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HEATS OF FORMATION OF INTERMETALLIC COMPOUNDS

Raleigh L. McKisson and Leroy A. Bromley

January 31, 1950

Berkeley, California

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Abstract

The heats of formation of intermetallic compounds as found in the literature have been tabulated. The values are listed for each compound in Kcal/gm mole and Kcal/gm atom. The probable best value in each case is also listed. A short discussion of the relationship between values of the heats of formation in a given system of several compounds is given. The derived equation is applied to the sodium - tin and sodium - mercury systems. The equation (Eq. 7) will allow a calculation of the heats of formation of peritectic melting compounds and in some cases congruent melting compounds, provided the phase diagram and one heat of formation in the system is known.

Introduction

A knowledge of the heats of formation of intermetallic compounds is useful as it enables one to calculate at least approximately the stability of the various intermetallic compounds. For an exact calculation, of course, a knowledge of the free energy is required; however, since the entropy change in the formation of intermetallic compounds is normally small, the heat becomes a measure of the free energy.

A knowledge of the heat of formation would enable one to calculate or at least estimate whether a given molten metal will attack a container, whether a solid alloy will resist (thermodynamically) attack of another element, and numerous other thermodynamic calculations.

Theory

Several authors[21, 24, 29, 32] have shown experimentally that if the heats of formation per gram atom of peritectic compound in a given system of elements are plotted vs. mole fraction a straight line relation results on each side of the congruent melting compound. In an attempt to show rigorously why this is true or not true, let us consider a representative but hypothetical case.

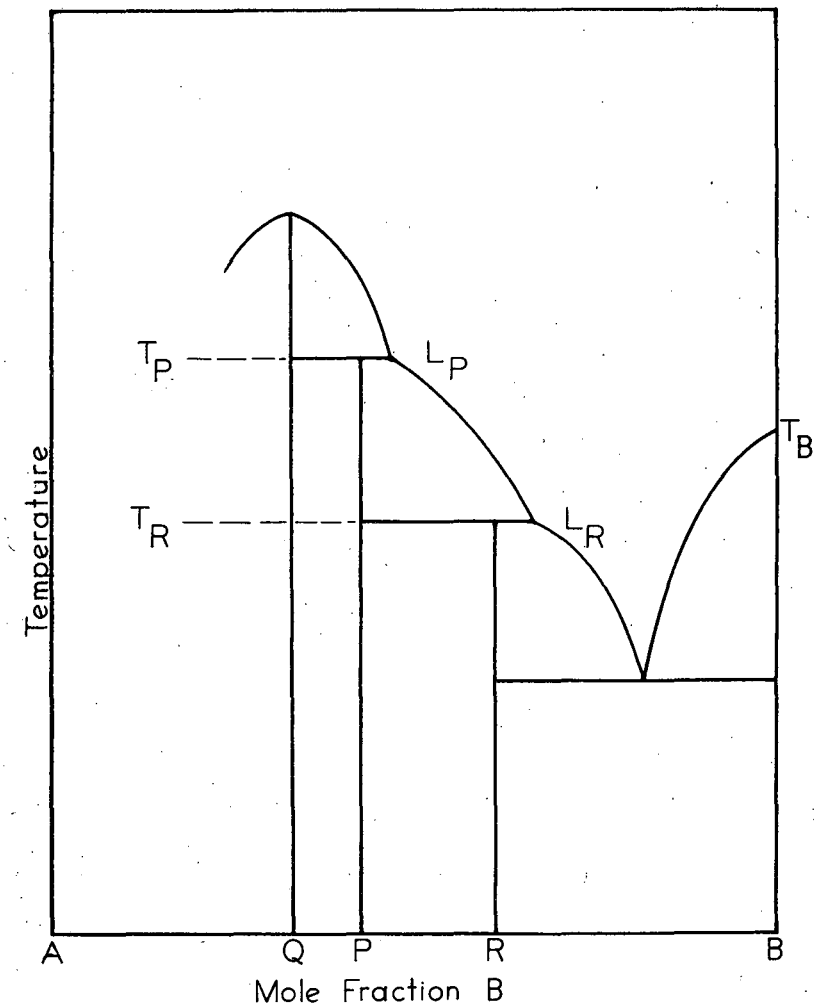
Peritectic Compounds

The relationship between the heat of formation of a peritectic compound and the heat of formation of the compound to which it decomposes is given in the following derivation.

In Figure 1 let

N_R = mole fraction of A in compound R.

Z_R = total no. of atoms in compound R.



Mu-35

Fig. 1.

T_R = peritectic melting temperature of R.

a_{BLR} = activity of B in liquid L_R.

$A_{Z_R N_R} B_{Z_R(1-N_R)}$ = formula of compound R.

$\Delta H^\circ_{f_R}$ = heat of formation R.

ΔF_m = free energy change on melting.

ΔC_{p_m} = heat capacity of liquid - heat capacity of solid near the melting point.

We would like to find ΔH° for the following reaction at 298°.

$$\frac{N_P}{Z_R N_R} A_{Z_R N_R} B_{Z_R(1-N_R)}(s) = \frac{1}{Z_P} A_{Z_P N_P} B_{Z_P(1-N_P)}(s) + \left(\frac{N_P}{N_R} - 1\right) B(s) \quad (1)$$

The following relation exists between the heats of formation of the compounds and the heat of reaction (1).

$$\frac{\Delta H^\circ_{f_P}}{Z_P} = \frac{N_P \Delta H^\circ_{f_R}}{N_R Z_R} + \Delta H^\circ_1 \quad \text{(for reaction 1)} \quad (1a)$$

At T_R we know that for the reaction

$$\frac{N_P}{Z_R N_R} A_{Z_R N_R} B_{Z_R(1-N_R)}(s) = \frac{1}{Z_P} A_{Z_P N_P} B_{Z_P(1-N_P)}(s) + \left(\frac{N_P}{N_R} - 1\right) B(l) \quad (2)$$

$$\Delta F^\circ_{2_{T_R}} = -RT_R \ln (a_{BLR})^{\left(\frac{N_P}{N_R} - 1\right)} \quad (2a)$$

If the solids are partially soluble in each other then of course the activities of these must also be included.

If we subtract from this expression the free energy for the following reaction at T_R

$$\left(\frac{N_P}{N_R} - 1\right) B(s) \longrightarrow \left(\frac{N_P}{N_R} - 1\right) B(l) \quad (3)$$

then we have the free energy of reaction (1) at T_R. Reaction (3) is the melting of $\left(\frac{N_P}{N_R} - 1\right)$ moles of B. At T_B, ΔF_m (per mol.) has

the value zero.

$$\left(\frac{\partial \Delta F_m}{\partial T}\right) = -\Delta S_m = -\Delta S_{m_{T_B}} - \Delta C_{p_m} \ln \frac{T}{T_B}$$

Integrating between the melting point of B, T_B and T_R we obtain for the free energy of reaction (3) at T_R

$$\left(\frac{N_P}{N_R} - 1\right) \Delta F_{m_{T_R}} = \left[\left(-\Delta S_{m_{T_B}} + \Delta C_{p_m}\right)(T_R - T_B) - \Delta C_{p_m} T_R \ln \frac{T_R}{T_B}\right]\left(\frac{N_P}{N_R} - 1\right) \quad (4)$$

The free energy of reaction (1) at 298 is then obtained by adding the free energy change in the solid reactions between T_R and 298. Assume ΔS_1° is approximately constant.

$$\Delta F^\circ_{1_{298}} - \Delta F^\circ_{1_{T_R}} = +\Delta S_1^\circ (T_R - 298) \quad (5)$$

Then

$$\Delta F^\circ_{1_{298}} = \Delta F^\circ_{2_{T_R}} - \left(\frac{N_P}{N_R} - 1\right) \Delta F_{m_{T_R}} + \Delta S_1^\circ (T_R - 298)$$

$$= \Delta H^\circ_{1_{298}} - 298\, \Delta S_1^\circ \quad (6)$$

Let us replace ΔH_1° in Eq. (1a) by that from Eq. (6) and then substitute for $\Delta F^\circ_{2_{T_R}}$ and $\Delta F_{m_{T_R}}$, the values from equations (2a) and (4) respectively. We thus obtain the following relationship for the heats of formation of a solid peritectic melting compound R and the heat of formation of the compound P to which it decomposes on melting. Both heats of formation are from the solid elements. It will be noted that it is assumed that this value is independent of temperature ($\Delta C_{p_f} = 0$) as long as all materials are in the solid state.

$$\frac{\Delta H^\circ_{f_P}}{Z_P} = \frac{N_P \Delta H^\circ_{f_R}}{N_R Z_R} + \left(\frac{N_P}{N_R} - 1\right)\left\{-RT_R \ln a_{BLR} + \left[\Delta S_{m_{T_B}} - \Delta C_{p_m}\right]\left[T_R - T_B\right] + \Delta C_{p_m} T_R \ln \frac{T_R}{T_B}\right\} + \Delta S_1^\circ T_R \quad (7)$$

Similarily the heats of formation of P and Q are related as follows.

$$\frac{\Delta H^{\circ}_{f_Q}}{Z_Q} = \frac{N_Q \Delta H^{\circ}_{f_P}}{N_P Z_P} + \left(\frac{N_Q}{N_P} - 1\right)\left\{-RT_P \ln a_{BLP} + \left[\Delta S_{m_{T_B}} - \Delta C_{p_m}\right]\left[T_P - T_B\right]\right.$$

$$\left. + \Delta C_{p_m} T_P \ln \frac{T_P}{T_B}\right\} + \Delta S^{\circ}_{P \longrightarrow Q} T_P \qquad (8)$$

These expressions are based on rigorous thermodynamics and assume only that the ΔC_{p_m} and ΔS°_1 are constants. To make use of these expressions to calculate the heat of formation of one compound when the other is known we must estimate the various unknown terms.

It will be noted that if all of the terms are neglected to the right of and including all terms in brackets in Eq. (7), then the rule of linear heats of formation versus mole fraction applies.

Activity of rich element in the liquid

The activity of B in the solution will be estimated by a procedure outlined by Hildebrand.[15b] It will be assumed that there is only one stable compound in the solution and that its formula is that of the highest congruent melting compound Q. The liquid L_R is then constituted as follows.

$$N_{L_R} A(l) + (1 - N_{L_R})\, B(l) \longrightarrow \frac{y}{Z_Q} A_{Z_Q} N_Q B_{Z_Q}(1 - N_Q)\ (l) +$$

$$(N_{L_R} - yN_Q)\, A(l) + (1 - N_{LR} - y + yN_Q)\, B(l) \qquad (9)$$

where y is the gram atoms of compound per gram atom of starting elements. The latter substances are all in solution. For the formation of one gram atom of pure Q we have at temperature T_R

$$N_Q A(l) + (1 - N_Q)\, B(l) \longrightarrow \frac{1}{Z_Q} A_{Z_Q} N_Q B_{Z_Q}(1 - N_R)\ (l) \qquad (10)$$

$$\frac{\Delta F^{\circ}_{f_Q}}{Z_Q} = -RT_R \ln \frac{(a_Q)^{\frac{1}{Z_Q}}}{(a_B)^{1-N_Q}\,(a_A)^{N_Q}} \qquad (11)$$

We now need a relationship between the activities and the concentrations. Perhaps the best workable procedure would be to assume that the liquids form regular solutions[15b] or at least that the activity coefficients could be calculated by a modified regular solution theory. Since the term involving the activity of B will usually be a rather small contribution to Eq. (7) we will use the simplified although less correct assumption that Raoult's Law applies. The moles of solution per atom of starting material is then

$$1 + \frac{y}{z} - y = 1 - y\left(1 - \frac{1}{z}\right)$$

Equation 11 then becomes

$$\frac{\Delta F^{\circ}_{f_Q}}{Z_Q} = -RT_R \ln \frac{\left[\dfrac{\frac{y}{z}}{\left[1 - y\left(1 - \frac{1}{Z_Q}\right)\right]}\right]^{\frac{1}{Z_Q}}}{\left[\dfrac{N_{L_R} - yN_Q}{\left[1 - y\left(1 - \frac{1}{Z_Q}\right)\right]}\right]^{N_Q} \left[\dfrac{(1 - N_{L_R} - y + yN_Q)}{1 - y\left(1 - \frac{1}{Z_Q}\right)}\right]^{1-N_Q}} \qquad (12)$$

Although this may be solved for y for a known $\Delta F^{\circ}_{f_Q}$ and then a_B obtained, the labor involved is great and hardly worthwhile. Since we will not, in general, be interested in the result unless there is appreciable compound formation and since in our previous derivation we chose the B rich side of the phase diagram, y will be only slightly less than N_{L_R}/N_Q.

Then for a quite stable intermetallic compound

$$a_{BLR} = a_B \approx \frac{1 - \frac{N_{L_R}}{N_Q}}{1 - \frac{N_{L_R}}{N_Q}\left(1 - \frac{1}{Z_Q}\right)} \qquad (14)$$

Entropy term

The last term to be estimated is the entropy change in reaction (1), the disproportionation of solid R into one gram atom of P and solid B. This term should be smaller than the entropies of formation of the compounds. The entropies of formation per gram atom of a few compounds are given in Table I.[28]

Table I

	ΔS°_{298} $\frac{\text{cal}}{\text{gm atom } ^\circ\text{K}}$
CdTe	-0.79
Cd_3Sb_2	+4.18
MnSe	+2.06
MnTe	+1.46
PbTe	+0.54
ZnTe	-1.42
ZnSb	+0.48
Zn_3Sb_2	+2.55
Zn_4Sb_3	+0.31

There seems to be little rhyme or reason to these values. About all that can be said is that they are all relatively small.

It should be noted, nevertheless, that this contribution to the heat may be quite large and may be either positive or negative.

Melting data for the elements

The entropy of melting ΔS_m and the change in heat capacity on melting ΔC_{p_m} are tabulated in Table II. All values containing ΔC_p terms are from Kelley[16s] and the others are from Brewer[2a]. Values in parenthesis are estimated. It will be noticed that in general it would be a satisfactory approximation to assume that ΔC_{p_m} is zero.

Two congruent melting compounds separated by a eutectic

One may apply the same reasoning as in the case of peritectic compounds and obtain essentially the same equations as (7) and (8). It is difficult to get a simple approximation for the activity of B in the eutectic liquid as there may be two compound species in the liquid. If one assumes that only the higher melting species is present in the liquid then one may calculate a heat of formation for the lower congruent melting compound by the use of equations (7) and (13). The activity of B is that in the liquid at the eutectic. This value will probably not be bad if there is a large separation in melting point (stability) of the congruent compounds. In any case the result calculated denotes the minimum stability.

Heats of formation of sodium-tin compounds

Let us use these equation to calculate the heats of formation of the various sodium-tin compounds using the value of 12.0 for NaSn given by Kubaschewski and Seith[20]. Thus $\Delta H^\circ_{NaSn} = -6.0$ Kcal per gram atom. The peritectic and eutectic melting points are taken from Hansen[15a].

Table II

Melting Point and the Change in Entropy and Heat Capacity on Melting for the Elements

Element	T_m °K	ΔS_m (e.u.)	ΔC_{pm} (e.u.)
Li	452	2.4	
Na	371	1.70	+0.5
K	337	1.70	+0.7
Rb	312	1.68	+0.5
Cs	302	1.67	+0.6
Be	1557	1.6	
Mg	923	2.34	0.0
Ca	1124	2.0	
Sr	1044	2.1	
Ba	990	(2.0)	
B	2300	2.7	
Al	932	2.76	-0.7
Sc	1670	(2.4)	
Y	1750	(2.3)	
La	1160	(2.0)	
Ce	1058	(2.0)	
C	3770		
Si	1683	6.6	
Ti	2000	(2.3)	
Zr	2400	(2.3)	
Hf	2600	(2.3)	
Th	2100	(2.2)	

Table II (cont.)

Element	T_m °K	ΔS_m (e.u.)	ΔC_{p_m} (e.u.)
V	1970	(2.0)	
Cb	2770	(2.3)	
Ta	3270	2.3	
Cr	1823	2.30	-0.7
Mo	2870	2.3	
W	3650	2.3	
U	1405	2.1	
Mn(δ)	1517	2.31	-0.3
Re	3440	(2.3)	
Fe(δ)	1803	2.05	-0.3
Co(γ)	1736	2.10	-1.3
Ni(β)	1725	2.44	+0.1
Ru	2700	(2.3)	
Rh	2240	(2.3)	
Pd	1828	2.25	
Os	2970	(2.2)	
Ir	2727	(2.4)	
Pt	2047	2.5	
Cu	1357	2.30	+0.05
Ag	1234	2.31	-0.3
Au	1336	2.21	-0.3

Table II (cont.)

Element	T_m °K	ΔS_m (e.u.)	ΔC_{p_m} (e.u.)
Zn	693	2.55	+0.5
Cd	594	2.44	0.0
Hg	234	2.4	0.0
Ga	303	4.41	+0.5
In	430	1.80	+0.6
Tl	576	1.75	+0.2
Ge	1232	6.7	
Sn	505	3.41	-0.2
Pb	600	2.04	-0.2
As	1090	6.05	
Sb	903	5.25	+0.4
Bi	544	4.54	+0.1
Se	490	2.65	+0.8
Te	726	4.5	

Compound	m. p.	Liquid Composition N_{Sn}	a_{Sn}
Na_4Sn_3	= 478°C (p)	0.42	0.276
Na_2Sn	= 440°C (E)	0.39	0.36
Na_4Sn	= 405°C (p)	0.20	0.75

Applying Eq. (8),

$$-6.0 = \frac{0.5 \times 7}{3} \frac{\Delta H^\circ_{Na_4Sn_3}}{7} + \left(\frac{7}{6} - 1\right)\left\{-4.6 \times 0.751 \log 0.276 + 1.2 \times 0.380 + 0.5 \times 0.751 \ln \frac{751}{371}\right\}$$

$$\frac{\Delta H^\circ_{Na_4Sn_3}}{7} = -5.52$$

For Na_2Sn,

$$-5.52 = \frac{9}{7} \frac{\Delta H^\circ_{f_{Na_2Sn}}}{3} + \left(\frac{9}{7} - 1\right)\left\{- 4.6 \times 0.713 \log 0.36 + 1.2 \times 0.342 + 0.5 \times 0.713 \ln \frac{713}{371}\right\}$$

$$\frac{1}{3} \Delta H^\circ_{f_{Na_2Sn}} = -4.76$$

This is in excellent agreement with the value of -4.8 given by Kubaschewski. This agreement is quite fortuitous as the following neglected factors should lead to disagreement. The data are probably not more accurate then about 1/2 Kcal per gram atom. The ΔS°_1 term was neglected and its magnitude might easily be 1/2 Kcal. If the liquid at the eutectic contains two compounds then the result above should be a minimum for the stability rather than the true value.

Let us calculate the heat of formation of Na_4Sn.

$$-4.76 = \frac{5}{3}\,\frac{\Delta H_{f_{Na_4Sn}}}{5} + \frac{2}{3}\left\{-4.6 \times 0.678 \log 0.75 + 1.2 \times 0.307 + 0.5 \times 0.678 \ln \frac{678}{371}\right\}$$

$$\frac{\Delta H_{f_{Na_4Sn}}}{5} = -3.24 \text{ Kcal/gm atom}$$

This is in only fair agreement with Kubaschewski and Seith's experimental value of -2.9 but this agreement is as good as could be expected.

We have estimated that the best probable value for the heat of formation of $\frac{1}{2}$ NaSn is -5.7. Using this we can calculate the value of $NaSn_2$. Noting from Hansen[15a] that the peritectic melting point is 578°K and that the mole fraction of sodium in the liquid formed is 0.20, we have, applying Eq. (7),

$$-5.7 = \frac{0.5 \times 3}{1}\,\frac{\Delta H_{f_{NaSn_2}}}{3} + \left(\frac{3}{2} - 1\right)\left\{-4.6 \times 0.578 \log 0.86 + 3.6 \times 0.073 - 0.2 \times 0.578 \ln \frac{578}{505}\right\}$$

$$\frac{\Delta H_{f_{NaSn_2}}}{3} = -3.95$$

which is considerably below the values of -5 and -6.7 given by Biltz et al[7, 8]. The neglected ΔS° term should not be much larger than 1 e.u. corresponding to about 0.4 Kcal. Hence we tabulated in Table III the value

$$\frac{\Delta H_{f_{NaSn_2}}}{3} = 4. \text{ Kcal/gm atom}$$

Heats in Na - Hg system

A similar calculation was carried out for the sodium - mercury system. The equation was applied to calculate heats of formation from solid mercury and sodium, and then the results were corrected

to give the heat of formation from liquid mercury and solid sodium by adding the heat of fusion of mercury. We chose to start our calculation using a value of -2.8 for the heat of formation per gram atom of Na_3Hg. This represents an average of numerous experimental values and should certainly be accurate to ±0.5 Kcal. The experimental and calculated results are summarized as follows. All values are Kcal per gram atom of compound.

Compound	Experimental Value Chosen	Experimental Range	Calculated
Na_3Hg	-2.8	-2.2 to -3.2	(-2.8 used)
Na_5Hg_2			-3.21
Na_3Hg_2	-4.5	-3.9 to -4.6	-4.45
NaHg	-5.5	-5.4 to -5.7	-5.48
Na_7Hg_8	-5.6	-5.3 to -5.6	-5.79
$NaHg_2$	-6.2	-5.8 to -6.2	-6.96
$NaHg_4$	-4.4	-3.9 to -4.5	-4.25

These results are certainly as satisfactory as could be expected. It appears that either the measured heat of formation of $NaHg_2$ is too positive or that $NaHg_2$ has an entropy of formation of about -1 cal per °K per gram atom.

Literature Data

Table III is the result of a literature search of articles reported in Chemical Abstracts. This table lists the heat of formation in kilocalories per mole, the heat of formation in kilocalories per gram-atom, the temperature of the measurement of the heat of formation, the melting point or the decomposition temperature of the solid compound, the references to the particular value, and a

selected value for the heat of formation at 298°K of the compound or alloy. The melting points and the decomposition temperatures were obtained from Hansen[15a] and the letters following these temperatures have the following meanings: c, congruent melting point; E, decomposes at a eutectic; p, peritectic decomposition; p*, decomposition at the peritectic temperature, but the particular alloy is not the peritectic compound; s, solid solution melting. Those references which tabulate values from other work are indicated by a "t" following the reference number. Each compound or alloy is listed twice, once under each element. The following diagram indicates the order of listing of the elements in the table, from LiNa as the first possible entry to TeSe as the last.

Although in most cases the selected value of the heat of formation at 298°K is given to a tenth of a kilocalorie, these heats should be considered to have a probable error of ±0.5 kilocalorie per gram atom.

This work was done under the auspices of the Atomic Energy Commission.

Table III

Heats of Formation of Binary Intermetallic Compounds and Alloys

Compound	ΔH, kcal./mol.	ΔH, kcal./g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/g. atm.
LiHg	-20.8	-10.4	291	873c	2t	-10.4
$LiHg_2$	-25.0	- 8.3	291	611p	2t	- 8.3
$LiHg_3$	-26.8	- 6.7	291	513p	2t	- 6.7
LiTl	-12.8±0.6	- 6.4	293	781c	19	- 6.4
Li_4Sn	-47.0	- 9.4	room	1038c	23t, 20	- 9.4
Li_7Sn_2	-86.4	- 9.6	room	1058c	20	- 9.6
LiSn	-16.8	- 8.4	room	758c	20	- 9.
(1)	-17.57±0.83	- 8.8	850		1	
	-18.6±1.5	- 9.3	298		1	
Li_7Pb_2	-75.6	- 8.4	293	999c	20t, 32	- 8.4
LiPb	-14.6	- 7.3	293	755c	20t, 32	- 7.3
Li_3Sb_2	-43.5	- 8.7	room	>1220	20	- 8.7
$LiSb_3$	-43.6	-10.9			23t	-10.9
Li_3Bi	-55.2	-13.8	293	1418c	20t, 32	-13.8
Li_2Se	-84.9	-28.3	291		2t	-28.3
Na_2K(1)	- 0.4	- 0.13	291	280p	2t	- 0.13
NaK(1)	- 2.1	- 1.05	291	260E	2t	- 1.05
NaK_2(1)	- 5.3	- 1.8	291	260E	2t	- 1.8
NaK_3(1)	- 5.6	- 1.4	291	260E	2t	- 1.4
$NaCd_2$	- 8.1	- 2.7	293	658c	20t, 32	- 2.7
	-8.5	- 2.8	291		2t, 3t, 5	
	-30.8	-10.3			30	
$NaCd_5$	-12.5	- 2.1	291	624E	2t, 3t, 5	- 2.1
	-60.6	-10.1			30	

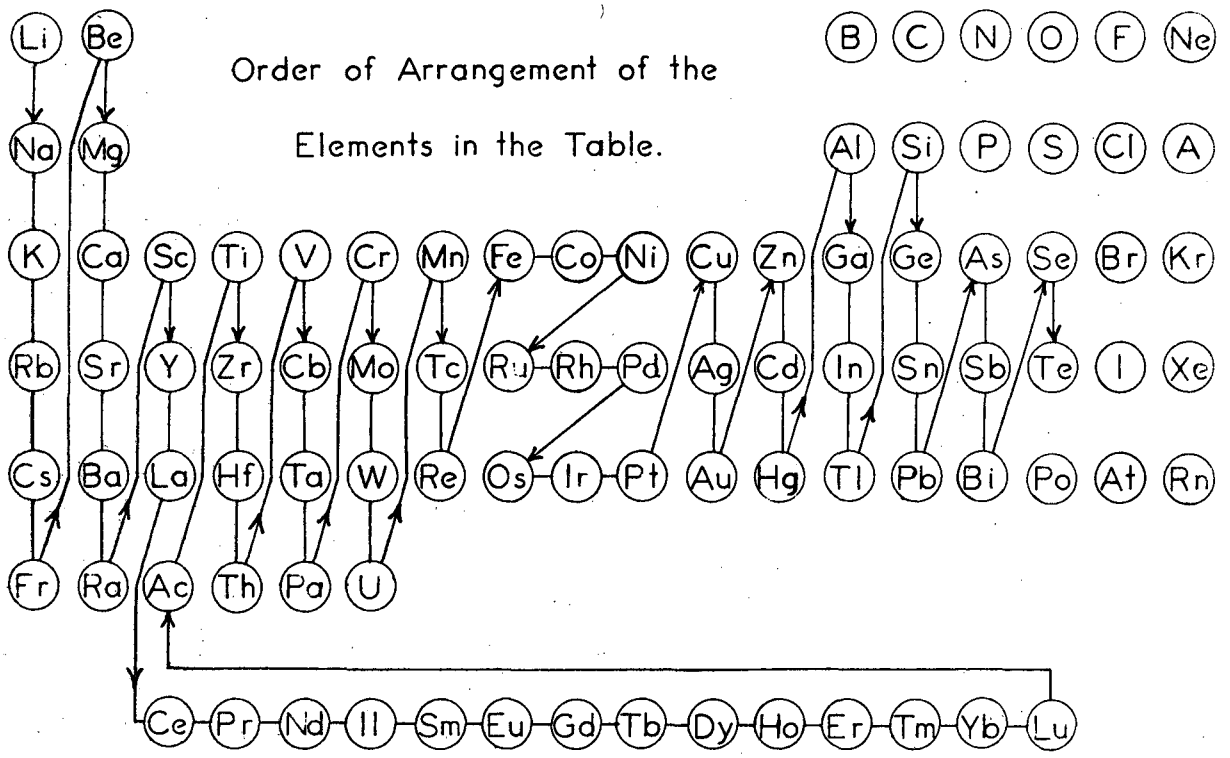

Order of Arrangement of the
Elements in the Table.
Li Be B C N O F Ne
Na Mg Al Si P S Cl A
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Cb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac Th Pa U
Ce Pr Nd Il Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

FIG. 2 Mu-36

Table III (continued)

Compound	ΔH, kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
$NaCd_6$	-12.6	- 1.8	293	638c	20t, 32	- 1.8
Na_3Hg	- 8.7	- 2.2	291	307p	3t	- 2.8
	-11.7	- 2.9	273		3t	
	-11.6	- 2.9	room		20	
	-12.9	- 3.2	291		5t	
	-9.3±0.3	- 2.3	291		8	
	-11.1	- 2.8	291		2t	
Na_3Hg_2	-19.6	- 3.9	291	396p	3t	- 4.5
	-20.7±0.3	- 4.1	291		3t, 8	
	-22.5	- 4.6	room		22t, 20	
	-22.2	- 4.4	291		2t	
NaHg	-11.3±0.1	-5.7	291	492p	3t, 8	- 5.5
	-10.7	- 5.4	291		3t	
	-11.0	- 5.5	291		2t	
Na_7Hg_8	-84.4±1.0	- 5.6	291	500p	3t, 8	- 5.6
	-79.9	- 5.3	291		3t	
$NaHg_2$	-17.6	- 5.8	291	628c	3t	- 6.2
	-18.7±0.3	- 6.2	291		3t, 8	
	-18.0	- 6.0	room		22t, 20	
	-18.5	- 6.2	291		2t	
$NaHg_4$	-22.4±0.4	-4.5	291	431p	3t, 8	- 4.4
	-19.5	- 3.9	room		20	
	-20.2	- 4.0	291		3t	
	-22.2	- 4.4	291		2t	

Table III (continued)

Compound	ΔH, kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
NaTl	-9.0±0.6	-4.5		579c	19	-4.5
Na_4Sn	-21.	-4.2	291	678p	7	-3.
	-34.	-6.8	291		2t, 3t, 8	
	-14.4	-2.9	room		23t, 20	
Na_2Sn	-21.	-7.0	291	750c	2t, 3t, 8	-4.8
	-14.4	-4.8	room		20	
	-12.	-4.	291		7	
Na_4Sn_3	-36.	-5.1	291	751p	7(see discussion)	-5.
	-56.	-8.	291		2t, 3t, 8	
NaSn	-16.	-8.	291	849c	2t, 3t, 8	-5.7
	-11.	-5.5	291		7	
(1)	-9.63±0.40	-4.8	873		1	
	-12.0	-6.0	room		20	
	-10.6±0.6	-5.3	298		1	
$NaSn_2$	-20.	-6.7	291	578p	2t, 3t, 8 (see discussion)	-4.
	-15.	-5.	291		7	
Na_4Pb	-20.0	-4.0	293	660c	20t, 32	
	-13.2	-2.6			17	
Na_5Pb_2	-35.0	-5.0	293	673c	20t, 32	-5.0
NaPb	-11.6	-5.8	293	641c	20t, 32	-5.8
$NaPb_3$	-15.2	-3.8	293	583c	19t	-3.8
Na_3Sb	-47.2	-11.8	room	1129c	23t, 20	-11.8
Na_3Bi	-45.6	-11.4	293	1048c	20t, 32	-11.4
Na_2Se	-59.1	-19.7	291	1148	2t, 19t	-19.7

Table III (continued)

Compound	ΔH, kcal./mol.	ΔH, kcal./g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/g. atm.
Na_2Te	~-60.	-20.		1226c	19	-20.
	-84.3	-28.1			23t, 17	-33.9
NaTe	-30.±3.	-15.		626p	19	-15.
$NaTe_2$	-101.8	-33.9		692E	17	-33.9
$NaTe_3$	-30.±3.2	- 7.5		709c	19	- 7.5
$K_3Na(l)$	- 5.6	- 1.4	291	260E	2t	- 1.4
$K_2Na(l)$	- 5.3	- 1.8	291	260E	2t	- 1.8
$KNa(l)$	- 2.1	- 1.05	291	260E	2t	- 1.05
$KNa_2(l)$	- 0.4	- 0.13	291	280p	2t	- 0.13
KHg	-11.0	- 5.5	291	451c	2t	- 5.5
KHg_3	-26.0	- 6.5	291	477p	2t	- 6.5
KHg_{10}	-33.0	- 3.0	291	230E	2t	- 3.0
K_2Se	-74.4	-24.8	291		2t	-24.8
Mg_4Ca_3	-43.0	- 6.1	291	993c	2t, 3t, 5t, 11t, 6	- 6.1
Mg_3La	-12.9	- 3.2	298	1039p	3t, 12	- 3.2
MgLa	- 5.7	- 2.9	298	1016c	3t, 12	- 2.9
Mg_3Ce	-17.	- 4.3	291	1053c	2t, 3t, 9	- 4.3
MgCe	-13.0	- 6.5	291	1013c	2t, 3t, 9	- 6.5
Mg_3Pr	-11.0	- 2.8	room	1071c	3t, 13	- 2.8
MgPr	- 8.2	- 4.1	room	1040c	3t, 13	- 4.1
$MgZn_2$	-13.1	- 4.4	291	863c	2t	- 4.4
	-12.6	- 4.2	291		3t, 5t, 6	

Table III (continued)

Compound	ΔH, kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
($MgZn_2$)	-24.9	-8.3	room	863c	30	
MgCd	-17.7	-8.9	room	~700s	30	-4.6
	- 9.2	-4.6	291		2t, 3t, 5t, 6	
$MgHg_4$	-17.3	-3.5	291	233E	2t	-3.5
Mg_4Al_3	-49.0	-7.0	291	728c	2t, 3t, 5t, 11t, 6	-7.0
	-164.8	-23.5	room		30	
MgTl	-10. to -13.	~-5.8		631c	19t	-5.8
Mg_2Si	-18.5 ± 1.5	-6.2	~685	1343c	24	-6.5
	-19.5	-6.5	~900		24t	
Mg_2Sn	-17.2	-5.7	~870	1051c	19t, 23t, 34t, 21	-6.
	-49.	-16.7	292		7	
	-59.	-19.7	291		2t, 3t, 8	
	-18.3	- 6.1	~900		24	
Mg_2Pb	-12.6	- 4.2	293	823c	19t, 20t, 21t, 22t, 24t, 34t, 32	-4.2
Mg_3Sb_2	-68.	-13.6	~870	1234c	23t, 34t, 21	-15.
	-76.5	-15.3	~870		24t	
Mg_3Bi_2	-36.0	- 7.2	293	988c	20t, 21t, 22t, 32	-7.4
	-37.5	- 7.5	~900		21t	
	-37.	- 7.4	870		34t	
	-40.5	- 8.1	~900		24t	
MgTe	-50. ± 5.	-25.	~900		19t, 24t, 23	-25.
Ca_3Mg_4	-43.0	-6.1	291	993c	2t, 3t, 5t, 11t, 6	-6.1
Ca_4Zn	-32.	-6.4	291	663	2t, 3t, 11	-6.4
Ca_2Zn_3	-40.	-8.	291	961c	2t, 3t, 11	-8.
$CaZn_4$	-55.6	-11.1	room	953p	30	-5.9

Table III (continued)

Compound	ΔH, kcal/mol.	ΔH, kcal./g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/g. atm.
($CaZn_4$)	-29.5	-5.9	291		2t, 3t, 11	
$CaZn_{10}$	-4.8	-4.4	291	990c	2t, 3t, 11	-4.4
	-199.1	-18.1	room		30	
$CaCd_3$	-30.	-7.5	291	885p	2t, 3t, 11	-7.5
$CaAl_3$	-51.	-12.8	291	973p	2t, 3t, 11	-13.3
	-53.	-13.3	900		21t	
CaTl	-35.	-17.5	~870	1243c	19t, 34t, 21	-18.
$CaTl_3$	≤ -35.2	- 8.8	900	797p	19t	-8.8
Ca_2Si	-50. ± 3.	-16.7	960	1183p	24	-16.7
CaSi	-87.	-43.5	291	1518c	2t	-18.
	-36. ± 2.	-18.	960		24	
$CaSi_2$	-220.	-73.3	291	1293p	2t	-12.
	-36. ± 2.	-12.	960		24	
Ca_2Sn	-75. ± 5.	-25.	955	1395c	24	-25.
CaSn	-38. ± 2.5	-19.	955	1260p	24	-19.
$CaSn_3$	-43.	-10.8	291	900c	7	-10.8
	-52.	-13.	291		2t, 3t, 19t, 8	
	-43. ± 4.	-10.8	955		24	
Ca_2Pb	-47.	-15.7	~870	~1383c	34t, 21	-17.
	-51.3	-17.1	~900		24t	
CaPb	-25.	-12.5	~870	1223p	34t, 21	-12.5
$CaPb_3$	-25.6	-6.4	900	923c	19t	- 6.4
Ca_3Sb_2	-160.	-32.	~870		23t, 34t, 21	-35.
	-174.0	-34.8	~900		24t	
Ca_3Bi_2	-112.	-22.4	~870	1201c	34t, 21	-25.
	-51.6	-10.3	294		25	
	-126.	-25.2	~900		24t	
CaSe	-81.8	-40.9	291		2t, 19t, 24t	-40.9

Table III (continued)

Compound	ΔH, kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
SrSe	-83.4	-41.7	291		2t, 19t	-41.7
Ba_2Sn	-90. ± 9.	-30.	~800		24	-30.
$BaSn_3$	-44. ± 4.	-11.	~800	973c	24	-11.
Ba_2Pb	-70. ± 3.	-23.3	840		24	-23.3
BaPb	-36. ± 2.	-18.	840		24	-18.
$BaPb_3$	-42. ± 2.5	-10.5	840		24	-10.5
Ba_3Sb_2	-175. ± 12.	-35.	~800		24	-35.
Ba_3Bi_2	-160. ± 10.	-40.	~800		24	-40.
BaSe	-81.3	-40.7	291		2t	-40.7
	-81.2	-40.6	~900		24t	
LaMg	- 5.7	- 2.9	298	1016c	3t, 12	- 2.9
$LaMg_3$	-12.9	- 3.2	298	1039p	3t, 12	- 3.2
$LaAl_2$	-36.1	-12.0	298	1697c	3t, 12	-12.0
$LaAl_4$	-42.2	- 8.4	298	1495p	3t, 12	- 4.
	-20.	- 4.	291		2t	
CeMg	-13.0	- 6.5	291	1013c	2t, 3t, 9	- 6.5
$CeMg_3$	-17.0	- 4.3	291	1053c	2t, 3t, 9	- 4.3
$CeZn_4$	-49.	- 9.8	291		2t	- 9.8
$CeHg_4$	-21.	- 4.2			3t	- 4.6
	-23.2	- 4.6	291		2t, 8	
Ce_3Al	-22.	- 5.5	291	887c	2t, 3t, 9	- 5.5
$CeAl_4$	-39.	- 7.8	291	1523p	2t, 3t, 9	- 7.8

Table III (continued)

Compound	ΔH, kcal./mol.	ΔH, kcal./g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal./g. atm.
PrMg	-8.2	-4.1	room	1040c	3t, 13	-4.1
$PrMg_3$	-11.0	-2.8	room	1071c	3t, 13	-2.8
$PrAl_4$	-52.1	-10.4	room	1517p	3t, 13	-10.4
CrNi	-6.3	-3.2	298	~1600E	15	-3.2
MnSe	-26.3	-13.2	291		2t	-13.2
Fe_3Al	-14.8	-3.7		1700s	16	-3.7
FeAl	-12.2	-6.1	293	1540s	29t, 16	-6.
	-12.	-6.	298		28t	
$FeAl_2$	-19.5	-6.5		1423p	16	-6.7
	-20.	-6.7	298		28t	
$FeAl_3$	-26.8	-6.7	293	1413c	29t, 16	-6.8
	-25.	-6.3	291		3t, 5	
	-27.	-6.8	298		28t	
$FeAl_5$	-25.0	-4.1	291	927E	2t	-4.1
Fe_3Si	-20.	-5.	291	1490s	2t, 28t	-5.
FeSi	-19.2	-9.6	293	1683c	22t, 28t, 29t, 16	-9.6
FeSn	< -2.	-1.	293	1073p	16t	-1.
FeSb	-2.4	-1.2		1001p*	29	+1.2
	+2.4	+1.2	298		28t	
$FeSb_2$	-3.6	-1.2		1001p	29	+1.2
	+3.6	+1.2	298		28t	
FeSe	-13.2	-6.6	291		2t	-8.3
	-16.5	-8.3	298		28t	

Table III (continued)

Compound	ΔH_f kcal/mol.	ΔH_f kcal./ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
FeTe	-8.	-4.	291		2t	-9.3
	-18.6	-9.3	298		28t	
CoAl	-32.	-16.	291	1901c	2t, 3t, 4	-13.
	-26.4	-13.2	293		19t, 16	
	-26.	-13.	298		28t	
$CoAl_2$	-31.8	-10.6	293	1050s	16	-10.6
Co_2Al_5	-86.	-12.3	291	1443p	3t, 4	-10.
	-70.	-10.	298		28t, 16	
$CoAl_4$	-38.5	-7.7		1216p	16t	-7.6
	-40.	-8.	293		16	
	-38.	-7.6	298		28t	
$CoAl_5$	-86.	-14.3	291	930E	2t	-14.3
Co_2Si	-27.6	- 9.2		1600c	28t	-9.2
CoSi	-24.0	-12.0	293	1668c	22t, 28t, 16	-12.0
$CoSi_2$	-24.6	-8.2		1550p	28t	-8.2
$CoSi_3$	-25.6	-6.4		1579c	28t	-6.4
Co_2Sn	-8.1	-2.7	291	1434c	3t	-2.8
	-8.4	-2.8	293		22t, 16	
CoSn	-7.2	-3.6	291	1209p	3t	-3.6
	-7.1	-3.6	293		22t, 16	
CoSb	-10.0	-5.0	293	1466c	28t, 29	-5.0
$CoSb_2$	-13.2	-4.4	293	1167p	28t, 29	-4.4
CoSe	-12.	-6.	291		2t	-5.
	-10.	-5.	298		28t	
CoTe	-11.	-5.5	291		2t	-4.5
	-9.	-4.5	291		28t	

Table III (continued)

Comp.	ΔH, kcal./mol.	ΔH, kcal./g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal./g. atm.
NiCr	-6.3	-3.2	~1420	1600E	15	-3.2
Ni_3Al	-37.6	-9.4		1643E	16	-9.5
	-38.	-9.5	298		28t	
NiAl	-34.	-17.	293	~1913c	19t, 28t, 29t, 16	-17.
$NiAl_2$	-37.8	-12.6	293	1405p	16	-12.7
	-38.	-12.7	298		28t	
$NiAl_3$	-38.	- 9.5	298	1115p	28t	- 9.5
Ni_2Si	-33.6	-11.2	room	1563c	22t, 28t, 16	-11.2
NiSi	-20.6	-10.3	room	1273c	22t, 28t, 16	-10.3
Ni_3Sn	-23.2	- 5.8		1443p	3t	- 5.8
Ni_3Sn_2	-37.5	-7.5	293	1533c	3t, 22t, 28t, 16	-7.5
NiSn	-15.0	-7.5	293	1066p	3t, 22t, 29t, 16	-7.4
	-14.8	-7.4	298		28t	
Ni_5Sb_2	-40.	-5.7	293	1348E	29	-5.2
	-36.4	-5.2	298		28t	
NiSb	-16.0	-8.0	293	1433c	29	-7.8
	-15.6	-7.8	298		28t	
$NiSb_2$	-17.0	-5.7	293	888E	29	-5.7
NiSe	-14.	-7.	291		2t	-5.
	-10.	-5.	298		28t	
NiTe	-11.	-5.5	291		2t	-4.5
	- 9.	-4.5	298		28t	
Cu_3Au	-4.0	-1.0		1190s	34	-1.0
Cu_3Au_2	-6.3	-1.25		1170s	34	-1.25
CuAu	-2.5	-1.25		1163s	34	-1.25
	-3.2	-1.6	640		19t, 37	

Table III (continued)

Compound	ΔH, kcal/mol.	ΔH, kcal./g. atm.	Temp. °K	m.p. °K	References	Selected valu ΔH_{298}, kcal/g. atm.
CuZn	-5.0	-2.5		1133s	3t, 36	-2.5
	-5.2	-2.6	291		19t, 36	
	-4.4	-2.2			35	
Cu_2Zn_3	-15.3	-3.1	293	1108p	22t	-3.3
	-15.0	-3.0			3t, 31	
	-16.0	-3.3	298		3t, 4, 28t	
	-14.0	-2.9			36	
Cu_5Zn_8	-33.8	-2.6		1100s	35	-2.9
	-37.7	-2.9			36	
	~ -39.0	-3.0			19t	
$CuZn_3$	- 7.6	-1.9		970p	3t	-2.
	-16.	-4.	291		2t	
	- 8.	-2.			35	
Cu_2Cd_3	-47.7	-9.5	room	836c	30	-0.9
	- 3.0	-0.6	291		2t, 3t, 18t	
	+ 1.3	+0.3	291		5t, 4	
	- 4.7	-0.9	298		28t	
Cu_3Al	-23.	-5.8	291	1320c	2t	-5.8
Cu_9Al_4	~ -68.9	-5.3		1300s	19t	-5.3
Cu_2Al	-16.	-5.3	298	1289p	22t, 28t, 29t, 16	-5.3
CuAl	- 9.5	-4.8	293	~ 900p	22t, 29t, 16	-5.
	-68.	-34.	291		2t	
	-10.	-5.	298		28t	
$CuAl_2$	-10.	-3.3	298	858p	28t	-3.3
	-84.	-28.	291		2t	
	-31.9	-10.6	room		30	
	- 9.5	-3.2			16	

Table III (continued)

Comp.	ΔH, kcal./mol.	ΔH, kcal./g. atm.	Temp. °K.	m.p. °K	References	Selected value ΔH_{298}, kcal/g. atm.
Cu_3Sn	-7.2	-1.8	293	973s	22t, 16	-2.0
	-8.0	-2.0	291		2t, 3t, 28t, 4	
Cu_3Sb	-2. to -3.	-0.6	291	940s	3t, 5	-0.5
	-2.5	-0.6	291		2t	
	-2.	-0.5	298		28t	
Cu_2Se	-14.5	-4.8	291	1386c	2t	-4.8
	-28.5	-9.5	291		19t	
CuSe	-19.	-9.5	291		2t	-3.3
	- 6.6	-3.3	298		28t	
Cu_2Te	- 6.0	-2.0	291	1153c	2t	-2.0
AgZn	-3.2	-1.6	room	960s	3t, 19t	-1.6
Ag_2Zn_3	-9.5	-1.9	room	948p	3t, 28t, 31	-1.9
Ag_5Zn_8	~-24.7	-1.9	room	945s	19t	-1.9
$AgZn_3$	-4.8	-1.2	room	888s	3t	-1.2
AgCd	-2.6	-1.3	710	958s	3t, 19t, 35	-1.3
Ag_2Cd_3	-7.1	-1.4	291	913p*	3t	-1.4
Ag_5Cd_8	~-18.	-1.4	710	913p*	19t, 35	-1.4
$AgCd_3$	-4.9	-1.2		735s	3t, 35	-1.2
Ag_3Hg_4	-0.7	-0.1	291	400p	2t	+0.1
	+0.7	+0.1	298		28t	
AgPb	-1.6	-0.8	770	577E	31	-0.8
Ag_2Se	-1.0	-0.3	291	1170c	2t	-1.0
	-2.9	-1.0	298		28t	

Table III (continued)

Compound	ΔH, kcal./mol.	ΔH, kcal./ g. atm.	Temp. °K.	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
AuCu	-3.2	-1.6	640	1163s	19t, 37	-1.25
	-2.5	-1.25	298		34	
Au_2Cu_3	-6.3	-1.25	298	1170s	34	-1.25
$AuCu_3$	-4.0	-1.0	298	1190s	34	-1.0
Au_3Zn	-24.	-6.	291	953s	3t, 10	-6.
AuZn	-11.	-5.5	291	998c	3t, 19t, 10	-5.5
Au_5Zn_8	-71.5	-5.5	291	899E	19t	-5.5
$AuZn_3$	-22.5	-5.6	291	873s	3t, 10	-5.6
AuCd	-7.8	-3.9	710	900c	3t, 19t, 35	-3.9
Au_2Cd_3	-19.0	-3.8		813p	3t	-3.8
$AuCd_3$	-13.0	-3.3		773c	3t, 35	-3.3
AuHg	+1.4	+0.7	298	675p*	3t	+0.7
AuSn	-8.2	-4.1	291	691c	3t, 10	-4.1
$AuSn_2$	-5.5	-1.8	291	582p	3t, 10	-1.8
$AuSb_2$	-3.5	-1.2	291	773p	3t, 10	-1.6
	-4.8	-1.6	298		28t	
Zn_2Mg	-12.6	-4.2	291	863c	3t, 5t, 6	-4.4
	-24.9	-8.3	room		30	
	-13.1	-4.4	291		2t	
$Zn_{10}Ca$	-48.0	-4.4	291	990c	2t, 3t, 11	-4.4
	-199.1	-18.1	room		30	
Zn_4Ca	-29.5	-5.9	291	953p	2t, 3t, 11	-5.9
	-55.6	-11.1	room		30	
Zn_3Ca_2	-40.	-8.	291	961c	2t, 3t, 11	-8.
$ZnCa_4$	-32.	-6.4	291	663	2t, 11	-6.4

Table III (continued)

Comp.	ΔH, kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K.	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
Zn_4Ce	-49.	-9.8	291		2t	-9.8
Zn_3Cu	-7.6	-1.9		970p*	3t	-2.
	-8.	-2.			35	
Zn_8Cu_5 N	-39.0	-3.0	291	1100s	19t	-2.9
	-33.8	-2.6			35	
	-37.7	-2.9			36	
Zn_3Cu_2	-16.0	-3.3	298	1108p	2t, 3t, 28t, 4	-3.3
	-15.3	-3.1	293		22t	
	-15.0	-3.0			3t, 31	
	-14.5	-2.9			36	
ZnCu	-5.0	-2.5		1133s	3t, 36	-2.5
	-5.2	-2.6	291		19t	
	-4.4	-2.2			35	
Zn_3Ag	-4.8	-1.2		888s	3t	-1.2
Zn_8Ag_5 N	-24.7	-1.9		945s	19t	-1.9
Zn_3Ag_2	-9.5	-1.9		948p	3t, 28t, 31	-1.9
ZnAg	-3.2	-1.6		960s	3t, 19t	-1.6
Zn_3Au	-22.5	-5.6	291	870s	3t, 10	-5.6
Zn_8Au_5 N	-71.5	-5.5	291	899E	19t	-5.5
ZnAu	-11.	-5.5	291	998c	3t, 19t, 10	-5.5
$ZnAu_3$	-24.	-6.	291	953s	3t, 10	-6.
Zn_3Sn	-2.73	-0.7	room	472E	26	-0.7
ZnSn	-1.60±0.14	-0.8	room	819p	26	-0.8
	-1.57±0.1	-0.8	room		26	
Zn_3Sb_2	-0.05	-0.01	298	839c	14	-0.01

Table III (continued)

Comp.	ΔH, kcal./mol.	ΔH, kcal./g. atm.	Temp. °K.	m.p. °K.	References	Selected value ΔH_{298}, kcal./g. atm.
Zn_4Sb_3	-13.1	-1.9	298	836p	14	-1.9
ZnSb	-3.6	-1.8	298	819p	22t, 28t	-1.8
	-3.07	-1.5			14	
ZnSe	-29.6	-14.8	291	>1373c	19t	-17.
	-34.	-17.	298		2t	
ZnTe	-29.4±1.4	-14.7		1512c	19	-15.0
	-28.21	-14.	298		3t, 27	
	-33.	-16.5	291		2t	
	-30.	-15.0	298		28t	
Cd_6Na	-12.6	-1.8	293	638c	20t, 32	-1.8
Cd_5Na	-12.4	-2.1	291	624E	2t, 3t, 5	-2.1
	-60.6	-10.1	room		30	
Cd_2Na	- 8.1	-2.7	293	658c	20t, 32	-2.7
	- 8.5	-2.8	291		2t, 3t, 5	
	-30.8	-10.3	room		30	
CdMg	-17.7	- 8.9	room	~700s	30	-4.6
	- 9.2	-4.6	291		2t, 3t, 5t, 6	
Cd_3Ca	-30.	-7.5	291	885p	2t, 3t, 11	-7.5
Cd_3Cu_2	-47.7	-9.5	room	836c	30	-0.9
	-3.0	-0.6	291		2t, 3t, 18t	
	+1.3	+0.3	291		4t, 5	
	-4.7	-0.9	298		28t	
Cd_3Ag	-4.9	-1.2		735s	3t, 35	-1.2
Cd_8Ag_5 ~	-18.	-1.4	710	913p*	19t, 35	-1.4
Cd_3Ag_2	-7.1	-1.4	291	913p*	3t	-1.4

Table III (continued)

Comp.	ΔH kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K.	m.p. °K.	References	Selected value ΔH_{298}, kcal/ g. atm.
CdAg	-2.6	-1.3	710	958s	3t, 19t, 35	-1.3
Cd_3Au	-13.0	-3.3		773c	3t, 35	-3.3
Cd_3Au_2	-19.0	-3.8		813p	3t	-3.8
CdAu	-7.8	-3.9	710	900c	3t, 19t, 35	-3.9
Cd_3Hg	-0.74	-0.2	291	461p	2t	-0.2
CdHg	-1.96	-1.0	291	398s	2t	-1.0
$CdHg_3$	-3.99	-1.0	291	298s	2t	-1.0
$CdHg_4$	-3.92	-0.8	291	280s	2t	-0.8
$CdHg_{19}$	-0.5	-0.03	291	239E	2t	-0.03
CdSn	-0.87±0.06	-0.4	room	450E	26	-0.45
	-0.93±0.09	-0.5	room		26	
CdPb	-1.	-0.5	770	521E	31	-0.5
	-1.25±0.1	-0.6	room		26	
	-0.92±0.04	-0.5	room		26	
Cd_3Sb_2	-4.0	-0.8	291	563E	2t, 3t, 5	-0.8
CdSb	-2.7	-1.4	291	729c	2t	-1.65
	-3.	-1.5	291		3t, 5	
	-3.7	-1.9			3t	
	-3.5	-1.8	298		3t, 18t, 33	
	-3.29	-1.65	298		28t	
CdSe	-25.	-12.5	291	>1623	2t	-12.5
	-24.2	-12.1	291		19t	
CdTe	-24.53	-12.3	298	1318c	3t, 19t, 27	-12.2
	-16.	- 8.	291		2t	
	-24.3	-12.2	298		28t	

Table III (continued)

Comp.	ΔH kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
Hg_3Li	-26.8	-6.7	291	513p	2t	-6.7
Hg_2Li	-25.0	-8.3	291	611p	2t	-8.3
HgLi	-20.8	-10.4	291	873c	2t	-10.4
Hg_4Na	-20.2	-4.0	291	431p	3t	-4.4
	-22.4±0.4	-4.5	291		3t, 8	
	-19.5	-3.9	room		20	
	-22.2	-4.4	291		2t	
Hg_2Na	-18.0	-6.0	room	628c	22t, 20	-6.2
	-18.7±0.3	-6.2	291		3t, 8	
	-17.6	-5.9	291		3t	
	-18.5	-6.2	291		2t	
Hg_8Na_7	-84.4±1.0	-5.6	291	500p	3t, 8	-5.6
	-79.9	-5.3	291		3t	
HgNa	-11.3±0.1	-5.7	291	492p	3t, 8	-5.5
	-10.7	-5.4	291		3t	
	-11.0	-5.5	291		2t	
Hg_2Na_3	-20.7±0.3	-4.1	291	396p	3t, 8	-4.5
	-19.6	-3.9	291		3t	
	-22.5	-4.5	room		22t, 20	
	-22.2	-4.4	291		2t	
$HgNa_3$	-8.7	-2.2	291	307p	3t	-2.8
	-11.7	-2.9	273		3t	
	-11.6	-2.9	room		20	
	-12.9	-3.2	291		5t	
	-9.3±0.3	-1.8	291		8	
	-11.1	-2.8	291		2t	

Table III (continued)

Compound	ΔH kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K	m.p. °K.	References	Selected value ΔH_{298}, kcal/ g. atm.
$Hg_{10}K$	-33.0	- 3.	291	230E	2t	-3.
Hg_3K	-26.0	-6.5	291	477p	2t	-6.5
HgK	-11.0	- 5.5	291	451c	2t	-5.5
Hg_4Mg	-17.3	- 3.5	291	233E	2t	-3.5
Hg_4Ce	-21.	- 4.2			3t	-4.6
	-23.2	- 4.6	291		2t, 8	
Hg_4Ag_3	-0.7	- 0.1	291	400p	2t	+0.1
	+0.7	+0.1	298		28t	
HgAu	+1.4	+0.7		675p*	3t	+0.7
$Hg_{19}Cd$	-0.5	-0.03	291	239E	2t	-0.03
Hg_4Cd	-3.92	-0.8	291	280s	2t	-0.8
Hg_3Cd	-3.99	-1.0	291	298s	2t	-1.0
HgCd	-1.96	-1.0	291	398s	2t	-1.0
$HgCd_3$	-0.74	-0.2	291	461p	2t	-0.2
Hg_5Tl_2	+0.4	+0.06	234	288s	3t	-0.34
	-2.50	-0.34	273		2t, 28t, 8	
$HgPb_2$	+0.05	+0.02	291	~273s	2t	+0.02
HgSe	-8.0	-4.0	291		2t	-2.6
	-5.1	-2.6	298		28t	
Al_3Mg_4	-49.0	-7.0	291	728c	2t, 3t, 5t, 6	-7.0
	-164.8	-23.5	room		30	
Al_3Ca	-51.	-12.8	291	973p	2t, 3t, 11	-13.3
	-53.	-13.3	900		21t	
Al_4La	-42.2	-8.4	room	1495p	3t, 12	-4.
	-20.	-4.	291		2t	

Table III (continued)

Compound	ΔH kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
Al_2La	-36.1	-12.0	room	1697c	3t, 12	-12.0
Al_4Ce	-39.	- 7.8	291	1523p	2t, 3t, 9	- 7.8
$AlCe_3$	-22.	- 5.5	291	887c	2t, 3t, 9	- 5.5
Al_4Pr	-52.1	-10.4	room	1517p	3t, 13	-10.4
Al_5Fe	-25.0	- 4.1	291	927E	2t	- 4.1
Al_3Fe	-26.8	- 6.7	293	1413c	29t, 16	- 6.8
	-25.	- 6.3	291		3t, 5	
	-27.	- 6.8	298		28t	
Al_2Fe	-19.5	- 6.5		1423p	16	- 6.7
	-20.	- 6.7	298		28t	
AlFe	-12.2	- 6.1	293	1540s	29t, 16	- 6.0
	-12.	- 6.0	298		28t	
$AlFe_3$	-14.8	- 3.7		1700s	16	-3.7
Al_5Co	-86.	-14.3	291	930E	2t	-14.3
Al_4Co	-38.5	- 7.7		1216p	16	- 7.6
	-40.	- 8.	293		16	
	-38.	- 7.6	298		28t	
Al_5Co_2	-70.	-10.	298	1443p	28t, 16	-10.
	-86.	-12.3	293		3t, 4	
Al_2Co	-31.8	-10.6	293	1050s	16	-10.6
AlCo	-26.4	-13.2	293	1901c	19t, 16	-13.
	-32.	-16.	291		2t, 3t, 4	
	-26.	-13.	298		28t	
Al_3Ni	-38.	- 9.5		1115p	28t	- 9.5
Al_2Ni	-37.8	-12.6	293	1405p	16	-12.7
	-38.	-12.7	298		28t	

Table III (continued)

Compound	ΔH kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K.	m.p. °K.	References	Selected value ΔH_{298}, kcal/ g. atm.
AlNi	-34.0	-17.0	293	~1913c	19t, 28t, 29t, 16	-17.0
$AlNi_3$	-37.6	- 9.4		1115p	16	- 9.5
	-38.	- 9.5	298		28t	
Al_2Cu	- 9.5	- 3.2		858p	16	- 3.3
	-31.9	-10.6	room		30	
	-84.	-28.	291		2t	
	-10.	- 3.3	298		28t	
AlCu	- 9.5	- 4.8	293	~900p	22t, 29t, 16	- 5.
	-68.	-34.	291		2t	
	-10.	- 5.	298		28t	
$AlCu_2$	-16.	- 5.3	293	1289p	22t, 28t, 29t, 16	-5.3
Al_4Cu_9	~ -68.9	- 5.3		1300s	19t	-5.3
$AlCu_3$	-23.	- 5.6	291	1320c	2t	-5.6
TlLi	-12.8±0.6	-6.4		781c	19t	-6.4
TlNa	- 9. ±0.6	-4.5		529c	19	-4.5
TlMg	-10 to -13	-5.8		631c	19t	-5.8
Tl_3Ca	≤ -35.2	-8.8	900	797p	19t	-8.8
TlCa	-35.	-17.5	~870	1243c	19t, 34t, 21	-17.5
Tl_2Hg_5	+ 0.4	+ 0.06	234	288c	3t, 8	- 0.34
	- 2.50	- 0.34	298		2t, 28t, 8	
Tl_7Bi	- 5.4	- 0.7		575c	3t	-0.7
TlBi	-1.3	- 0.7	710	461E	19t, 35	-0.7
Tl_2Bi_3	-3.5	- 0.6	~420	486c	18	-0.6
$TlBi_2$	-1.4	- 0.5	~420	471E	3t, 18	-0.5

Table III (continued)

Compound	ΔH, kcal./mol.	ΔH, kcal./ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
Tl_2Se	-18.	-6.	291	641c	2t, 28t	-6.
Tl_2Te	- 7.	-2.3	291	685E	2t, 28t	-2.3
$SiMg_2$	-18.5±1.5	-6.2	~685	1375c	24	-6.5
	-19.5	-6.5	~900		24t	
Si_2Ca	-220.	-73.3	291	1293p	2t	-12.
	-36. ±2.	-12.	~685		24	
SiCa	-87.	-43.5	291	1518c	2t	-18.
	-36. ± 2.	-18.	~685		24	
$SiCa_2$	-50. ± 3.	-16.7	~685	1183p	24	-16.7
SiFe	-19.2	-9.6	293	1683c	22t, 28t, 29t, 16	-9.6
$SiFe_3$	-20.	-5.	291	1490s	2t, 28t	-5.
Si_3Co	-25.6	-6.4		1579c	28t	-6.4
Si_2Co	-24.6	-8.2		1550p	28t	-8.2
SiCo	-24.0	-12.0	293	1668c	22t, 28t, 16	-12.0
$SiCo_2$	-27.6	- 9.2		1600c	28t	-9.2
SiNi	-20.6	-10.3	room	1273c	22t, 28t, 16	-10.3
$SiNi_2$	-33.6	-11.2	room	1563c	22t, 28t, 16	-11.2
SnLi	-16.8	- 8.4	room	758c	20	-9.
(1)	-17.57±0.83	- 8.8	850		1	
	-18.6 ±1.5	- 9.3	298		1	
Sn_2Li_7	-86.4	- 9.6	room	1056c	20	-9.6
$SnLi_4$	-47.0	- 9.4	room	1038c	23t	-9.4
Sn_2Na	-20.	- 6.7	291	578p	2t, 3t, 8 (see discussion)	-4.
	-15.	- 5.0	291		7	

Table III (continued)

Compound	ΔH kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
SnNa	-16.	-8.	291	849c	2t, 3t, 8	-5.7
	-11.	-5.5	291		7	
	-12.0	-6.0	room		20	
	-10.6±0.6	-5.3	298		1	
(1)	-9.63±0.40	-4.8	873		1	
Sn_3Na_4	-56.	-8.	291	751p	2t, 3t, 8 (see discussion)	-5.
	-36.	-5.1	291		7	
$SnNa_2$	-21.	-7.	291	750c	2t, 3t, 8	-4.8
	-14.4	-4.8	room		20	
	-12.	-4.	291		7	
$SnNa_4$	-21.	-4.3	291	678p	7	-2.9
	-34.	-6.8	291		2t, 3t, 8	
	-14.4	-2.9	room		23t, 20	
$SnMg_2$	-17.2	-5.7	≈870	1051c	19t, 23t, 34t, 21	-6.
	-49.	-16.3	291		7	
	-59.	-19.7	291		2t, 3t, 8	
	-18.3	-6.1			24t	
Sn_3Ca	-52.	-13.	291	900c	2t, 3t, 19t, 8	-10.8
	-43.	-10.8	291		7	
	-43.±4.	-10.8	≈950		24	
SnCa	-38.±2.5	-19.	≈950	1260p	24	-19.
$SnCa_2$	-75.±5.	-25.	≈950	1395c	24	-25.
Sn_3Ba	-44.±4.	-11.	≈950	973c	24	-11.
$SnBa_2$	-90.±9.	-30.	≈950		24	-30.
SnFe	< -2.	- 1.	293	1073p	16	- 1.
SnCo	-7.1	-3.6	293	1209p	22t, 16	-3.6
	-7.2	-3.6	293		3t	

Table III (continued)

Compound	ΔH, kcal./mol.	ΔH, kcal./ g. atm.	Temp. °K.	m.p. °K.	References	Selected value ΔH_{298}, kcal/ g. atm.
$SnCo_2$	-8.1	-2.7	293	1434c	3t	-2.8
	-8.4	-2.8	293		22t, 16	
SnNi	-15.	-7.5	293	1066p	3t, 22t, 29t, 16	-10.3
	-20.6	-10.3	298		28t	
Sn_2Ni_3	-37.5	-7.5	293	1533c	3t, 22t, 28t, 16	-7.5
$SnNi_3$	-23.2	-5.8	293	1443p	3t	-5.8
$SnCu_3$	-7.2	-1.8	293	973s	22t, 16	-2.0
	-8.0	-2.0	298		2t, 3t, 28t, 4	
Sn_2Au	-5.5	-1.8	291	582c	3t, 10	-1.8
SnAu	-8.2	-4.1	291	691c	3t, 10	-4.1
SnZn	-1.57±0.1	-0.8	room	819p	26	-0.8
	-1.60±0.14	-0.8	room		26	
$SnZn_3$	-2.73	-0.7	room	472E	26	-0.7
SnCd	-0.87±0.06	-0.4	room	450E	26	-0.4
	-0.93±0.02	-0.4	room		26	
SnPb	-0.58±0.02	-0.3	room	456E	26	-0.25
	-0.24±0.15	-0.1	room		26	
	-0.5	-0.25	770		31	
Sn_5Bi	+0.39±0.25	+0.07	room	412E	26	+0.13
	+0.78	+0.13	291		2t	
Sn_2Bi	+0.45±0.12	+0.15	room	412E	26	+0.04
	+0.12	+0.04	291		2t	
SnBi	+0.41±0.12	+0.2	room	412E	26	-0.2
	+1.	+0.5	750		31	
	-0.37	-0.2	291		2t	
$SnBi_2$	+0.39±0.15	+0.13	room	412E	26	+0.06
	+0.17	+0.06	291		2t	

Table III (continued)

Compound	ΔH kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K.	m.p. °K.	References	Selected value ΔH_{298}, kcal/ g. atm.
$SnBi_5$	+0.33±0.36	+0.06	room	412E	26	+0.03
	+0.19	+0.03	291		2t	
SnTe	-14.65	-7.3	298	~1063c	3t, 19t, 27	-7.3
PbLi	-14.6	-7.3	293	755c	20t, 32	-7.3
Pb_2Li_7	-75.6	-8.5	293	999c	20t, 32	-8.5
Pb_3Na	-15.2	-3.8	293	583c	19t	-3.8
PbNa	-11.6	-5.8	293	641c	20t, 32	-5.8
Pb_2Na_5	-35.0	-5.0	293	673c	20t, 32	-5.0
$PbNa_4$	-20.0	-4.0	293	660c	20t, 32	-4.0
	-13.2	-2.6			17	
$PbMg_2$	-21.6	-4.2	293	823c	19t, 20t, 21t, 22t, 28t, 34t, 32	-4.2
Pb_3Ca	-25.6	-6.4	900	923c	19t	-6.4
PbCa	-25.0	-12.5	~870	1223p	34t, 21	-12.5
$PbCa_2$	-47.	-15.7	~870	~1383c	34t, 21	-17.1
	-51.	-17.1			24t	
Pb_3Ba	-42.±2.5	-10.5	~840		24	-10.5
PbBa	-36.±2.	-18.	~840		24	-18.
$PbBa_2$	-70.±3.	-23.3	~840		24	-23.3
PbAg	-1.6	-0.8	~770	577E	31	-0.8
PbCd	-0.92±0.04	-0.5	room	521E	26	-0.5
	-1.25±0.1	-0.6	room		26	
	-1.	-0.5	770		31	
Pb_2Hg	+0.05	+0.03	291	~273s	2t	+0.03
PbSn	-0.24±0.15	-0.1	room	456E	26	-0.25
	-0.58±0.02	-0.3	room		26	
	-0.5	-0.25	~770		31	

Table III (continued)

Compound	ΔH, kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K.	m.p. °K.	References	Selected val ΔH_{298}, kcal/ g. atm.
PbBi	+2.	+1.	~750	398E	31	+1.
PbSe	-20.	-10.	291	1361c	2t	-9.
	-18.	-9.	298		28t	
PbTe	-6.0	-3.0	291	1183c	2t	-8.8
	-16.81	-8.4	298		19t, 3t, 27	
	-17.5	-8.8	298		28t	
Sb_3Li	-43.6	-10.9			23t	-10.9
Sb_2Li_3	-43.5	-8.7	room	>1220	20	-8.7
$SbNa_3$	-47.2	-11.8	room	1129c	23t, 20	-11.8
Sb_2Mg_3	-68.	-13.6	~870	1234c	23t, 34t, 21	-15.
	-76.5	-15.3	~850		24t	
Sb_2Ca_3	-160.	-32.	~870		23t, 34t, 21	-35.
	-174.	-34.8			24t	
Sb_2Ba_3	-175.±12.	-35.	~950		24	-35.
Sb_2Fe	-3.6	-1.2		1001p	29	+ 1.2
	+3.6	+1.2	298		28t	
SbFe	-2.4	-1.2		1001p*	29	+1.2
	+2.4	+1.2	298		28t	
Sb_2Co	-13.2	-4.4	293	1167p	28t, 29	-4.4
SbCo	-10.0	-5.0	293	1466c	28t, 29	-5.0
Sb_2Ni	-17.	-5.7	293	888E	29	-5.7
SbNi	-16.0	-8.0	293	1433c	29	-7.8
	-15.6	-7.8	298		28t	
Sb_2Ni_5	-40.	-5.7	293	1348E	29	-5.2
	-36.4	-5.2			28t	

Table III (continued)

Compound	ΔH kcal/mol.	ΔH, kcal./ g. atm.	Temp. °K.	m.p. °K.	References	Selected value ΔH_{298}, kcal/ g. atm.
$SbCu_3$	-2. to -3.	-0.6	291	940s	3t, 5	-0.5
	-2.5	-0.6	291		2t	
	-2.	-0.5	298		28t	
Sb_2Au	-3.5	-1.2	291	773p	3t, 10	-1.6
	-4.8	-1.6	298		28t	
SbZn	-3.6	-1.8	298	819p	22t, 28t	-1.8
	-3.07	-1.5	298		14	
Sb_3Zn_4	-13.1	-1.9	298	836p	14	-1.9
Sb_2Zn_3	- 0.05	-0.01	298	839c	14	-0.01
SbCd	-3.	-1.5	291	729c	3t, 5	-1.65
	-0.9	-0.5	~920		18	
	-3.72	-1.9	293		3t	
	-3.5	-1.8	298		3t, 18t, 33	
	-2.7	-1.4	291		2t	
	-3.29	-1.65	298		28t	
Sb_2Cd_3	-4.0	-0.8	291	563E	2t, 3t, 5	-0.8
$BiLi_3$	-55.2	-13.8	293	1418c	20t, 32	-13.8
$BiNa_3$	-45.6	-11.4	293	1048c	20t, 32	-11.4
Bi_2Mg_3	-36.0	- 7.2	293	988c	20t, 21t, 22t, 32	-7.4
	-37.5	- 7.5	room		21t	
	-37.	-7.4	~870		34t	
	-40.5	-8.1			24t	
Bi_2Ca_3	-112.	-22.4	~870	1201c	34t, 21	-25.
	-51.6	-10.3	294		25	
	-126.	-25.2			24t	
Bi_2Ba_3	-160.±10.	-40.	~850		24	-40.

(Table III continued)

Compound	ΔH kcal/mol.	ΔH kcal/ g. atm.	Temp. °K	m.p. °K	References	Selected value ΔH_{298}, kcal/ g. atm.
Bi_2Tl	-1.4	-0.5	293	471E	3t, 18t	-0.5
Bi_3Tl_2	-3.5	-0.6	~420	486c	18	-0.6
BiTl	-1.3	-0.7	291	461E	2t, 19t, 35	-0.7
$BiTl_7$	-5.4	-0.7		575c	3t	-0.7
Bi_5Sn	+0.33 ± 0.36	+0.06	room	412E	26	+0.03
	+0.19	+0.03	291		2t	
Bi_2Sn	+0.39 ± 0.15	+0.13	room	412E	26	+0.06
	+0.17	+0.06	291		2t	
BiSn	+0.41 ± 0.12	+0.21	room	412E	26	+0.5
	+1.	+0.5	~750		31	
	-0.37	-0.19	291		2t	
$BiSn_2$	+0.45 ± 0.12	+0.15	room	412E	26	+0.04
	+0.12	+0.04	291		2t	
$BiSn_5$	+0.39 ± 0.25	+0.07	room	412E	26	+0.13
	+0.78	+0.13	291		2t	
BiPb	+2.	+1.	~750	398E	31	+1.
$SeLi_2$	-84.9	-28.3	291		2t	-28.3
$SeNa_2$	-59.1	-19.7	291	>1148	2t, 19t	-19.7
SeK_2	-74.4	-24.8	291		2t	-24.8
SeCa	-81.8	-40.9	291		2t, 19t, 24t	-40.9
SeSr	-83.4	-41.7	291		2t, 19t	-41.7
SeBa	-81.3	-40.7	291		2t	-40.6
	-81.2	-40.6	298		24t	
SeMn	-26.3	-13.2	291		2t	-13.2
SeFe	-13.2	-6.6	291		2t	- 8.3
	-16.5	-8.3	298		28t	

Table III (continued)

Compound	ΔH kcal/mol.	ΔH kcal./ g. atm.	Temp. °K.	m.p. °K.	References	Selected value ΔH_{298}, kcal./ g. atm.
SeCo	-12.	-6.	291		2t	-5.
	-10.	-5.	298		28t	
SeNi	-14.	-7.	291		2t	-5.
	-10.	-5.	298		28t	
SeCu	-19.	-9.5	291		2t	-3.3
	- 6.6	-3.3	298		28t	
$SeCu_2$	-14.5	-4.8	291	1383c	2t	-4.8
	-28.5	-9.5	291		19t	
$SeAg_2$	-1.0	-0.3	291	1170c	2t	-1.5
	-2.9	-1.5	298		28t	
SeZn	-29.6	-14.8	291	>1373c	19t	-17.
	-34.	-17.	298		28t	
SeCd	-24.2	-12.1	291	>1623	19t	-12.5
	-25.0	-12.5	298		2t	
SeHg	-8.0	-4.0	291		2t	-2.6
	-5.1	-2.6	298		28t	
$SeTl_2$	-18.	-6.	291	641c	2t, 28t	-6.
SePb	-20.	-10.	291	1361c	2t	-9.
	-18.	-9.	298		28t	
Te_3Na	-30. ± 3.2	-7.5		709c	19	-7.5
Te_2Na	-101.8	-33.9		692E	17	-33.9
TeNa	-30. ± 3.	-15.		626p	19	-15.
$TeNa_2$	-84.3	-28.1		1226c	23t, 17	-20.
	-60.	-20.			19	
TeMg	-50. ± 5.	-25.	~890		19t, 24t, 23	-25.

Table III (continued)

Compound	ΔH kcal/mol.	ΔH kcal./ g. atm.	Temp. °K.	m.p. °K.	References	Selected value ΔH_{298}, kcal./ g. atm.
TeFe	-8.	-4.	291		2t	-9.3
	-18.6	-9.3	298		28t	
TeCo	-11.	-5.5	291		2t	-4.5
	- 9.	-4.5	298		28t	
TeNi	-11.	-5.5	291		2t	-4.5
	-9.	-4.5	298		28t	
$TeCu_2$	-6.0	-2.0	291	1153c	2t	-2.0
TeZn	-33.	-16.5	291	1512c	2t	-15.
	-30.	-15.	298		28t	
	-28.21	-14.1	298		3t, 27	
TeZn	-29.4	-14.7			19t	
TeCd	-16.	-8.	291	1318c	2t	-12.2
	-24.53	-12.3	298		3t, 19t, 27	
	-24.3	-12.2	298		28t	
$TeTl_2$	-7.	-2.3	291	685E	2t, 28t	-2.3
TeSn	-14.65	-7.3	298	1063c	3t, 19t, 27	-7.3
TePb	-16.81	-8.4	298	1183c	3t, 19t, 27	-8.8
	-6.0	-3.0	291		2t	
	-17.5	-8.8	291		28t	

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