cdot 8H_2O$	c	746.808		-1513.	-1322.		155.8	140.5

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 69(4) — Gadolinium

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	
$Gd(NO_3)_3 \cdot 6H_2O$		c	451.357				19.16	133.2	106.2
$GdPO_4 \cdot H_2O$		c	270.237			-490.			
GdAs		c	232.172		-74.				
GdC_2		c	181.272		-25.				
		g		128.2	128.2		2.5		
$Gd_2(C_2O_4)_3 \cdot 10H_2O$		c	758.713			-1407.			
$Gd(C_2H_3O_2)^{2+}$	std. state, m=1	aq	216.295		-278.29	-248.		-13.7	
$Gd(CH_2OHCOO)^{2+}$	std. state, m=1	aq	232.294		-320.52				
$Gd(C_2H_3O_2)_2^{+}$	std. state, m=1	aq	275.340		-393.08	-338.9		17.5	
$Gd(CH_2OHCOO)_2^{+}$	std. state, m=1	aq	307.339		-477.57				
$Gd(C_2H_3O_2)_3$	undissoc., std state, m=1	aq	334.385		-508.94	-428.0		42.0	
$Gd(CH_2OHCOO)_3$	undissoc., std state, m=1	aq	382.383		-635.2				
$Gd(CH_2OHCOO)_4^{-}$	std. state, m=1	aq	457.428		-791.9				
$GdAl_2$		c	211.213				3.772	26.62	17.71
$Gd(MoO_4)^{+}$	std. state, m=1	aq	317.188			-363.9			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 70(1) — Europium

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	
Eu		c	151.96	0	0	0	1.913	18.59	6.61
		g		42.232	41.9	34.0	1.481	45.097	4.968
Eu^+		g		172.93	174.08				
Eu^{2+}		g		432.	435.				
	std. state, m=1	aq			-125.	-129.1		1.	
Eu^{3+}	std. state, m=1	aq			-144.6	-137.2		-53.	2.
EuO		c	167.959		-141.5	-133.1		15.	
		g			-31.				
Eu_2O_3	cubic	c	351.918		-397.4				29.6
	monoclinic	c			-394.7	-372.1		35.	29.2
Eu_3O_4		c	519.878		-543.	-512.		49.	
$Eu(OH)_3$		c	202.982			-285.5			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 70(2) — Europium

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	
EuF		g	170.958		-70.				
EuF_3		c	208.955						
		g			-322.				
$EuF_3 \cdot \frac{1}{2}H_2O$		c	217.963		-413.7				
$EuCl^{2+}$	std. state, m=1	aq	187.413		-184.6	-169.8		-36.	
$EuCl_2$		c	222.866		-194.				
		g			-110.				
$EuCl_2^+$	std. state, m=1	aq				-200.2			
$EuCl_3$		c	258.319		-223.7				
	std. state, m=1	aq			-264.4	-231.3		-13.	-96.
	in 10,000 H_2O	aq			-263.97				
	10,000 H_2O + 2N HCl	aq			-261.2				
	10,000 H_2O + 4N HCl	aq			-258.1				
	10,000 H_2O + 6N HCl	aq			-254.7				
$EuCl_3 \cdot 6H_2O$			366.411		-665.6	-565.5		97.3	87.7

National Bureau of Standards — Washington, D. C.

Table 70(3) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Europium

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	
$EuBr^{2+}$	std. state, m=1	aq	231.869			-161.7			
$EuBr_2^+$	std. state, m=1	aq	311.778			-185.9			
$Eu(BrO_3)_3$	in 45.9 H_2O (satd)	aq	535.682		-205.4				
	5,500 H_2O	aq			-204.07				
$Eu(BrO_3)_3 \cdot 9H_2O$		c	697.820		-835.3				
EuI^+	std. state, m=1	aq	278.864			-149.1			
$Eu(IO_3)_3$		c	676.668		-308.4				
EuS		g	184.024	27.					
$EuSO_4^+$	std. state, m=1	aq	248.022		-358.3	-320.0		-20.	
$Eu(SO_4)_2^-$	std. state, m=1	aq	344.083		-574.1	-500.4		-2.	
$Eu_2(SO_4)_3 \cdot 8H_2O$		c	736.228					160.6	146.0
EuSe		g	230.92	31.					
EuTe		g	279.56	41.					
$Eu(NO_3)^{2+}$	std. state, m=1	aq	213.965			-164.23			
$Eu(NO_3)_3 \cdot 6H_2O$		c	446.067		-706.9				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 70(4) — Europium

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	
$Eu_2(P_2O_7)^{2+}$	std. state, m=1	aq	477.863			-760.7			
EuC_2		c	175.982		-15.	-16.		24.	
$Eu(HCOO)^{2+}$	std. state, m=1	aq	196.978			-222.9			
$Eu(HCOO)_2^{+}$	std. state, m=1	aq	241.996			-309.6			
$Eu(CH_2OHCOO)^{2+}$	std. state, m=1	aq	227.004		-301.34				
$Eu(CH_2OHCOO)_2^{+}$	std. state, m=1	aq	302.049		-457.3				
$Eu(CNS)^{2+}$	std. state, m=1	aq	210.042			-116.0			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 71(1) — Samarium

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	
Sm		c	150.35	0	0	0	1.81	16.63	7.06
		g		49.26	49.4	41.3	1.953	43.722	7.255
Sm^+		g		179.1	180.7				
Sm^{2+}		g		434.	438.				
	std. state, m=1	aq				-118.9			
Sm^{3+}	std. state, m=1	aq			-165.3	-159.3		-50.6	-5.
SmO		g	166.349	-31.					
Sm_2O_3	monoclinic	c	348.698	-433.89	-435.7	-414.6	5.02	36.1	27.37
	cubic	c					5.0		26.86
Sm_4O_5		c	681.397						
SmF		g	169.348		-63.				
SmF_3		c	207.345						
		g			-328.				
$SmF_3 \cdot \frac{1}{2}H_2O$		c	216.353		-436.2				

National Bureau of Standards — Washington, D. C.

Table 71(2) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Samarium

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	
$SmCl^+$	std. state, m=1	aq	185.803			-191.1			
$SmCl_2$		c	221.256		-194.9				
$SmCl_3$		c	256.709		-245.2				
	std. state, m=1	aq			-285.2	-253.4		-10.2	-103.
	in 300 H_2O	aq			-283.781				
	400 H_2O	aq			-283.895				
	500 H_2O	aq			-283.976				
	600 H_2O	aq			-284.041				
	700 H_2O	aq			-284.092				
	800 H_2O	aq			-284.134				
	900 H_2O	aq			-284.170				
	1,000 H_2O	aq			-284.202				
	2,000 H_2O	aq			-284.403				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 71(3) — Samarium

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	
$SmCl_3$ in 3,000 H_2O	aq			-284.508				
4,000 H_2O	aq			-284.581				
5,000 H_2O	aq			-284.632				
7,000 H_2O	aq			-284.704				
10,000 H_2O	aq			-284.771				
15,000 H_2O	aq			-284.838				
20,000 H_2O	aq			-284.879				
50,000 H_2O	aq			-284.987				
100,000 H_2O	aq			-285.046				
∞ H_2O	aq			-285.2				
in 40,000 dimethyl-sulfoxide	nonaq			-296.				
$SmCl_3 \cdot 6H_2O$	c	364.801		-686.0	-587.1		99.	86.4
SmOCl	c	201.802		-237.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 71(4) — Samarium

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	
$Sm(BrO_3)_3$	in 5,500 H_2O	aq	534.072		-224.7				
$Sm(BrO_3)_3 \cdot 9H_2O$		c	696.210		-856.1				
SmI_3		c	531.063		-148.2				
$Sm(IO_3)_3$		c	675.058		-330.				
$SmSO_4^+$	std. state, m=1	aq	246.412		-378.9	-342.0		-17.	
$Sm(SO_4)_2^-$	std. state, m=1	aq	342.473		-595.2	-523.2		2.	
$Sm_2(SO_3)_3$		c	540.887			-697.4			
$Sm_2(SO_4)_3$		c	588.885		-931.9				
$Sm_2(SO_4)_3 \cdot 8H_2O$		c	733.008	-1489.43	-1513.1	-1323.8	24.04	160.7	145.0
$Sm_2(SeO_4)_3 \cdot 8H_2O$		c	873.696		-1306.0				
$Sm(NO_3)_3$		c	336.365		-289.7				
$Sm(NO_3)_3 \cdot 6H_2O$		c	444.457		-727.29				
$Sm_2(P_2O_7)^{2+}$	std. state, m=1	aq	474.643			-804.8			
SmAs		c	225.272		-72.				

National Bureau of Standards — Washington, D. C.

Table 71(5) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity — Samarium

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	
SmC_2	c	174.372		-17.	-18.1		23.	
$Sm_2(CO_3)_3$	c	480.728			-741.4			
$Sm_2(C_2O_4) \cdot 10H_2O$	c	744.913			-1410.			
$Sm(C_2H_3O_2)^{2+}$ std. state, m=1	aq	209.395		-280.01	-250.36		-15.7	
$Sm(CH_2OHCOO)^{2+}$ std. state, m=1	aq	225.394		-322.18				
$Sm(C_2H_3O_2)_2^{+}$ std. state, m=1	aq	268.440		-394.74	-340.37		15.5	
$Sm(CH_2OHCOO)_2^{+}$ std. state, m=1	aq	300.439		-479.5				
$Sm(C_2H_3O_2)_3$ undissoc., std state, m=1	aq	327.485		-510.01	-429.49		42.0	
$Sm(CH_2OHCOO)_3$ undissoc., std state, m=1	aq	375.483		-636.9				
$Sm(CH_2OHCOO)_4^{-}$ std. state, m=1	aq	450.528		-793.8				
$Sm(MoO_4)^{+}$ std. state, m=1	aq	310.288			-365.8			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 72 — Promethium

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	
^{147}Pm	g	146.915				1.545	44.692	5.797

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 73(1) Neodymium

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	
Nd		c	144.24	0	0	0	1.73	17.1	6.56
		g		78.53	78.3	69.9	1.498	45.243	5.280
Nd^{+}		g		205.1	206.3				
Nd^{2+}		g		452.	455.				
Nd^{3+}	std. state, m=1	aq			-166.4	-160.5		-49.4	-5.
NdO		g	160.239	-30.2					
Nd_2O_3	hexagonal	c	336.478	-430.50	-432.1	-411.3	5.00	37.9	26.60
NdH_2		c	146.256		-46.				
NdF		g	163.238		-38.				
NdF_2		g	182.237		-165.				
NdF_3		c	201.235		-396.				
		g			-306.				
$NdF_3 \cdot \frac{1}{2}H_2O$		c	210.243		-437.4				
$NdCl_2$		c	215.146		-163.				
$NdCl_3$		c	250.599		-248.8				27.
		g			-173.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 73(2) — Neodymium

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	
$NdCl_3$	std. state, m=1	aq	250.59		-286.3	-254.7		-9.0	-103.
	in 300 H_2O	aq			-284.903				
	400 H_2O	aq			-285.020				
	500 H_2O	aq			-285.105				
	600 H_2O	aq			-285.170				
	700 H_2O	aq			-285.223				
	800 H_2O	aq			-285.267				
	900 H_2O	aq			-285.303				
	1,000 H_2O	aq			-285.333				
	1,500 H_2O	aq			-285.445				
	2,000 H_2O	aq			-285.516				
	3,000 H_2O	aq			-285.615				
	4,000 H_2O	aq			-285.683				
	5,000 H_2O	aq			-285.730				

National Bureau of Standards — Washington, D. C.

Table 73(3) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Neodymium

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	
$NdCl_3$ in 7,000 H_2O	aq			-285.800				
10,000 H_2O	aq			-285.865				
15,000 H_2O	aq			-285.931				
20,000 H_2O	aq			-285.975				
50,000 H_2O	aq			-286.085				
100,000 H_2O	aq			-286.145				
∞ H_2O	aq			-286.3				
in 40,000 dimethyl-sulfoxide	nonaq			-294.				
$NdCl_3 \cdot 6H_2O$	c	358.691	-678.72	-687.0	-588.1	15.14	99.7	86.25
$NdOCl$	c	195.692		-239.				
$Nd(BrO_3)_3$ in 5,500 H_2O	aq	527.962		-225.9				
$Nd(BrO_3)_3 \cdot 9H_2O$	c	690.100		-856.7				
NdI_3	c	524.953		-152.8				
$Nd(IO_3)_3$	c	668.948		-332.				

National Bureau of Standards — Washington, D. C.

Table 73(4) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Neodymium

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	
NdS	g	176.304	33.					
Nd_2S_3	c	384.672		-284.	-280.2	6.160	44.28	29.28
$NdSO_4^+$ std. state, m=1	aq	240.302		-380.1	-343.2		-17.	
$Nd(SO_4)^-_2$ std. state, m=1	aq	336.363		-595.8	-523.5		1.	
$Nd_2(SO_4)_3 \cdot 8H_2O$	c	720.788		-1513.1			160.9	144.9
Nd_2Se_3	c	525.36				7.13	53.6	31.1
$Nd_2(SeO_3)_3 \cdot 8H_2O$ amorp.	c	813.477		-1230.3				
$Nd_2(SeO_4)_3 \cdot 5H_2O$	c	807.430		-1100.4				
$Nd(NO_3)_3$	c	330.255		-294.2				
$Nd(NO_3)_3 \cdot 3H_2O$	c	384.301		-515.				
$Nd(NO_3)_3 \cdot 4H_2O$	c	402.316		-588.6				
$Nd(NO_3)_3 \cdot 6H_2O$	c	438.347		-728.39				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 73(5) — Neodymium

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	
NdC_2	g	168.262	130.5	130.75	117.9	2.48	6.3	10.6
$NdC_2O_4^+$ std. state, m=1	aq	232.260			-335.			
$Nd(C_2O_4)_2^-$ std. state, m=1	aq	320.280			-499.			
$Nd_2(CO_3)_3$	c	468.508			-744.5			
$Nd_2(C_2O_4)_3 \cdot 10H_2O$	c	732.693		-1621.	-1412.		-191.	
$Nd(C_2H_3O_2)^{2+}$ std. state, m=1	aq	203.285		-280.85	-251.42		-14.1	
$Nd(CH_2OHCOO)^{2+}$ std. state, m=1	aq	219.284		-323.40				
$Nd(C_2H_3O_2)_2^+$ std. state, m=1	aq	262.330		-395.23	-341.25		17.7	
$Nd(CH_2OHCOO)_2^+$ std. state, m=1	aq	294.329		-480.30				
$Nd(C_2H_3O_2)_3$ undissoc., std state, m=1	aq	321.275		-510.52	-430.17		43.4	
$Nd(CH_2OHCOO)_3$ undissoc., std state, m=1	aq	369.373		-637.58				
$Nd(CH_2OHCOO)_4^-$ std. state, m=1	aq	444.418		-794.0				
$NdAl_2$	c	198.203				3.738	27.67	17.45
NdAu	g	341.207	95.	94.3	82.2	2.46	69.	8.8

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 74(1) Praseodymium

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	
Pr		c	140.907	0	0	0	1.74	17.5	6.50
		g		85.25	85.0	76.7	1.487	45.339	5.105
Pr^{+}		g		210.3	211.5				
Pr^{2+}		g		453.6	456.3				
Pr^{3+}		g		952.3	956.5				
	std. state, m=1	aq			-168.4	-162.3		-50.	-7.
Pr^{4+}		g		1851.	1856.				
Pr^{5+}		g		3176.	3183.				
PrO		g	156.906	-38.					
PrO_2		c	172.906		-226.9				
Pr_2O_3	hexagonal	c	329.812		-432.5				28.06
	cubic	c			-432.5				
Pr_7O_{12}		c	1178.342		-1556.				
Pr_9O_{16}		c	1524.153		-2017.				
$Pr_{10}O_{18}$		c	1697.059		-2248.				
$Pr_{11}O_{20}$		c	1869.965		-2479.				
$Pr_{12}O_{22}$		c	2042.871		-2706.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 74(2) — Praseodymium

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	
PrH_2	c	142.923	-45.47	-47.4	-36.9	1.83	13.6	9.8
$PrOH^{2+}$ std. state, m=1	aq	157.914			-206.			
$Pr(OH)_2^+$ std. state, m=1	aq	174.922			-257.			
$Pr(OH)_3$	c	191.929			-307.1			
$PrF_3 \cdot \frac{1}{2}H_2O$	c	206.910		-439.4				
$PrCl^{2+}$ std. state, m=1	aq	176.360			-194.9			
$PrCl_3$	c	247.266		-252.6				24.
	g			-187.				
std. state, m=1	aq			-288.3	-256.4		-10.	-105.
in 13.96 H_2O (satd)	aq			-280.63				
20 H_2O	aq			-283.150				
25 H_2O	aq			-284.115				
30 H_2O	aq			-284.680				
40 H_2O	aq			-285.311				
50 H_2O	aq			-285.647				
75 H_2O	aq			-286.102				
100 H_2O	aq			-286.329				

National Bureau of Standards — Washington, D. C.

Table 74(3) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Praseodymium

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	
$PrCl_3$ in 150 H_2O	aq			-286.583				
200 H_2O	aq			-286.738				
300 H_2O	aq			-286.912				
400 H_2O	aq			-287.020				
500 H_2O	aq			-287.099				
600 H_2O	aq			-287.162				
700 H_2O	aq			-287.213				
800 H_2O	aq			-287.256				
1,000 H_2O	aq			-287.325				
1,500 H_2O	aq			-287.443				
2,000 H_2O	aq			-287.523				
3,000 H_2O	aq			-287.626				
4,000 H_2O	aq			-287.692				
5,000 H_2O	aq			-287.741				
7,000 H_2O	aq			-287.809				
10,000 H_2O	aq			-287.873				
15,000 H_2O	aq			-287.938				
20,000 H_2O	aq			-287.980				
50,000 H_2O	aq			-288.087				
100,000 H_2O	aq			-288.146				
∞ H_2O	aq			-288.3				

National Bureau of Standards — Washington, D. C.

Table 74(4) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Praseodymium

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	
$PrCl_3 \cdot 6H_2O$	c	355.358		-688.5				
$PrCl_3 \cdot 7H_2O$	c	373.373		-759.5				
PrOCl	c	192.359		-242.				
$Pr(BrO_3)_3$ in 29.1 H_2O (satd.)	aq	524.629		-229.6				
5,500 H_2O	aq			-227.89				
$Pr(BrO_3)_3 \cdot 9H_2O$	c	686.767		-858.5				
PrI_3	c	521.620		-156.4				
$Pr(IO_3)_3$	c	665.615		-333.8				
$PrSO_4^+$ std. state, m=1	aq	236.969		-382.3	-345.1		-17.	
$Pr(SO_4)_2^-$ std. state, m=1	aq	333.030		-598.4	-525.6		0.	
$Pr_2(SeO_3)_3 \cdot 5H_2O$	amorp	752.765		-1031.1				
$Pr_2(SeO_4)_3 \cdot 5H_2O$	c	800.764		-1105.5				
$Pr_2(SeO_3)_3 \cdot H_2SeO_3$	c	791.663		-808.47				
$Pr_2(SeO_3)_3 \cdot H_2SeO_3 \cdot 5H_2O$	c	881.739		-1166.38				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 74(5) — Praseodymium

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	
$Pr(NO_3)^{2+}$	std. state, m=1	aq	202.192			-190.5			
$Pr(NO_3)_3$		c	326.922		-293.8				
	in HNO_3 (aq)	aq			-316.7				
$Pr(NO_3)_3 \cdot 6H_2O$		c	435.014		-731.05				
PrAs		c	215.829		-73.				
PrSb		c	262.657				3.042	25.11	12.71
PrBi		c	349.887				3.202	27.18	13.00
PrC		c	152.918		-13.0				
PrC_2		g	164.929	131.	131.3	118.7	2.48	62.6	10.6
$Pr_2(CO_3)_3$		c	461.842		-768.				
$Pr_2(C_2O_4)_3 \cdot 10H_2O$		c	726.027		-1415.				
$Pr(C_2H_3O_2)^{2+}$	std. state, m=1	aq	199.952		-282.84	-253.09		-15.1	
$Pr(C_2H_3O_2)_2^{+}$	std. state, m=1	aq	258.997		-396.54	-342.79		18.4	
$Pr(C_2H_3O_2)_3$	std. state, m=1	aq	318.042		-513.27	-431.54		39.4	
$PrAl_2$		c	194.870				3.629	27.42	17.64
$PrAl_4$		c	248.833		-52.1				
PrAu		g	337.874	100.	99.3	87.3	2.46	69.	8.8
$Pr(MoO_4)^{+}$	std. state, m=1	aq	300.845			-368.2			

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 75(1) — Cerium

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	
Ce	γ	c	140.12	0	0	0	1.8	17.2	6.44
		g		101.2	101.	92.	1.594	45.807	5.515
Ce^+		g		227.3	228.5				
Ce^{2+}		g		478.	480.				
Ce^{3+}		g		942.7	947.4				
	std. state, m=1	aq			-166.4	-160.6		-49.	
Ce^{4+}		g		1790.	1796.				
	std. state, m=1	aq			-128.4	-120.4		-72.	
Ce_2		g	280.24	145.	143.9	134.2	2.47	67.	8.85
CeO		g	156.119	-30.	-30.7	-35.6	2.12	58.1	7.58
CeO_2		c	172.119	-256.69	-260.2	-244.9	2.478	14.89	14.73
Ce_2O_3		c	328.238	-427.64	-429.3	-407.8	5.13	36.0	27.4
CeH_2		c	142.136	-47.83	-49.		1.776	13.3	9.78
Ce^2H_2		c	144.148		-46.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 75(2) — Cerium

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	
CeF^{2+}	std. state, m=1	aq	159.118			-232.7			
CeF_3		c	197.115				4.237	27.5	22.3
$CeF_3 \cdot \frac{1}{2}H_2O$		c	206.123		-438.2				
$CeCl^{2+}$	std. state, m=1	aq	175.573		-200.9	-190.9		-21.1	
$CeCl_3$		c	246.479		-251.8	-233.7		36.	20.9
		g			-174.				
	std. state, m=1	aq			-286.2	-254.7		-9.	
	in 200 H_2O	aq			-284.62				
	300 H_2O	aq			-284.80				
	400 H_2O	aq			-284.92				
	500 H_2O	aq			-284.99				
	600 H_2O	aq			-285.05				
	700 H_2O	aq			-285.10				
	800 H_2O	aq			-285.14				
	900 H_2O	aq			-285.18				
	1,000 H_2O	aq			-285.21				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 75(3) — Cerium

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	
$CeCl_3$ in 1,000 H_2O	aq			-285.21				
1,500 H_2O	aq			-285.32				
2,000 H_2O	aq			-285.41				
3,000 H_2O	aq			-285.51				
4,000 H_2O	aq			-285.58				
5,000 H_2O	aq			-285.63				
7,000 H_2O	aq			-285.70				
10,000 H_2O	aq			-285.77				
15,000 H_2O	aq			-285.84				
20,000 H_2O	aq			-285.88				
50,000 H_2O	aq			-285.99				
100,000 H_2O	aq			-286.05				
∞ H_2O	aq			-286.2				
$CeCl_3 \cdot 7H_2O$	c	372.587		-757.5				
CeOCl	c	191.572		-239.				
$CeClO_4^{2+}$ std. state, m=1	aq	239.571		-209.1	-165.2		-37.	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 75(4) — Cerium

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	
$CeBr^{2+}$	std. state, m=1	aq	220.029			-186.3			
CeI_3		c	520.833		-155.3				
$Ce(IO_3)_3$		c	664.828		-332.				
$Ce(IO_3)_3 \cdot 2H_2O$		c	700.858			-378.3			
CeS		c	172.184	-110.06	-109.8	-107.9	2.590	18.7	11.94
		g		32.	31.4	20.2	2.24	62.2	8.3
CeS_2		c	204.248		-146.3				
		g		3.	2.4	-8.8	3.28	70.	13.8
Ce_2S		g	312.304	73.	71.6	60.0	3.25	81.	12.9
Ce_2S_3		c	376.432		-284.				
Ce_3S_4		c	548.616		-397.				
$CeSO_4^+$	std. state	aq	236.182		-380.2	-343.3		-17.	
$Ce(SO_4)_2^-$	std. state	aq	332.243		-595.9	-523.6		2.	
$Ce_2(SO_4)_3$		c	568.425		-945.1				
$Ce_2(SO_4)_3 \cdot 5H_2O$		c	658.502						132.
$Ce_2(SO_4)_3 \cdot 8H_2O$		c	712.548		-1320.6				

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 75(5) Cerium

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	
$Ce_2(SeO_3)_3 \cdot 10H_2O$		c	841.268		-1367.6				
CeN		g	154.127	90.	89.3		2.15		7.70
$Ce(NO_3)^{2+}$	std. state, m=1	aq	202.125			-188.7			
$Ce(NO_3)_3$		c	326.135		-293.0				
	in 2600 H_2O	aq			-314.7				
$Ce(NO_3)_3 \cdot 3H_2O$		c	380.181		-516.				
$Ce(NO_3)_3 \cdot 4H_2O$		c	398.196		-588.9				
$Ce(NO_3)_3 \cdot 6H_2O$		c	434.227		-729.14				
$CeCl_3 \cdot 2NH_3$		c	280.540		-311.1				
$CeCl_3 \cdot 4NH_3$		c	314.601		-364.0				
$CeCl_3 \cdot 8NH_3$		c	382.724		-442.2				
$CeCl_3 \cdot 12NH_3$		c	450.846		-513.4				
$CeCl_3 \cdot 20NH_3$		c	587.091		-649.6				
CeAs		c	215.042		-69.				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 75(6) Cerium

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	
CeC		g	152.131		163.				
CeC_2		c	164.142		-15.	-15.2		20.	
		g		136.	136.2	122.9	2.47	64.	10.5
CeC_4		g	188.165	167.1	168.	152.	3.68	73.	17.3
$CeC_2O_4^+$	std. state, m=1	aq	228.140			-330.7			
$Ce(C_2O_4)_2^-$	std. state, m=1	aq	316.160			-497.			
$Ce_2(C_2O_4)_3 \cdot 10H_2O$		c	724.453		-1621.	-1411.		191.	
$Ce(C_2H_3O_2)^{2+}$	std. state, m=1	aq	199.165		-280.47	-251.22		-13.5	
$Ce(CH_2OHCOO)^{2+}$	std. state, m=1	aq	215.164		-323.11				
$Ce(C_2H_3O_2)_2^+$	std. state, m=1	aq	258.210		-395.06	-340.91		17.2	
$Ce(CH_2OHCOO)_2^+$	std. state, m=1	aq	290.209		-479.80				
$Ce(C_2H_3O_2)_3$	undissoc., std state, m=1	aq	317.255		-509.27	-429.83		44.9	
$Ce(CH_2OHCOO)_3$	undissoc., std state, m=1	aq	365.253		-636.37				
$Ce(CH_2OHCOO)_4^-$	std. state, m=1	aq	440.298		-793.0				

National Bureau of Standards — Washington, D. C.

Table 75(7) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Cerium

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	
CeB_6	c	204.986		-81.				
$CeAl_2$	c	194.083				3.655	25.87	17.85
$CeAl_4$	c	248.046		-39.				
Ce_3Al	c	447.341		-22.				
CeZn	c	205.49		-21.				
$CeHg_4$	c	942.48		-21.				
CeAu	g	337.087	-110.	-109.2	-97.4	2.44	68.	8.8
$CeCrO_3$	c	240.114		-368.	-347.		25.	

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 76(1) Lanthanum

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	
La	α	c	138.91	0	0	0	1.593	13.6	6.48
		g		103.084	103.0	94.07	1.509	43.563	5.438
La^+		g		231.690	233.087				
La^{2+}		g		487.	490.				
La^{3+}		g		929.2	933.2				
	std. state, m=1	aq			-169.0	-163.4		-52.0	-3.
La_2		g	277.82	147.8	147.2	135.6	2.4	66.0	8.7
LaO		g	154.909	-28.5	-29.01	-34.72	2.121	57.27	7.59
La_2O		g	293.819	-2.	-3.2		3.00		12.0
La_2O_2		g	309.819	-145.	-146.6		3.67		16.2
La_2O_3		c	325.818	-427.19	-428.7	-407.7	4.742	30.43	26.00
LaH_2		c	140.926		-48.3				
La^2H_2		c	142.938		-45.2				
$La(OH)_3$		c	189.932		-337.0				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 76(2) Lanthanum

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	
LaF	g	157.908				2.173	56.9	7.98
LaF^{2+} std. state, m=1	aq				-234.1			
LaF_3	g	195.905				4.14	78.7	17.4
$LaF_3 \cdot \frac{1}{2}H_2O$	c	204.913		-440.9				
$LaCl_3$	c	245.269		-256.0				26.0
	g			-177.				
std. state, m=1	aq			-288.9	-257.5		-12.	-101.
14.18 H_2O (satd)	aq			-281.28				
15 H_2O	aq			-281.715				
20 H_2O	aq			-283.539				
25 H_2O	aq			-284.528				
30 H_2O	aq			-285.127				
40 H_2O	aq			-285.799				
50 H_2O	aq			-286.172				
75 H_2O	aq			-286.652				
100 H_2O	aq			-286.888				
150 H_2O	aq			-287.147				
200 H_2O	aq			-287.309				

National Bureau of Standards — Washington, D. C.

Table 76(3) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity — Lanthanum

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	
$LaCl_3$ in 300 H_2O	aq			-287.495				
400 H_2O	aq			-287.601				
500 H_2O	aq			-287.681				
600 H_2O	aq			-287.736				
700 H_2O	aq			-287.785				
800 H_2O	aq			-287.826				
1,000 H_2O	aq			-287.892				
1,500 H_2O	aq			-288.006				
2,000 H_2O	aq			-288.087				
3,000 H_2O	aq			-288.197				
4,000 H_2O	aq			-288.271				
5,000 H_2O	aq			-288.324				
7,000 H_2O	aq			-288.397				
10,000 H_2O	aq			-288.467				
15,000 H_2O	aq			-288.535				
20,000 H_2O	aq			-288.578				
50,000 H_2O	aq			-288.686				
100,000 H_2O	aq			-288.745				
∞ H_2O				-288.9				

National Bureau of Standards — Washington, D. C.

Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity

Table 76(4) — Lanthanum

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	
$LaCl_3$	in 40,000 dimethyl-sulfoxide	nonaq	245.269		-295.				
$LaCl_3 \cdot 7H_2O$		c	371.376		-759.7	-648.5	17.12	110.6	103.0
$LaOCl$		c	190.362		-241.6				
$La(BrO_3)_3$	in 5,500 H_2O	aq	522.632		-228.4				
$La(BrO_3)_3 \cdot 9H_2O$		c	684.770		-857.9				
LaI_3		c	519.623		-159.4				
$La(IO_3)_3$		c	663.618		-334.	-270.4		62.	
LaS		c	170.974	-108.9	-109.	-107.9	2.6	17.5	14.
		g		32.9	32.5	44.1	2.22	60.	8.22
La_2S_3		c	374.012		-289.				
$LaSO_4^+$	std. state, m=1	aq	234.972		-383.1	-346.2		-20.	
$La(SO_4)_2^-$	std. state, m=1	aq	331.033		-599.2	-526.7		-3.	
$La_2(SO_4)_3$		c	566.005		-942.0				67.

National Bureau of Standards — Washington, D. C.

Table 76(5) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity — Lanthanum

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	
$La_2(SO_4)_3$ in 2,400 H_2O	aq			-980.88				
3,000 H_2O	aq			-981.01				
4,000 H_2O	aq			-981.14				
5,000 H_2O	aq			-981.25				
7,000 H_2O	aq			-981.45				
10,000 H_2O	aq			-981.72				
$La_2(SO_4)_3 \cdot 9H_2O$	c	728.143		-1589.				152.
$La_2(SeO_3)_3$	c	658.695		-688.20	-629.5		81.	
La_2Te_3	c	660.62	-172.61	-173.	-170.8	7.19	55.36	31.58
LaN	c	152.917		-72.5				
$La(NO_3)_3$	c	324.925		-299.8				

National Bureau of Standards — Washington, D. C.

Table 76(6) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Lanthanum

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	
$La(NO_3)_3$ in 250 H_2O	aq			-316.709				
300 H_2O	aq			-316.746				
500 H_2O	aq			-316.809				
700 H_2O	aq			-316.849				
1,000 H_2O	aq			-316.901				
2,000 H_2O	aq			-317.024				
5,000 H_2O	aq			-317.199				
10,000 H_2O	aq			-317.316				
20,000 H_2O	aq			-317.413				
50,000 H_2O	aq			-317.510				
100,000 H_2O	aq			-317.562				
200,000 H_2O	aq			-317.601				
500,000 H_2O	aq			-317.636				
1,000,000 H_2O	aq			-317.655				
∞ H_2O	aq			-317.7				

National Bureau of Standards — Washington, D. C.

Table 76(7) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity — Lanthanum

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	
$La(NO_3)_3$	in 400 CH_3OH	nonaq			-325.0				
	in 400 C_2H_5OH	nonaq			-321.3				
	in 400 $(CH_3)_2CO$	nonaq			-323.4				
$La(NO_3)_3 \cdot 3H_2O$		c	378.971		-520.0				
$La(NO_3)_3 \cdot 4H_2O$		c	396.986		-592.3				
$La(NO_3)_3 \cdot 6H_2O$		c	433.017		-732.23				
LaSb		c	260.66				2.798	21.22	12.12
LaBi		c	347.890				3.080	24.10	13.37
LaC_2		c	162.932		-17.	-17.3		17.	
		g		140.	140.4	127.1	2.48	61.	10.6
$La_2(CO_3)_3$		c	457.848			-750.9			
$La_2(C_2O_4)_3 \cdot 10H_2O$		c	722.033			-1414.			
$La(C_2H_3O_2)^{2+}$	std. state, m=1	aq	197.955		-282.98	-253.85		-16.7	
$La(CH_2OHCOO)^{2+}$	std. state, m=1	aq	213.954		-325.60				

National Bureau of Standards — Washington, D. C.

Table 76(8) — Enthalpy and Gibbs Energy of Formation; Entropy and Heat Capacity
Lanthanum

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	
$La(CHO_2)_3$		c	273.964						79.7
$La(C_2H_3O_2)_2^+$	std. state, m=1	aq	257.000		-397.53	-343.42		13.6	
$La(CH_2OHCOO)_2^+$	std. state, m=1	aq	288.999		-481.86				
$La(C_2H_3O_2)_3$	undissoc., std state, m=1	aq	316.045		-512.86	-432.41		39.3	
$La(CH_2OHCOO)_3$	undissoc., std state, m=1	aq	364.043		-638.38				
$La(CH_2OHCOO)_4^-$	std. state, m=1	aq	439.088		-794.8				
$La_2(CN_2)_3$	lanthanum cyanamide	c	397.894		-199.				
LaB_6		c	203.776		-31.				
$LaAl_2$		c	192.873				3.529	23.60	17.62
$LaInTe_3$		c	636.53		-131.				
LaAu		g	335.877	111.4	110.8	98.2	2.46	67.	8.8
LaY		g	227.815		157.		2.4		8.7

APPENDIX

Errata for Technical Notes 270-3, 270-4, 270-5, and 270-6

TN	Page					
3	22	HF(liq)	ΔHf°_{298}	=	-71.65 kcal/mol	
			x denotes undetermined residual entropy			
3	26	HCl in $150H_2O$(aq)	ΔHf°_{298}	=	-39.710 kcal/mol	
3	32	HBr(g)	ΔHf°_0	=	-6.826 kcal/mol	
3	41	I_2Cl^-, std. state, m=1(aq)	ΔHf°_{298}	=	-32.9 kcal/mol	
			ΔGf°	=	-27.8 kcal/mol	
			S°	=	52.9 cal/deg mol	
3	43	S(g)	ΔGf°	=	56.951 kcal/mol	
			S°	=	40.084 cal/deg mol	
3	48	H_2S^+(g)	ΔHf°_0	=	237.0 kcal/mol	
		H_2S_2(liq)	ΔHf°_{298}	=	-4.33 kcal/mol	
		H_2S_2(g)		=	3.71 kcal/mol	
		H_2S_3(liq)		=	-3.57 kcal/mol	
		H_2S_3(g)		=	7.29 kcal/mol	
		H_2S_4(liq)		=	-2.99 kcal/mol	
		H_2S_4(g)		=	10.57 kcal/mol	
		H_2S_5(liq)		=	-2.49 kcal/mol	
		H_2S_5(g)		=	13.84 kcal/mol	
		H_2S_6(liq)		=	-1.99 kcal/mol	
3	56	Se(g)	$H^\circ-H^\circ_0$	=	1.4815 kcal/mol	
			S°	=	42.21 cal/deg mol	
			Cp°	=	4.978 cal/deg mol	
3	61	N(g)	ΔGf°	=	108.886 kcal/mol	
			S°	=	36.613 cal/deg mol	
3	85	PH_3, std. state, m=1(aq)	ΔHf°_{298}	=	-2.27 kcal/mol	
			ΔGf°	=	6.05 kcal/mol	
			S°	=	28.7 cal/deg mol	

APPENDIX

Errata (Cont.)

TN	Page			
3	85	PH_4^+, std. state, m=1(aq)	$\Delta Gf°$	= 22.0 kcal/mol
3	86	$H_2PO_4^-$, std. state, m=1(aq)	$\Delta Gf°$	= -270.17 kcal/mol
3	87	H_3PO_4 in $0.75H_2O$(aq)	$\Delta Hf°_{298}$	= -304.35 kcal/mol
3	89	PH_4OH, std state,	$\Delta Hf°_{298}$	= -70.59 kcal/mol
		m=1(aq)	$\Delta Gf°$	= -50.64 kcal/mol
			$S°$	= 45.4 cal/deg mol
		$H_4P_2O_7$ in $500H_2O$ should be in $150H_2O$		
3	91	PN(g)	$\Delta Hf°_0$	= 8. kcal/mol
			$\Delta Hf°_{298}$	= 7.76 kcal/mol
			$\Delta Gf°$	= 2.47 kcal/mol
3	97	$AsCl_3$(liq)	$\Delta Gf°_{298}$	= -62.0 kcal/mol
			$S°$	= 51.7 cal/deg mol
		$AsCl_3$(g)	$\Delta Hf°_0$	= -62.12 kcal/mol
			$\Delta Hf°_{298}$	= -62.5 kcal/mol
			$\Delta Gf°_{298}$	= -59.5 kcal/mol
3	132	$C_2H_3O_3^-$ glycollate ion std. state, m=1(aq)	$\Delta Hf°_{298}$	= -155.9 kcal/mol
3	196	B(amorp)	x denotes undetermined residual entropy	
3	208	Al_2O_3(c); the third, fourth and fifth lines should read:		
		ρ	$\Delta Hf°_{298}$	= -391. kcal/mol
		k		= -397. kcal/mol
			(Delete value for $\Delta Gf°_{298}$)	
		γ	$\Delta Hf°_{298}$	= -395. kcal/mol
3	231	$Te(SeO_3)_3$ should be $Tl_2(SeO_3)_3$		
		Tl_2Se(c)	formula weight = 487.70	
		$TlOCH_3$(c)	$\Delta Hf°_{298}$	= -39.7 kcal/mol

APPENDIX

Errata (Cont.)

TN	Page			
3	233	$ZnO \cdot 2ZnO_2 \cdot 2H_2O$(c)	ΔHf°_{298}	= -368.6 kcal/mol
		$ZnO \cdot 2ZnO_2 \cdot 3H_2O$(c)	ΔHf°_{298}	= -438.6 kcal/mol
3	234	ZnF_2(c)	ΔGf°	= -170.5 kcal/mol
3	244	$ZnAs_2$(c)	ΔHf°_{298}	= -10.0 kcal/mol
		Zn_3As_2(c)	ΔHf°_{298}	= -7.7 kcal/mol
3	248	CdF_2, std. state, m=1(aq)	ΔHf°_{298}	= -177.14 kcal/mol
4	3	HgI(g)	ΔHf°_0	= 32.9 kcal/mol
			ΔHf°_{298}	= 31.64 kcal/mol
			ΔGf°_{298}	= 21.14 kcal/mol
4	14	$CuCl_2$(c)	Cp°	= 17.18 cal/deg mol
4	16	$Cu_2(OH)_3Cl$ should be $CuCl_2 \cdot 3Cu(OH)_2$, formula weight 427.110		
4	57	$CoBr_2$ in $1000H_2O$(aq)	ΔHf°_{298}	= -71.6 kcal/mol
4	59	$[Co(NH_3)_6]^{3+}$, std. state, m=1(aq)	ΔGf°	= -37.6 kcal/mol
			S°	= 35. eu cal/deg mol
		$[Co(NH_3)_6]N_3^{2+}$, std. state, m=1(aq)	ΔGf°	= 42.9 kcal/mol
			S°	= 60. cal/deg mol
4	60	$[Co(NH_3)_4(H_2O)_2]^{3+}$(aq)	ΔHf°_{298}	= -244.2 kcal/mol
4	62	$[Co(NH_3)_6](NO_3)_3$, (c)	ΔGf°	= -125.5 kcal/mol
		std. state, m=1(aq)	S°	= 107 cal/deg mol
			ΔGf°	= -117.4 kcal/mol
			S°	= 140. cal/deg mol
4	63	$[Co(NH_3)_4Cl_2]^+$ cis(aq)	ΔHf°_{298}	= -160.5 kcal/mol
		trans(aq)	ΔH°_{298}	= -162.3 kcal/mol
		$[Co(NH_3)_4Cl_2]Cl$ cis(c)	ΔHf°_{298}	= -209.1 kcal/mol
		trans(c)	ΔHf°_{298}	= -209.7 kcal/mol
		cis(aq)	ΔHf°_{298}	= -200.5 kcal/mol
		trans(aq)	ΔHf°_{298}	= -202.3 kcal/mol

APPENDIX

Errata (Cont.)

TN	Page			
4	63	$[Co(NH_3)_6]Cl_3$, std. state, m=1(aq)	$\Delta Gf°$	= -131.7 kcal/mol
			$S°$	= 75. cal/deg mol
4	63	$[Co(NH_3)_4(H_2O)_2]Cl_3$(c)	$\Delta Hf°_{298}$	= -366.9 kcal/mol
		in 10,000H_2O (aq)	$\Delta Hf°_{298}$	= -364.1 kcal/mol
4	64	$[Co(NH_3)_6](ClO_4)_3$(c)	$\Delta Gf°$	= -53.0 kcal/mol
			$S°$	= 147. cal/deg mol
		std. state, m=1(aq)	$\Delta Gf°$	= -43.8 kcal/mol
			$S°$	= 166. cal/deg mol
4	65	$[Co(NH_3)_6]Br_3$ (aq) std. state, m=1	$\Delta Gf°$	= -112.2 kcal/mol
			$S°$	= 94. cal/deg mol
4	66	$[Co(NH_3)_6]I_3$ (aq) std. state, m=1	$\Delta Gf°$	= -74.6 kcal/mol
			$S°$	= 113. cal/deg mol
4	67	$[Co(NH_3)_6]SO_4^+$	$\Delta Gf°$	= -220.2 kcal/mol
		std. state, m=1(aq)	$S°$	= 57. cal/deg mol
4	68	$Co(HCO_2)$ should be $Co(HCO_2)_2$		
4	70	$[Co(NH_3)_4C_2O_4]^+$(aq)	$\Delta Hf°_{298}$	= -298.0 kcal/mol
4	98	PtS(c)	$H_{298}-H_0$	= 1.946 kcal/mol
			$\Delta Hf°_0$	= -19.020 kcal/mol
4	99	$PtTe_2$(c)	$H_{298}-H_0$	= 3.984 kcal/mol
			$S°$	= 28.92 cal/deg mol
			$Cp°$	= 18.03
4	108	$MnI_2 \cdot 4H_2O$(c)	$\Delta Hf°_{298}$	= -343.9 kcal/mol
4	113	MnC_2O_4(c)	$\Delta Hf°_{298}$	= -245.9 kcal/mol
		$MnC_2O_4 \cdot 2H_2O$(c)	$\Delta Hf°_{298}$	= -389.2 kcal/mol
			$S°$	= 48. cal/deg mol
		$MnC_2O_4 \cdot 3H_2O$(c)	$\Delta Hf°_{298}$	= -459.1 kcal/mol
5	2	$HV_{10}O_{28}^{5-}$ std. state, m=1(aq)	$\Delta Gf°_{298}$	=-1841. kcal/mol
			$S°$	= 53. cal/deg mol
		$H_2V_{10}O_{28}^{4-}$ std. state, m=1(aq)	$\Delta Gf°_{298}$	=-1846. kcal/mol

INDEX OF CONTENTS

Chemical Symbol	Element	Table Number	Volume - Page Number
He	Helium	3	3- 15
Hf	Hafnium	59	5- 22
Hg	Mercury	35	4- 1
Ho	Holmium	66	7- 16
I	Iodine	12	3- 36
In	Indium	31	3-223
Ir	Iridium	46	4-103
Kr	Krypton	6	3- 18
La	Lanthanum	76	7- 60
Lu	Lutetium	62	7- 1
Mg	Magnesium	93	6- 9
Mn	Manganese	48	4-106
Mo	Molybdenum	52	4-129
N	Nitrogen	18	3- 61
Nb	Niobium	55	5- 6
Nd	Neodymium	73	7- 43
Ne	Neon	4	3- 16
Ni	Nickel	39	4- 43
O	Oxygen	1	3- 11
Os	Osmium	47	4-104
P	Phosphorus	19	3- 84
Pb	Lead	27	3-187
Pd	Palladium	42	4- 90
Pm	Promethium	72	7- 42
Po	Polonium	17	3- 60
Pr	Praseodymium	74	7- 48
Pt	Platinum	45	4- 96
Ra	Radium	97	6-103

Chemical Symbol	Element	Table Number	Volume - Page Number
Re	Rhenium	50	4-117
Rh	Rhodium	43	4- 93
Rn	Radon	8	3- 20
Ru	Ruthenium	44	4- 94
S	Sulfur	14	3- 43
Sb	Antimony	21	3- 99
Sc	Scandium	60	5- 24
Se	Selenium	15	3- 56
Si	Silicon	24	3-171
Sm	Samarium	71	7- 37
Sn	Tin	26	3-181
Sr	Strontium	95	6- 57
Ta	Tantalum	56	5- 10
Tb	Terbium	68	7- 25
Tc	Technetium	49	4-116
Te	Tellurium	16	3- 58
Ti	Titanium	57	5- 12
Tl	Thallium	32	3-227
Tm	Thulium	64	7- 9
V	Vanadium	54	5- 1
W	Tungsten	53	4-134
Xe	Xenon	7	3- 19
Y	Yttrium	61	5- 28
Yb	Ytterbium	63	7- 4
Zn	Zinc	33	3-233
Zr	Zirconium	58	5- 18

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Contains tables of values for the standard heats and Gibbs (free) energies of formation, entropies and enthalpies at 298.15 K and heats of formation at 0 K for compounds of the rare-earth elements (the lanthanides; lutetium through lanthanum; elements 62 through 76 in the Standard Order of Arrangement). These tables are a continuation of the comprehensive revision of NBS Circular 500.

Key words: Cerium compounds; dysprosium compounds; enthalpy; entropy; erbium compounds; europium compounds; gadolinium compounds; Gibbs energy of formation; holium compounds; lanthanides; lanthanum compounds; lutetium compounds; neodymium compounds; praseodymium compounds; promethium compounds; rare-earth elements; samarium compounds; terbium compounds; thulium compounds; ytterbium compounds.

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