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**GEOCHEMICAL MODELING RESEARCH RELATED TO THE SURFACE
DISPOSAL OF PROCESSED OIL SHALE SOLID WASTE**

By
K. J. Reddy
J. I. Drever

October 1987

Work Performed Under Contract No. FC21-86MC11076

For
U. S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Laramie Project Office
Laramie, Wyoming

By
Western Research Institute
Laramie, Wyoming

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**GEOCHEMICAL MODELING RESEARCH RELATED TO THE SURFACE DISPOSAL
OF PROCESSED OIL SHALE SOLID WASTE**

By
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Laramie, Wyoming 82071

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ABSTRACT

Several geochemical codes are available in the literature to model chemical processes such as oxidation-reduction, precipitation-dissolution, formation of solution complex, adsorption, and ion exchange. However, these models differ in the environments to which they apply. The objective of this research was to evaluate the applicability of existing geochemical codes to predict water quality from an oil shale solid waste environment. We selected EQ3/EQ6, GEOCHEM, MINTEQ, PHREEQE, SOLMNEQ, and WATEQFC geochemical models for further evaluation. We concluded that all these models lack thermodynamic data for minerals and solution complexes which are important for oil shale solid waste studies. Selection of any one of the models would require development of a more reliable thermodynamic database, and this report describes the initiation of that work. So far, critical evaluation of thermodynamic data has been completed for Sr, F, Mo, and Se.

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PART I - GEOCHEMICAL MODELING

INTRODUCTION

A major environmental issue associated with the disposal of processed oil shale solid waste is the ability to understand and predict the quality of water from oil shale solid waste disposal environments. The behavior in water of potentially hazardous organic and inorganic chemicals in oil shale solid waste is controlled by a number of chemical processes such as oxidation-reduction, precipitation-dissolution, formation of organic and inorganic complexes, adsorption, and ion exchange. It is necessary to understand these processes in detail to adequately predict water quality.

Several geochemical codes are available in the literature to model these chemical processes. However, these models differ in the environments to which they apply and in their numerical analysis techniques. Thus, it was necessary to evaluate the applicability of existing geochemical models to predict water quality from oil shale waste disposal environments.

MATERIALS AND METHODS

In order to evaluate the applicability of existing geochemical codes for oil shale solid waste, the following criteria were established for preliminary screening of codes.

- 1) Is the code in the public domain?
- 2) Is the code well documented?
- 3) Is the code in use and being kept updated?
- 4) Is the code able to model processes of interest, or could it be readily modified to include such processes?

Having met these criteria, the following six geochemical codes were obtained and examined in detail:

- 1) EQ3/EQ6 (Worley, 1979)
- 2) GEOCHEM (Sposito and Mattigod, 1980)
- 3) MINTEQ (Felmy et al., 1984)
- 4) PHREEQE (Parkhurst et al., 1980)
- 5) SOLMNEQ (Kharaka and Barenz, 1973)
- 6) WATEQFC (Runnells and Lindberg, 1981)

RESULTS AND DISCUSSION

Table 1 summarizes the capability of each code to model important processes. The WATEQFC, GEOCHEM, SOLMNEQ, and MINTEQ are speciation/saturation codes. The EQ3/EQ6 and PHREEQE codes model mass transfer as well as speciation/saturation.

The models were difficult to compare with one another. We noted large differences between the equilibrium constants used in the models to make identical calculations (see Table 2). All models worked well for a pH range of 6 to 9. However, the pH of oil shale solid waste water ranges from 2 to 13. All the models lacked thermodynamic data for high temperature minerals (e.g., silicates) and solution complexes (both organic and inorganic) which are important for oil shale solid waste environment studies. It was decided that selection of any one of the models would require the development of a more reliable thermodynamic database.

The establishment of a reliable thermodynamic database requires critical evaluation of thermodynamic data, reviewing available literature, and selecting the most reliable thermodynamic data for minerals

Table 1. Capabilities of Selected Geochemical Codes.

CAPABILITY	CODE					
	1	2	3	4	5	6
Number of elements	18	44	32	19	24	34
Number of species	140	2000	373	120	181	500
Number of minerals	250	500	238	24	158	375
Speciation/saturation	Yes	Yes	Yes	Yes	Yes	Yes
Adsorption	No	Yes	Yes	No	No	No
Ion exchange	No	Yes	No	No	No	No
Organic complexation	No	Yes	No	No	No	No
Mass transfer	Yes	No	No	Yes	No	No
Temperature range (°C)	0-300	1	0-300	-	0-350	25
Pressure range (bars)	1-500	1	-	-	1-1000	1
Database						
easily modified	Yes	Yes	Yes	Yes	No	Yes

1. EQ3/EQ6 (Worley, 1979)
2. GEOCHEM (Sposito and Mattigod, 1980)
3. MINTEQ (Felmy et al. 1984)
4. PHREEQE (Parkhurst et al. 1980)
5. SOLMNEQ (Kharaka and Barnes, 1973)
6. WATEQFC (Runnells and Lindberg, 1981)

Table 2. Comparison of Equilibrium Constants of $\text{SrCO}_3(\text{c})$, $\text{BaCO}_3(\text{c})$, and $\text{CaF}_2(\text{c})$ Used by Different Geochemical Models Along with Recently Reported Values.

Reaction	log equilibrium constant					Recently reported value
	WATEQFC	GEOCHEM	MINTEQ	EQ3/EQ6	PHREEQE	
$\text{SrCO}_3(\text{c}) \longrightarrow \text{Sr}^{2+} + \text{CO}_3^{2-}$	-11.41	-9.00	-9.25	-11.70	-9.25	-9.27 ¹
$\text{BaCO}_3(\text{c}) \longrightarrow \text{Ba}^{2+} + \text{CO}_3^{2-}$	-13.22	-----	-8.58	-13.90	-----	-8.56 ²
$\text{CaF}_2(\text{c}) \longrightarrow \text{Ca}^{2+} + 2\text{F}^-$	-10.96	-9.00	-10.96	-10.96	-10.96	-10.41 ³

¹Reported by Busenberg et al. (1981) in *Geochimica Cosmochimica Acta*.

²Reported by Busenberg et al. (1985) in *Geochimica Cosmochimica Acta*.

³Reported by Elrashidi and Lindsay (1986) in *Soil Science Journal*.

and solution complexes that are important for oil shale solid waste studies. So far, critical evaluations of thermodynamic data have been completed for Sr, Mo, F, and Se solid phases and solution complexes. These evaluations are given in Part II.

CONCLUSIONS

On the basis of progress made thus far in this research, the following conclusions may be drawn:

- 1) In evaluating available geochemical codes, we noted large differences between models in the equilibrium constants used to make identical calculations.
- 2) All of the models lacked thermodynamic data for high temperature minerals (e.g., silicates) and solution complexes (both organic and inorganic) which are important for oil shale solid waste environment studies.
- 3) There is need to develop a reliable thermodynamic database for oil shale solid waste geochemical models.

PART II - CRITICAL EVALUATION OF THERMODYNAMIC DATA
ON Sr, Mo, F, AND Se AT 25°C, 0.1 MPa, ZERO IONIC STRENGTH
FOR OIL SHALE SOLID WASTE GEOCHEMICAL MODEL

INTRODUCTION

The most important references to thermodynamic data on various elements include Garrels and Christ (1965), Technical Notes of the U.S. National Bureau of Standards (NBS), Wagman et al. (1968, 1969, 1982), Smith and Martell (1976), Parker et al. (1971), Stull et al. (1971), Naumov et al. (1971), and Karapet'yants and Karapet'yants (1970).

Often, large differences are found in the free energy of formation (ΔG°_f) values reported by the various compilers. Users of these data are faced with the frustration of trying to select the best value for their use. In this report, we have attempted to review the available literature on thermodynamic, electrochemical, and solubility data of various compounds to obtain the most reliable values.

Selection criteria:

The free energies of formation (ΔG°_f) values showing wide scatter have been eliminated. In cases where the agreement of ΔG°_f values is poor, the original sources of the compilers were traced and compared with other available data to obtain the most reliable values. When solubility data was available, the ΔG°_f value for a species was calculated using selected ΔG°_f values of the products and reactants involved in the equilibrium expression.

Methods of calculating standard free energies of formation (ΔG°_f):

The standard free energies of formation of elements (in solid phases, solution complexes, and ion pairs) compiled in this report

were calculated from calorimetric, electrochemical, or solubility data. In cases where ΔG°_f was derived from calorimetric data, the standard heat of reaction and entropy of reaction, ΔH°_r and Δs°_r , were evaluated. The standard heat of formation (ΔH°_f) and standard entropy (s°) were calculated from equations:

$$\Delta H^\circ_r = \sum \Delta H^\circ_f (\text{products}) - \sum \Delta H^\circ_f (\text{reactants}) \quad (1)$$

$$\Delta s^\circ_r = \sum \Delta s^\circ (\text{products}) - \sum \Delta s^\circ (\text{reactants}) \quad (2)$$

The Gibbs free energy of reaction (ΔG°_r) was calculated from the equations:

$$\Delta G^\circ_r = \Delta H^\circ_r - T\Delta s^\circ_r \quad (3)$$

$$\Delta G^\circ_r = \sum \Delta G^\circ_f (\text{products}) - \sum \Delta G^\circ_f (\text{reactants}) \quad (4)$$

where ΔG°_f is the standard free energy of formation at 298.15°k (25°C).

When electrochemical data were available, ΔG°_r was calculated from the equation:

$$\Delta G^\circ_r = -nFE^\circ \quad (5)$$

where

n = Number of moles of electrons participating in the reaction

F = Faraday constant (96.487 kJ volt⁻¹ or 23.061 kcal volt⁻¹)

E° = Standard cell potential

When ΔG°_f values were available, ΔG°_r was calculated using equation (4). Once ΔG°_r was known, the equilibrium constant (k°) was calculated from the equation:

$$\Delta G^\circ_r = -RT \ln k^\circ \quad (6)$$

where

k° = Activity equilibrium constant

R = Universal gas constant (0.00831 kJ/mole or 0.001987 kcal/mole)

T = Absolute temperature

At standard conditions (25°C and 1 atm) equation (6) becomes

$$\log k^\circ = - \frac{\Delta G^\circ_r}{1.364} \quad (7)$$

(ΔG°_f in kcal/mole), or

$$\log k^\circ = - \frac{\Delta G^\circ_r}{5.707} \quad (8)$$

(ΔG°_f in kJ/mole). Substituting

$$\Delta G^\circ_r = \Sigma \Delta G^\circ_f (\text{products}) - \Sigma \Delta G^\circ_f (\text{reactants})$$

into equations (7) and (8) gives

$$\log k^\circ = - \frac{1}{1.364} [\Delta G^\circ_f (\text{products}) - \Sigma \Delta G^\circ_f (\text{reactants})] \quad (9)$$

(ΔG°_f in kcal/mole), or

$$\log k^\circ = - \frac{1}{5.707} [\Sigma \Delta G^\circ_f (\text{products}) - \Sigma \Delta G^\circ_f (\text{reactants})] \quad (10)$$

(ΔG°_f in kJ/mole).

Discussion of selected values:

The auxiliary data (free energy of formation, ΔG°_f) for various anionic species, taken from Sadiq and Lindsay (1979), are listed in Table 3. These data were used to calculate equilibrium constants.

Table 3. Free Energy of Formation (ΔG°_f) of Anionic Species Selected from Sadiq and Lindsay (1979) to Calculate Equilibrium Constants.

No.	Species	ΔG°_f	
		(kJ/mole)	(kcal/mole)
1.	Br^-	-104.05	-24.87
2.	$\text{CO}_2(\text{g})$	-394.38	-94.26
3.	CO_3^{2-}	-527.94	-126.18
4.	HCO_3^-	-586.89	-140.27
5.	$\text{H}_2\text{CO}_3^\circ$	-623.20	-148.95
6.	Cl^-	-131.25	-31.37
7.	C	0.00	0.00
8.	F^-	-284.22	-67.93
9.	H^+	0.00	0.00
10.	OH^-	-157.29	-37.59
11.	H_2O	-237.17	-56.69
12.	I^-	-51.80	-12.38

Table 3. (cont.)

No.	Species	(kJ/mole)	ΔG°_f (kcal/mole)
13.	NO_2^-	-37.74	-9.02
14.	NO_3^-	-111.46	-26.64
15.	PO_4^{3-}	-1025.83	-245.18
16.	HPO_4^{2-}	-1096.34	-262.03
17.	H_2PO_4^-	-1137.42	-271.85
18.	$\text{H}_3\text{PO}_4^\circ$	-1149.68	-274.78
19.	SO_4^{2-}	-744.54	-177.95
20.	SiO_4^{4-}	-1045.96	-249.99
21.	HSiO_4^{3-}	-1120.72	-267.86
22.	$\text{H}_2\text{SiO}_4^{2-}$	-1177.00	-281.31
23.	H_3SiO_4^-	-1252.77	-299.42
24.	$\text{H}_4\text{SiO}_4^\circ$	-1308.17	-312.66

STRONTIUM Sr^{2+}

Recommended standard free energy of formation (ΔG°_f) of Sr^{2+} ion are summarized below:

Investigator	$\Delta G^\circ f$ (kJ/mole)	(kcal/mole)
Wagman et al. (1982)	-559.47	-133.72
Busenberg et al. (1984)	-563.83	-134.76
Robie et al. (1978)	-559.43	-133.70
Parker et al. (1971)	-559.44	-133.71
Naumov et al. (1971)	-571.44	-136.58

Wagman et al. (1982) reported $\Delta G^\circ f = -559.47$ kJ/mole (-133.72 kcal/mole) from $\Delta H^\circ f = -545.80$ kJ/mole (-130.45 kcal/mole) and $s^\circ = -32.6$ J/mole (-7.80 cal/mole). Parker et al. (1971) listed similar value (-559.44 kJ/mole) for Sr^{2+} . Robie et al. (1978) reported $\Delta G^\circ f = -559.43$ kJ/mole (-133.70 kcal/mole) from Parker et al. (1971). Naumov et al. (1971) recommended $\Delta G^\circ f = -571.44$ kJ/mole (-136.58 kcal/mole) from $pK = 6.78$ for the reaction:

Busenberg et al. (1984) recommended $\Delta G^\circ f = -563.83$ kJ/mole (-134.76 kcal/mole). Authors reported this value from Khodakovsky et al. (1981).

Khodakovsky et al. (1981) calculated $\Delta G^\circ f$ of Sr^{2+} from $\Delta H^\circ f = -551.45 \pm 0.59$ kJ/mole (-131.80 kcal/mole) and $s^\circ = -33.1 \pm 2.9$ J/mole (7.91 cal/mole) based on their vapor pressure measurements of $\text{Sr}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$. The listed $\Delta G^\circ f$ value for Sr^{2+} by Busenberg et al. (1984) is reasonably in agreement with Wagman et al. (1981), Robie et al. (1978), and Parker et al. (1971). Therefore, we adopted $\Delta G^\circ f = -563.83$ kJ/mole (-134.76 kcal/mole) for Sr^{2+} after Busenberg et al. (1984).

$\text{SrSO}_4(\text{c})$

Robie et al. (1978) listed $\Delta G^\circ_f = -1340.97$ kJ/mole (-320.50 kcal/mole) from Kelley (1937), Kelley and King (1961), and Parker et al. (1971). Wagman et al. (1982) recommended $\Delta G^\circ_f = -1340.89$ kJ/mole (-320.48 kcal/mole) from $\Delta H^\circ_f = -1453.10$ kJ/mole (-347.30 kcal/mole) and $s^\circ = 116.98$ J/mole (27.96 cal/mole). Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ_f = -1334.44$ kJ/mole (-318.94 kcal/mole) from $\Delta H^\circ_f = -529.70$ kJ/mole (-126.60 kcal/mole).

Helgerson et al. (1978) reported $\Delta G^\circ_f = -1340.68$ kJ/mole (-320.43 kcal/mole) for $\text{SrSO}_4(\text{c})$ from $\Delta G^\circ_f = \Delta H^\circ_f - T\Delta s^\circ$. Authors adopted $\Delta H^\circ_f = -1453.10$ kJ/mole (-347.30 kcal/mole) and $s^\circ = 117.15$ J/mole (-1353.35 cal/mole) from Wagman et al. (1968, 1969). Naumov et al. (1971) listed $\Delta G^\circ_f = -1353.35$ kJ/mole (-323.46 kcal/mole) from ΔH°_f values for the reaction:

Recently, Keardon and Armstrong (1987) made reliable solubility measurements of $\text{SrSO}_4(\text{c})$ and reported $\text{p}K = 6.63$ for the following reaction: $\text{SrSO}_4(\text{c}) \longrightarrow \text{Sr}^{2+} + \text{SO}_4^{2-}$. We adopted the above reaction and calculated $\Delta G^\circ_f = -1346.16$ kJ/mole (-321.74 kcal/mole) for $\text{SrSO}_4(\text{c})$ using selected ΔG°_f values for Sr^{2+} and SO_4^{2-} .

$\text{SrO}(\text{c})$

The standard free energy of formation of $\text{SrO}(\text{c})$ ranges from -559.82 kJ/mole (-133.80 kcal/mole) to -574.13 kJ/mole (-137.22 kcal/mole). Recommended ΔG°_f values for $\text{SrO}(\text{c})$ by various investigators are summarized below:

Investigator	ΔG°_f	
	(kJ/mole)	(kcal/mole)
Garrels and Christ (1968)	-559.82	-133.80
Robie et al. (1978)	-560.32	-133.92
Wagman et al. (1982)	-561.87	-134.29
Pankratz (1982)	-560.57	-133.98
Busenberg et al. (1984)	-559.95	-133.83
Karapet'yants and Karapet'yants (1970)	-573.00	-137.07
Naumov et al. (1971)	-574.13	-137.22

Reported ΔG°_f values for SrO(c) agree very well except Karapet'yants and Karapet'yants (1970) and Naumov et al. (1971). Recently Busenberg et al. (1984) critically evaluated ΔG°_f for SrO(c) and recommended -559.95 kJ/mole (-133.83 kcal/mole) from $\Delta H^\circ_f = -590.57$ kJ/mole (-141.15 kcal/mole) and $s^\circ = 55.44$ J/mole (13.25 kcal/mole).

In this report we selected $\Delta G^\circ_f = -559.95$ kJ/mole (-133.83 kcal/mole) of Busenberg et al. (1984).

Sr(NO₃)₂(c)

Robie et al. (1978) reported $\Delta G^\circ_f = -779.06$ kJ/mole (-186.20 kcal/mole). Wagman et al. (1982) listed $\Delta G^\circ_f = -780.02$ kJ/mole (-186.43 kcal/mole) from $\Delta H^\circ_f = -978.22$ kJ/mole (-233.80 kcal/mole) and $s^\circ = -194.55$ J/mole (-46.50 cal/mole). Naumov et al. (1971) recommended $\Delta G^\circ_f = -790.40$ kJ/mole (-188.91 kcal/mole) from $\Delta H^\circ_f = 17.53$ kJ/mole (4.19 kcal/mole) for the reaction:

Busenberg et al. (1984) calculated $\Delta G^\circ_f = -783.28$ kJ/mole (-187.21 kcal/mole) from $\Delta H^\circ_f = -982.36$ kJ/mole (-234.79 kcal/mole) and $s^\circ = 194.60$ J/mole (46.51 cal/mole). Karapet'yants and Karapet'yants (1971) reported $\Delta G^\circ_f = -778.22$ kJ/mole (-186.00 kcal/mole) from approximate calculations of ΔH°_f and s° . We adopted $\Delta G^\circ_f = -783.28$ kJ/mole (-187.21 kcal/mole) for $\text{Sr}(\text{NO}_3)_2(\text{c})$ after Busenberg et al. (1984).

$\text{SrBr}_2(\text{c})$

Robie et al. (1978) reported $\Delta G^\circ_f = -695.89$ kJ/mole (-166.32 kcal/mole) from ΔH°_f and s° calculations. Wagman et al. (1982) listed $\Delta G^\circ_f = -697.10$ kJ/mole (-166.61 kcal/mole) from $\Delta H^\circ_f = -717.60$ kJ/mole (-171.51 kcal/mole) and $s^\circ = 135.10$ J/mole (32.29 cal/mole). Karapet'yants and Karapet'yants (1970) recommended $\Delta G^\circ_f = -695.80$ kJ/mole (-166.30 kcal/mole) from approximate calculations of ΔH°_f and s° values. Pankratz (1984) listed $\Delta G^\circ_f = -699.77$ kJ/mole (-167.25 kcal/mole) from $\Delta H^\circ_f = -717.97$ kJ/mole (-171.60 kcal/mole) and $s^\circ = 143.42$ J/mole (34.28 cal/mole).

The standard free energy of formation (ΔG°_f) for $\text{SrBr}_2(\text{c})$ reported by Pankratz (1984) agree well with the values reported by Robie et al. (1978) and Wagman et al. (1982). Therefore, we selected $\Delta G^\circ_f = -699.77$ kJ/mole (-167.25 kcal/mole) of Pankratz (1984).

$\text{SrHPO}_4(\text{c})$

Garrels and Christ (1965) reported $\Delta G^\circ_f = -1672.34$ kJ/mole (-399.70 kcal/mole) from $\Delta H^\circ_f = -1804.56$ kJ/mole (-431.30 kcal/mole) and $s^\circ = 130.54$ J/mole (31.2 cal/mole) from Latimer (1952). However, Latimer (1952) calculated ΔG°_f value for $\text{SrHPO}_4(\text{c})$ compound from estimated s° values. Wagman et al. (1982) listed $\Delta G^\circ_f = -1688.60$ kJ/mole (-403.58

kcal/mole) from $\Delta H^\circ_f = -1821.67$ kJ/mole (-435.39 kcal/mole) and $s^\circ = 120.96$ J/mole (28.91 cal/mole).

Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ_f = -1681.13$ kJ/mole (-408.80 kcal/mole) from approximate ΔH°_f and s° values. In this report we adopted $\Delta G^\circ_f = -1688.60$ kJ/mole (-403.58 kcal/mole) after Wagman et al. (1982).

$\text{SrF}_2(\text{c})$

Garrels and Christ (1965) reported $\Delta G^\circ_f = -1162.31$ kJ/mole (-277.80 kcal/mole) from Latimer (1952). However, Latimer (1952) calculated this value from $\Delta H^\circ_f = -1214.61$ kJ/mole (-290.30 kcal/mole) and estimated s° of 89.53 J/mole (21.40 cal/mole). Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ_f = -1162.31$ kJ/mole (-277.80 kcal/mole) for $\text{SrF}_2(\text{c})$.

Pankratz (1984) reported $\Delta G^\circ_f = -1164.74$ kJ/mole (-278.38 kcal/mole) from $\Delta H^\circ_f = -1216.28$ kJ/mole (-290.70 kcal/mole) and $s^\circ = -82.13$ J/mole (-19.63 cal/mole) from Parker et al. (1971). Naumov et al. (1971) reported $\Delta G^\circ_f = -1180.56$ kJ/mole (-282.16 kcal/mole) from $\log K = 8.61$ for the reaction:

Wagman et al. (1982) recommended $\Delta G^\circ_f = -1164.57$ kJ/mole (-278.34 kcal/mole) from $\Delta H^\circ_f = -1216.28$ kJ/mole (-290.70 kcal/mole) and $s^\circ = 82.13$ J/mole (19.63 cal/mole). No other information is available to evaluate ΔG°_f for this compound. In this report we selected $\Delta G^\circ_f = -1180.56$ kJ/mole (-282.16 kcal/mole) of Naumov et al. (1971).

$\text{SrCrO}_4(\text{c})$

Latimer (1952) reported $\Delta G^\circ_f = -1319.21$ kJ/mole (-315.30 kcal/mole) for $\text{SrCrO}_4(\text{c})$. No other information is available. Naumov et al. (1971)

listed $\Delta G^\circ_f = -1318.37$ kJ/mole (-315.10 kcal/mole) from $pK = 4.65 \pm 0.1$ for the reaction:

Reported ΔG°_f values for $\text{SrCrO}_4(\text{c})$ agree well. Therefore, we adopted $\Delta G^\circ_f = -1318.37$ kJ/mole (-315.10 kcal/mole) after Naumov et al. (1971).

Naumov et al. (1971) reported $\Delta G^\circ_f = -969.43$ kJ/mole (-231.70 kcal/mole) from $pK = 6.10$ for the reaction:

Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ_f = -965.83$ kJ/mole (-230.84 kcal/mole) from approximate ΔH°_f and s° values. No further information is available. Therefore, we selected $\Delta G^\circ_f = -969.43$ kJ/mole (-231.70 kcal/mole) after Naumov et al. (1971).

Naumov et al. (1970) listed $\Delta G^\circ_f = -2196.01$ kJ/mole (-524.86 kcal/mole) from $\Delta H^\circ_f = -158.36$ kJ/mole (-37.85 kcal/mole) for the reaction:

Parker et al. (1971) reported $\Delta G^\circ_f = -2170.60$ kJ/mole (-520.70 kcal/mole) from $\Delta H^\circ_f = -2287.40$ kJ/mole (-546.70 kcal/mole) and $s^\circ = 159.00$ J/mole (38.00 cal/mole). Wagman et al. (1982) $\Delta G^\circ_f = -2172.30$ kJ/mole (-519.19 kcal/mole) from $\Delta H^\circ_f = -2287.40$ kJ/mole (-546.70 kcal/mole) and $s^\circ = 159.00$ J/mole (38.00 cal/mole). Therefore, we

selected $\Delta G^\circ_f = -2196.01$ kJ/mole (-524.86 kcal/mole) after Naumov et al. (1971).

Recommended ΔG°_f values for SrOH^+ species are listed below:

Investigator	(kJ/mole)	ΔG°_f (kcal/mole)
Parker et al. (1971)	-721.32	-172.40
Wagman et al. (1982)	-721.32	-172.40
Naumov et al. (1971)	-733.46	-175.30

Parker et al. (1971) recommended $\Delta G^\circ_f = -721.32$ kJ/mole (-172.40 kcal/mole). No further information is available to evaluate this value. Wagman et al. (1982) also reported similar (-721.32 kJ/mole) value for SrOH^+ species. The source was not documented.

Naumov et al. (1971) listed $\Delta G^\circ_f = -733.46$ kJ/mole (-175.30 kcal/mole) from $pK = 0.82$ and $s^\circ = -4.81$ J/mole (-1.15 cal/mole) for the reaction:

We selected $\Delta G^\circ_f = -733.46$ kJ/mole (-175.30 kcal/mole) for SrOH^+ after Naumov et al. (1970).

Wagman et al. (1982) recommended $\Delta G^\circ_f = -1304.03$ kJ/mole (-311.67 kcal/mole) from ΔH°_f and s° values. Sposito and Mattigod (1980) estimated equilibrium constant for the following equation:

Smith and Martell (1978) reported equilibrium constant of $10^{2.55}$ for the same reaction:

No other information is available to evaluate ΔG°_f of SrSO_4° . Therefore, we selected Smith and Martell (1978) equilibrium constant for the above reaction and calculated $\Delta G^\circ_f = -1320.89$ kJ/mole (-315.70 kcal/mole) for SrSO_4° species.

SrCO_3 (Strontianite)

The reported ΔG°_f values range from -1137.64 to -1152.31 kJ/mole (-271.90 to -275.40 kcal/mole). Naumov et al. (1971) listed $\Delta G^\circ_f = -1152.31$ kJ/mole (-275.40 kcal/mole) for $\text{SrCO}_3(\text{c})$. This value was calculated from $\Delta H^\circ_f = -982.02$ kJ/mole (-234.71 kcal/mole) for the reaction:

Khodakovskiy et al. (1981) reported $\Delta G^\circ_f = -114.72$ kJ/mole (-273.60 kcal/mole), based on their vapor pressure measurements of $\text{Sr}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}(\text{c})$ and ΔH°_f and s° values. Wagman et al. (1982) listed $\Delta G^\circ_f = -1140.10$ kJ/mole (-272.49 kcal/mole). Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ_f = -1138.13$ kJ/mole (-272.02 kcal/mole) from approximate calculations of ΔH°_f and s° values. Robie et al. (1978) reported $\Delta G^\circ_f = -1137.63$ kJ/mole (-271.90 kcal/mole).

The reported ΔG°_f values for $\text{SrCO}_3(\text{c})$ in literature differ significantly. Therefore, further investigation was done to obtain a reliable value for $\text{SrCO}_3(\text{c})$. The equilibrium constant ($\log k^\circ$) for the following reaction:

reported by the various investigators and geochemical models are listed below:

Investigator/Geochemical Model	$\log k^\circ$
Naumov et al. (1971)	-9.28
Busenberg et al. (1984)	-9.27
WATEQ-2, Ball et al. (1980)	-9.25
PHREEQE, Parkhurst et al. (1980)	-9.25
Smith and Martell (1976)	-9.03
GEOCHEM, Sposito and Mattigod (1980)	-9.00

Naumov et al. (1971) reported a value of -9.28 from products of activities of substances involved in the reaction. However, further information was not available to evaluate this value. Equilibrium constants reported by WATEQ-2, PHREEQE, and Busenberg et al. (1984) agree fairly well, except Smith and Martell (1976) and GEOCHEM.

Recently, Busenberg et al. (1984) made reliable solubility measurements for SrCO_3 (Strontianite) in $\text{CO}_2 - \text{H}_2\text{O}$ system between 2 and 91°C. Authors also made corrections for temperature, ionic strength, and solution complexes. Therefore, we selected $\log k^\circ$ of -9.271 after Busenberg et al. (1984). The ΔG°_f value for $\text{SrCO}_3(\text{c})$ was then

calculated to be -1144.63 kJ/mole (-273.33 kcal/mole) with selected $\Delta G^\circ f$ values of Sr^{2+} and CO_3^{2-} .

$\text{SrSiO}_3(\text{c})$

Naumov et al. (1971) listed $\Delta G^\circ f = -1561.64$ kJ/mole (-373.24 kcal/mole) from $\Delta H^\circ f = -546.85$ kJ/mole (-130.70 kcal/mole) for the reaction:

Karapet'yants and Karapet'yants (1971) reported $\Delta G^\circ f = -1467.75$ kJ/mole (-350.80 kcal/mole). Where as Wagman et al. (1981) listed $\Delta G^\circ f = -1549.70$ kJ/mole (-370.39 kcal/mole). The source of information was not documented. Therefore, at present we adopted $\Delta G^\circ f = -1561.64$ kJ/mole (-373.24 kcal/mole) after Naumov et al. (1971).

$\text{Sr}_2\text{SiO}_4(\text{c})$

Wagman et al. (1982) listed $\Delta G^\circ f = -2191.10$ kJ/mole (-523.68 kcal/mole). Naumov et al. (1971) reported $\Delta G^\circ f = -2215.09$ kJ/mole (-529.42 kcal/mole) from $\Delta H^\circ f = -876.00$ kJ/mole (-209.37 kcal/mole) for the reaction:

Garrels and Christ (1968) and Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ f = -2074.00$ kJ/mole (-495.70 kcal/mole) from Latimer (1952). No further information is available for this compound. We tentatively adopted $\Delta G^\circ f = -2191.10$ kJ/mole (-523.68 kcal/mole) after Wagman et al. (1982).

Garrels and Christ (1965) reported $\Delta G^\circ_f = -3899.90$ kJ/mole (-932.10 kcal/mole) for this compound. Authors listed this value from Latimer (1956). No further information is available on ΔG°_f of $\text{Sr}_3(\text{PO}_4)_2(\text{c})$ in the literature. We adopted the value reported by Garrels and Christ (1968).

Busenberg et al. (1984) critically evaluated ΔG°_f of $\text{Sr}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}(\text{c})$ and recommended -1734.19 kJ/mole (-414.48 kcal/mole). Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ_f = -1725.48$ kJ/mole (-412.40 kcal/mole) from ΔH°_f and s° calculations. We adopted $\Delta G^\circ_f = -1734.19$ kJ/mole (-414.48 kcal/mole) after Busenberg et al. (1984) for this compound.

Garrels and Christ (1956) listed $\Delta G^\circ_f = -781.15$ kJ/mole (-186.70 kcal/mole) from Rossini et al. (1952). Latimer (1952) reported $\Delta G^\circ_f = -781.15$ kJ/mole (-186.70 kcal/mole) value calculated from $\Delta H^\circ_f = -828.43$ kJ/mole (-198.00 kcal/mole) and $s^\circ = 117.15$ J/mole (28.00 cal/mole). Wagman et al. (1982) listed $\Delta G^\circ_f = -781.10$ J/mole (-186.69 kcal/mole). Pankratz (1984) reported $\Delta G^\circ_f = -781.02$ kJ/mole (-186.67 kcal/mole) from ΔH°_f and s° values. Busenberg et al. (1984) recommended $\Delta G^\circ_f = -785.00$ kJ/mole (-187.62 kcal/mole). This value calculated from $\Delta H^\circ_f = -833.85$ kJ/mole (-199.30 kcal/mole) and $s^\circ = 114.85$ J/mole (27.50 cal/mole). ΔG°_f value reported by Busenberg et al. (1984) agree very well with the other values. Therefore, we adopted Busenberg et al. (1984) recommended value -785.00 kJ/mole (-187.62 kcal/mole) for this compound.

Wagman et al. (1982) reported $\Delta G^\circ_f = -1036.30$ kJ/mole (-247.68 kcal/mole). Karapet'yants and Karapet'yants (1971) reported $\Delta G^\circ_f = -1038.47$ kJ/mole (-248.20 kcal/mole) from approximate calculations of ΔH°_f and s° values. This value is questionable. At present, we adopted $\Delta G^\circ_f = -1036.30$ kJ/mole (-247.68 kcal/mole) reported by Wagman et al. (1982) for this compound.

Wagman et al. (1982) reported $\Delta G^\circ_f = -954.30$ kJ/mole (-228.08 kcal/mole). No further information is available. We adopted $\Delta G^\circ_f = -954.30$ kJ/mole (-228.08 kcal/mole) after Wagman et al. (1982).

Latimer (1952) reported $\Delta G^\circ_f = -3222.10$ kJ/mole (-770.10 kcal/mole) from $\Delta H^\circ_f = -3350.13$ kJ/mole (-800.70 kcal/mole) and $s^\circ = 312.12$ J/mole (-74.60 cal/mole) values. However, s° value was estimated. Recently, Wagman et al. (1982) recommended $\Delta G^\circ_f = -3080.10$ kJ/mole (-736.16 kcal/mole) from ΔH°_f and s° values. Therefore, we adopted the Wagman et al. (1982) value.

Naumov et al. (1971) reported $\Delta G^\circ_f = -1039.14$ kJ/mole (-248.36 kcal/mole) from $\Delta H^\circ_f = 2.42$ kJ/mole (0.58 kcal/mole) and from $pK = 4.60$ for the reaction:

Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ_f = -1023.87$ kJ/mole

(-244.71 kcal/mole) from $\Delta H^\circ f$ and s° values. Since Naumov et al. (1971) reported $\Delta G^\circ f$ from pk values, we adopted their value.

$\text{SrMoO}_4(\text{c})$

Naumov et al. (1971) listed $\Delta G^\circ f = -1454.36$ kJ/mole (-347.60 kcal/mole) from $\Delta H^\circ f = 19.24$ kJ/mole (-4.60 kcal/mole) and $\text{pk} = 7.89$ for the reaction:

Karapet'yants and Karapet'yants (1970) reported -1448.50 kJ/mole (-346.20 kcal/mole) from $\Delta H^\circ f$ and s° values. No further information is available. Therefore, we adopted $\Delta G^\circ f = -1454.36$ kJ/mole (-347.60 kcal/mole) for $\text{SrMoO}_4(\text{c})$ after Naumov et al. (1971).

$\text{Sr}(\text{OH})_2(\text{c})$

Garrels and Christ (1965) reported $\Delta G^\circ f = -869.43$ kJ/mole (-207.80 kcal/mole) from Latimer (1952). Latimer (1952) calculated this value from $\Delta H^\circ f = -959.39$ kJ/mole (-229.30 kcal/mole) and s° value of 87.86 J/mole (-21.00 kcal/mole). Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ f = 870.27$ kJ/mole (-208.00 kcal/mole). Both $\Delta G^\circ f$ values for $\text{Sr}(\text{OH})_2(\text{c})$ agree very well. Therefore, we adopted $\Delta G^\circ f = -870.27$ kJ/mole (-208.00 kcal/mole) for this compound after Karapet'yants and Karapet'yants (1970).

$\text{SrI}_2(\text{c})$

Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ f = -562.33$ kJ/mole (-134.40 kcal/mole) from approximate $\Delta H^\circ f$ and s° values. Pankratz (1984) recommended $\Delta G^\circ f = -558.71$ kJ/mole (-133.53 kcal/mole)

from $\Delta H^\circ_f = -561.69$ kJ/mole (-134.24 kcal/mole) and $s^\circ = 159.12$ J/mole (-38.03 cal/mole). We adopted $\Delta G^\circ_f = -558.71$ kJ/mole (-133.53 kcal/mole) after Pankratz (1984) for this compound.

$\text{SrTiO}_3(\text{c})$

Naumov et al. (1971) reported $\Delta G^\circ_f = -1600.38$ kJ/mole (-382.50 kcal/mole). The enthalpy of formation is determined from average of ΔH°_f (298.18) = -1684.48 ± 4.184 kJ/mole (-402.60 kcal/mole). The $\Delta H^\circ_f = 99.16 \pm 0.83$ J/mole (-23.70 cal/mole) for the reaction:

Similar $\Delta H^\circ_f = -1684.64 \pm 4.184$ kJ/mole (-402.64 kcal/mole) was calculated from $\Delta H^\circ_f = -135.770 \pm 1.04$ kJ/mole (-32.45 kcal/mole) from the reaction:

Parker et al. (1971) reported $\Delta G^\circ_f = -1588.41$ kJ/mole (-379.64 kcal/mole) from $\Delta H^\circ_f = -1672.38$ kJ/mole (-399.70 kcal/mole) and $s^\circ = 108.78$ J/mole (25.00 kcal/mole). Wagman et al. (1982) reported $\Delta G^\circ_f = -1588.36$ kJ/mole (-379.62 kcal/mole) from $\Delta H^\circ_f = -1672.38$ kJ/mole (-399.70 kcal/mole) and $s^\circ = 108.87$ J/mole (26.02 cal/mole). We selected $\Delta G^\circ_f = -1600.38$ kJ/mole (-382.50 kcal/mole) after Naumov et al. (1971).

$\text{SrZrO}_3(\text{c})$

Naumov et al. (1971) reported $\Delta G^\circ_f = -2548.89$ kJ/mole (-609.20 kcal/mole) from $\Delta H^\circ_f = -2904.20$ kJ/mole (-694.12 kcal/mole) for the reaction:

Parker et al. (1971) listed $\Delta G^\circ_f = -1682.80$ kJ/mole (-402.20 kcal/mole) from $\Delta H^\circ_f = -1767.32$ kJ/mole (-422.40 kcal/mole) and $s^\circ = 115.06$ J/mole (27.50 cal/mole). Wagman et al. (1982) reported $\Delta G^\circ_f = -1682.80$ kJ/mole (-402.20 kcal/mole) from $\Delta H^\circ_f = -1767.30$ kJ/mole and $s^\circ = 115.10$ J/mole (27.51 cal/mole). We adopted $\Delta G^\circ_f = -1682.79$ kJ/mole (-402.20 kcal/mole) after Wagman et al. (1982).

Busenberg et al. (1984) recommended $\Delta G^\circ_f = -1157.50$ kJ/mole (-276.65 kcal/mole) from $\Delta H^\circ_f = -1215.53$ kJ/mole (-290.52 kcal/mole) and $s^\circ = 174.39$ J/mole (41.68 cal/mole). No other information is available. Therefore, we adopted $\Delta G^\circ_f = -1157.50$ kJ/mole (-276.65 kcal/mole) after Busenberg et al. (1984).

Wagman et al. (1982) reported $\Delta G^\circ_f = -1087.30$ kJ/mole (-259.87 kcal/mole) from $\Delta H^\circ_f = -1222.94$ kJ/mole (-292.29 kcal/mole) and $s^\circ = -87.50$ J/mole (-21.39 cal/mole). Parker et al. (1971) reported $\Delta G^\circ_f = -1087.33$ kJ/mole (-259.88 kcal/mole) from $\Delta H^\circ_f = -1222.94$ kJ/mole (-292.29 kcal/mole) and $s^\circ = 89.53$ J/mole (-21.40 cal/mole). Busenberg et al. (1984) reported $\Delta G^\circ_f = -1175.50$ kJ/mole (-280.95 kcal/mole) from $\Delta H^\circ_f = -1226.12$ kJ/mole (-293.05 kcal/mole) and $s^\circ = -81.46$ J/mole (-19.47 cal/mole). Since reported ΔG°_f values for SrCO_3 agree very well, we selected $\Delta G^\circ_f = -1175.50$ kJ/mole (-280.95 kcal/mole) for SrCO_3 species after Busenberg et al. (1984).

Wagman et al. (1982) reported $\Delta G^\circ_f = -781.99$ kJ/mole (-186.90 kcal/mole) from $\Delta H^\circ_f = -960.52$ kJ/mole (-229.57 kcal/mole) and $s^\circ = 260.20$ J/mole (-62.19 cal/mole). No other information is available. Therefore, we adopted $\Delta G^\circ_f = -781.99$ kJ/mole (-186.90 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) listed $\Delta G^\circ_f = -821.90$ kJ/mole (-196.44 kcal/mole) from $\Delta H^\circ_f = -880.10$ kJ/mole (-210.35 kcal/mole) and $s^\circ = 80.29$ J/mole (-19.19 cal/mole). We adopted $\Delta G^\circ_f = -821.90$ kJ/mole (-196.44 kcal/mole) after Wagman et al. (1982).

Only Wagman et al. (1982) reported $\Delta G^\circ_f = -662.62$ kJ/mole (-158.37 kcal/mole). No other information is available. Therefore, we adopted ΔG°_f value from Wagman et al. (1982) for this species.

Parker et al. (1971) reported $\Delta G^\circ_f = -767.38$ kJ/mole (-183.41 kcal/mole) from $\Delta H^\circ_f = -788.89$ kJ/mole (-188.55 kcal/mole) and $s^\circ = 132.21$ J/mole (-31.60 cal/mole). No other information is available. Therefore, we adopted $\Delta G^\circ_f = -763.38$ kJ/mole (-183.41 kcal/mole) after Parker et al. (1971) for this species.

FLUORINE

Wagman et al. (1982) reported $\Delta G^\circ_f = -278.79$ kJ/mole (-66.63 kcal/mole) from $\Delta H^\circ_f = -332.63$ kJ/mole (-79.50 kcal/mole) and $s^\circ = -13.8$

J/mole (-3.29 cal/mole). Sadiq and Lindsay (1979) used $\Delta H^\circ_f = -335.34$ kJ/mole (-80.15 kcal/mole) of Johnson et al. (1973) and $s^\circ = -13.18$ J/mole (-3.15 cal/mole) of CODATA (1976) to calculate $\Delta G^\circ_f = -284.22$ kJ/mole (-67.93 kcal/mole) for F^- species.

Robie et al. (1978) recommended $\Delta G^\circ_f = -281.70$ kJ/mole (-67.33 kcal/mole) from $\Delta H^\circ_f = -335.350$ kJ/mole (-80.15 kcal/mole) which is similar to Sadiq and Lindsay (1979) selection to calculate ΔG°_f for F^- species. Recently, Elrashidi and Lindsay (1984) critically evaluated standard free energies of formation of F species and reported $\Delta G^\circ_f = -284.22$ kJ/mole (-67.93 kcal/mole). In this report we selected $\Delta G^\circ_f = -284.22$ kJ/mole (-67.93 kcal/mole) after Sadiq and Lindsay (1979).

HF°

Naumov et al. (1971) used $pK = 3.180$ and 3.173 for the reaction:

after Ellis (1963), and Broene and Devries (1947) to calculate the mean $\Delta G^\circ_f = -298.11$ kJ/mole (-71.25 kcal/mole). Wagman et al. (1982) recommended $\Delta G^\circ_f = -296.82$ kJ/mole (-70.94 kcal/mole) from $\Delta H^\circ_f = -320.08$ kJ/mole (-76.50 kcal/mole) and $s^\circ = 88.7$ J/mole (21.20 cal/mole).

We adopted $\Delta G^\circ_f = -296.82$ kJ/mole (-70.94 kcal/mole) after Wagman et al. (1982).

HF_2^-

Naumov et al. (1971) calculated $\Delta G^\circ_f = -581.50$ kJ/mole (-138.98 kcal/mole) from $pK = 0.59$ for the reaction:

after Broene and Devries (1947). Authors also calculated $s^\circ = 67.78$ J/mole (16.2 cal/mole) from $S^\circ_r = 7.99$ J/mole (1.91 cal/mole) for the equation:

after Cox and Harrop (1965).

Wagman et al. (1982) listed $\Delta G^\circ_f = -578.08$ kJ/mole (-138.16 kcal/mole) from $\Delta H^\circ_f = -649.94$ kJ/mole (-155.34 kcal/mole) and $s^\circ = 92.5$ J/mole (22.10 cal/mole).

In this report, we selected $\Delta G^\circ_f = -578.08$ kJ/mole (-138.16 kcal/mole) after Wagman et al. (1982) for HF_2^- species.

Sadiq and Lindsay (1979) reported $\Delta G^\circ_f = -1131.27$ kJ/mole (-270.38 kcal/mole) from Baumann (1969) measurements on $\text{pk} = 5.62 \pm 0.04$ for reaction:

Smith and Martell (1976) listed $\text{pk} = 12.60$ for the reaction:

Wagman et al. (1982) reported $\Delta G^\circ_f = -1113.00$ kJ/mole (-266.01 kcal/mole) which agree with the value reported by Sadiq and Lindsay (1979).

We selected $\Delta G^\circ_f = -1131.27$ kJ/mole (-270.38 kcal/mole) after Sadiq and Lindsay (1979) for our purpose.

Naumov et al. (1971) reported $\Delta G^\circ_f = -811.82 \text{ kJ/mole}$ ($-194.03 \text{ kcal/mole}$). Authors based their calculation on $\text{pk} = 6.98$ for the reaction:

adopted from the solubility measurements of Baumann (1969). Where as Brosset (1941), Paul (1955), and Smith and Martell (1976) reported $\text{pk} = 7.0$ for the above reaction. Sadiq and Lindsay (1979) selected $\text{pk} = 6.98$ for the reaction:

and calculated ΔG°_f to be -814.96 kJ/mole ($-194.78 \text{ kcal/mole}$). Wagman et al. (1982) reported $\Delta G^\circ_f = -803.00 \text{ kJ/mole}$ ($-191.92 \text{ kcal/mole}$).

We selected $\Delta G^\circ_f = -814.96 \text{ kJ/mole}$ ($-194.78 \text{ kcal/mole}$) after Sadiq and Lindsay (1979).

Naumov et al. (1971) listed $\Delta G^\circ_f = -1427.03 \text{ kJ/mole}$ ($-341.07 \text{ kcal/mole}$). Smith and Martell (1976) recommended $\text{pk} = 16.7$ for the reaction:

which determined $\Delta G^\circ_f = -1438.88 \text{ kJ/mole}$ ($-343.90 \text{ kcal/mole}$) for AlF_3° species. Baumann (1969) reported $\text{pk} = 4.05$ for the reaction:

This pk calculated $\Delta G^\circ_f = -1438.58$ kJ/mole (-343.83 kcal/mole). Sadiq and Lindsay (1979) reported $\Delta G^\circ_f = -1438.58$ kJ/mole (-343.83 kcal/mole) based on the solubility measurements of Baumann (1969). Wagman et al. (1982) reported $\Delta G^\circ_f = -1414.00$ kJ/mole (-337.95 kcal/mole) from $\Delta H^\circ_f = -1519.00$ kJ/mole (-363.05 kcal/mole) and $s^\circ = -25.00$ J/mole (-5.97 cal/mole).

In this report, we selected $\Delta G^\circ_f = -1438.58$ kJ/mole (-343.83 kcal/mole) after Sadiq and Lindsay (1979).

Naumov et al. (1971) $\Delta G^\circ_f = -1720.63$ kJ/mole (-411.24 kcal/mole) from $\text{pk} = -2.39$ for the reaction:

Smith and Martell (1976) recommended $\text{pk} = 19.1$ for the reaction:

Sadiq and Lindsay (1979) calculated $\Delta G^\circ_f = -1736.40$ kJ/mole (-415.01 kcal/mole) from $\text{pk} = -2.39$ recommended by Naumov et al. (1971). Therefore, we selected $\Delta G^\circ_f = -1736.40$ kJ/mole (-415.01 kcal/mole) for this species.

Wagman et al. (1982) reported $\Delta G^\circ_f = -322.60$ kJ/mole (-77.10 kcal/mole) from $\Delta H^\circ_f = -371.10$ kJ/mole (-88.70 kcal/mole) and $s^\circ = -163.00$ J/mole (-38.96 kcal/mole). Naumov et al. (1971) listed $\Delta G^\circ_f = -332.33$ kJ/mole (-79.43 kcal/mole). Authors based their calculations on $\text{pk} = 6.04$ for the reaction:

given by Davies (1938a and 1938b). Where as Ashland (1967) and Smith and Martell (1976) recommended $\text{pk} = 6.03$ and 6.00 , respectively for the above reaction. Sadiq and Lindsay (1979) selected $\text{pk} = 6.00$ and calculated $\Delta G^\circ_f = -335.30 \text{ kJ/mole}$ (-80.14 kcal/mole) for FeF^{2+} species.

In this report, we selected $\Delta G^\circ_f = -335.30 \text{ kJ/mole}$ (-80.14 kcal/mole) after Sadiq and Lindsay (1979).

Wagman et al. (1982) reported $\Delta G^\circ_f = -636.48 \text{ kJ/mole}$ ($-152.12 \text{ kcal/mole}$) from $\Delta H^\circ_f = -754.40 \text{ kJ/mole}$ ($-180.30 \text{ kcal/mole}$) and $s^\circ = -165.30 \text{ J/mole}$ (-39.50 cal/mole). No other information was available. Therefore, we selected $\Delta G^\circ_f = -636.48 \text{ kJ/mole}$ ($-152.12 \text{ kcal/mole}$) after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = -628.40 \text{ kJ/mole}$ ($-150.19 \text{ kcal/mole}$) from $\Delta H^\circ_f = -696.20 \text{ kJ/mole}$ ($-166.40 \text{ kcal/mole}$) and $s^\circ = -63.00 \text{ J/mole}$ (-15.05 cal/mole). Elrashidi and Lindsay (1984) recommended $\Delta G^\circ_f = -645.55 \text{ kJ/mole}$ ($-154.29 \text{ kcal/mole}$) from $\Delta H^\circ_f = -696.21 \text{ kJ/mole}$ ($-166.40 \text{ kcal/mole}$) and $s^\circ = -62.76 \text{ J/mole}$ (-15.00 cal/mole).

Sadiq and Lindsay (1979) listed $\Delta G^\circ_f = -637.76 \text{ kJ/mole}$ ($-152.43 \text{ kcal/mole}$) from $\text{pk} = 9.2$ for the reaction:

after Smith and Martell (1976). We selected $\Delta G^\circ_f = -637.76 \text{ kJ/mole}$ ($-152.43 \text{ kcal/mole}$) after Sadiq and Lindsay (1984).

Sadiq and Lindsay (1979) reported $\Delta G^\circ_f = -936.25$ kJ/mole (-233.77 kcal/mole) from $\text{pk} = 11.7$ for the reaction:

after Smith and Martell (1976). No other information was available. Therefore, we adopted $\Delta G^\circ_f = -936.25$ kJ/mole (-223.77 kcal/mole) after Sadiq and Lindsay (1979).

Naumov et al. (1971) listed $\Delta G^\circ_f = -311.70$ kJ/mole (-74.50 kcal/mole). Wagman et al. (1982) reported $\Delta G^\circ_f = -310.37$ kJ/mole (-74.18 kcal/mole). No other information was available. The value reported by Naumov et al. (1971) was based on $\text{pk} = 1.26$ for the reaction:

determined at ionic strength (μ) = 2.0. Sadiq and Lindsay (1979) reported $\Delta G^\circ_f = -317.40$ kJ/mole (-75.86 kcal/mole) from $\text{pk} = 1.65$ at $\mu=0$.

We selected $\Delta G^\circ_f = -317.40$ kJ/mole (-75.86 kcal/mole) for PbF^+ species after Sadiq and Lindsay (1979).

Sadiq and Lindsay (1979) calculated $\Delta G^\circ_f = -606.09$ kJ/mole (-164.86 kcal/mole) for PbF_2° species after the solubility measurements of Talipov and Kutumova (1956). Naumov et al. (1971) calculated $\Delta G^\circ_f = -597.47$ kJ/mole (-142.80 kcal/mole) from $\text{pk} = 2.27$ for the equation:

Wagman et al. (1982) reported $\Delta G^\circ_f = -596.60$ kJ/mole (-142.60 kcal/mole) but their source was not known. In this report, we selected $\Delta G^\circ_f = -606.09$ kJ/mole (-144.86 kcal/mole) after Sadiq and Lindsay (1979).

Sadiq and Lindsay (1979) recommended $\Delta G^\circ_f = -896.84$ kJ/mole (-214.35 kcal/mole) for PbF_3^- species from $\text{pk} = 3.42$ reported by Talipov and Kutumova (1956). Naumov et al. (1971) reported $\Delta G^\circ_f = -884.08$ kJ/mole (-211.30 kcal/mole) but their source was not known. Therefore, we adopted $\Delta G^\circ_f = -896.84$ kJ/mole (-216.35 kcal/mole) after Sadiq and Lindsay (1979).

Sadiq and Lindsay (1979) recommended $\Delta G^\circ_f = -1179.26$ kJ/mole (-281.85 kcal/mole) from $\text{pk} = 3.1$ reported by Talipov and Kutumova (1956) for the reaction:

No other information was available. Therefore, we selected $\Delta G^\circ_f = -1179.26$ kJ/mole (-281.85 kcal/mole) after Sadiq and Lindsay (1979).

Wagman et al. (1982) reported $\Delta G^\circ_f = -1607.40$ kJ/mole (-384.18 kcal/mole) for SiF_4° . They did not list ΔH°_f or s° for SiF_4° . Naumov et al. (1971) calculated $\Delta G^\circ_f = -1611.67$ kJ/mole (-385.20 kcal/mole) from $\text{pk} = 6.19$ for reaction:

after Russian investigators. No further information was available to evaluate Naumov et al. (1971) pK value. Therefore, we accepted $\Delta G^{\circ}f = -1607.40$ kJ/mole (-384.18 kcal/mole) for SiF_4° after Wagman et al. (1982).

The standard free energy of formation listed for SiF_6^{2-} ranges from -2138.02 kJ/mole (-511.00 kcal/mole) to -2207.06 kJ/mole (-527.50 kcal/mole). Wagman et al. reported $\Delta G^{\circ}f = -2199.40$ kJ/mole (-525.67 kcal/mole) from $\Delta H^{\circ}f = -2389.10$ kJ/mole (-571.00 kcal/mole) and $s^{\circ} = 122.20$ J/mole (29.20 cal/mole). Naumov et al. (1971) calculated $\Delta G^{\circ}f = -2207.31$ kJ/mole (-527.56 kcal/mole) from $pK = 26.38$ for the reaction:

They also calculated $\Delta H^{\circ}f = -2395.60$ kJ/mole (-572.56 kcal/mole) and $s^{\circ} = 125.10$ kJ/mole (29.9 cal/mole) after Stephenson et al. (1964).

Karapet'yants and Karapet'yants (1970) reported $\Delta G^{\circ}f = -2138.24$ kJ/mole (-511.00 kcal/mole) using thermodynamic data determined by Latimer (1952).

In this report we selected $\Delta G^{\circ}f = -2199.40$ kJ/mole (-525.67 kcal/mole) for SiF_6^{2-} species after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^{\circ}f = -433.00$ kJ/mole (-103.49 kcal/mole) but no $\Delta H^{\circ}f$ or s° values were listed. Naumov et al. (1971)

calculated $\Delta G^\circ_f = -434.38$ kJ/mole (-103.82 kcal/mole) from $pK = 1.26$ for the equation:

after Smith and Martell (1976). But Smith and Martell (1976) reported $pK = 1.15$ for the same reaction. Elrashidi and Lindsay (1984) reported $\Delta G^\circ_f = -437.98$ kJ/mole (-104.68 kcal/mole) from $pK = 1.15$ for the above reaction after Smith and Martell (1976).

In this report, we selected $\Delta G^\circ_f = -437.98$ kJ/mole (-104.68 kcal/mole) after Elrashidi and Lindsay (1984) for ZnF^+ species.

Wagman et al. (1982) reported $\Delta G^\circ_f = -704.64$ kJ/mole (-168.41 kcal/mole) from $\Delta H^\circ_f = -819.14$ kJ/mole (-195.78 kcal/mole) and $s^\circ = -139.7$ J/mole (-33.39 cal/mole). No further information was available for this species. We selected $\Delta G^\circ_f = -704.64$ kJ/mole (-168.41 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = -540.68$ kJ/mole (-129.22 kcal/mole) from $\Delta H^\circ_f = -572.75$ kJ/mole (-136.90 kcal/mole) and $s^\circ = 45.2$ J/mole (10.80 cal/mole). We adopted $\Delta G^\circ_f = -540.68$ kJ/mole (-129.22 kcal/mole) for NaF° after Wagman et al. (1982).

Wagman et al. (1982) calculated $\Delta G^\circ_f = -562.07$ kJ/mole (-134.34 kcal/mole) from $\Delta H^\circ_f = -585.01$ kJ/mole (-139.82 kcal/mole) and $s^\circ = 88.7$ J/mole (21.20 cal/mole). No other information was available. We

selected $\Delta G^\circ_f = -562.07$ kJ/mole (-134.34 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = -220.50$ kJ/mole (-52.70 kcal/mole) from $\Delta H^\circ_f = -261.10$ kJ/mole (-62.40 kcal/mole) and $s^\circ = -67.00$ J/mole (-16.01 kcal/mole). Naumov et al. (1971) calculated $\Delta G^\circ_f = -221.75$ kJ/mole (-53.00 kcal/mole), $\Delta H^\circ_f = -261.50$ kJ/mole (-62.50 kcal/mole), and $s^\circ = 64.01$ J/mole (15.30 cal/mole) for CuF^+ . They based their calculations on $pK = 1.23$ and $S_r = -46.02$ J/mole (-11.00 cal/mole) for the reaction:

after Sillen and Martell (1964).

Smith and Martell (1976) reported $pK = 1.2$ for the same reaction. Elrashidi and Lindsay (1984) adopted $pK = 1.2$ for the above reaction after Smith and Martell (1976) and calculated $\Delta G^\circ_f = -225.51$ kJ/mole (-53.90 kcal/mole) for CuF^+ species.

In this report, we selected $\Delta G^\circ_f = -225.51$ kJ/mole (-53.90 kcal/mole) after Elrashidi and Lindsay (1984).

Wagman et al. (1982) reported $\Delta G^\circ_f = -635.18$ kJ/mole (-151.81 kcal/mole) from $\Delta H^\circ_f = -741.15$ kJ/mole (-177.14 kcal/mole) and $s^\circ = -100.80$ J/mole (-24.10 cal/mole). Elrashidi and Lindsay recommended $\Delta G^\circ_f = -619.57$ kJ/mole (-148.08 kcal/mole). They used $\Delta H^\circ_f = -770.23$ kJ/mole (-172.14 kcal/mole) and $s^\circ = -100.83$ J/mole (-24.10 cal/mole)

after Wagman et al. (1968) to calculate $\Delta G^\circ_f = -619.57$ kJ/mole (-148.08 kcal/mole) for CdF_2° .

We adopted $\Delta G^\circ_f = -635.18$ kJ/mole (-151.81 kcal/mole) after Wagman et al. (1982).

HgF^+

Wagman et al. (1982) reported $\Delta G^\circ_f = -123.40$ kJ/mole (-29.50 kcal/mole) from $\Delta H^\circ_f = -158.20$ kJ/mole (-37.81 kcal/mole) and $s^\circ = -4.00$ J/mole (-0.95 cal/mole). Paul (1955) reported $\Delta G^\circ_f = -128.40$ kJ/mole (-30.69 kcal/mole) from $pK = 1.56$ for the reaction:

Hepler and Olofason (1975) calculated $\Delta G^\circ_f = -128.40$ kJ/mole (-30.69 kcal/mole) from $pK = 1.58$ for the above reaction. Smith and Martell (1976) recommended $\Delta G^\circ_f = -128.64$ kJ/mole (-30.74 kcal/mole) from $pK = 1.60$ for the same reaction. Elrashidi and Lindsay (1984) calculated $\Delta G^\circ_f = -128.66$ kJ/mole (-30.75 kcal/mole) from $pK = 1.60$ for the above reaction.

In this report, we selected $\Delta G^\circ_f = -128.66$ kJ/mole (-30.75 kcal/mole) after Elrashidi and Lindsay (1984).

MnF^+

Wagman et al. (1982) reported $\Delta G^\circ_f = -511.70$ kJ/mole (-122.30 kcal/mole) for MnF^+ species. They did not recommend ΔH°_f or s° values for this species. We accepted the only available value $\Delta G^\circ_f = -511.70$ kJ/mole (-122.30 kcal/mole).

CaF^+

Smith and Martell (1976) reported $pK = 1.10$ for the reaction:

No other information was available. We calculated $\Delta G^\circ_f = -844.00$ kJ/mole (-201.72 kcal/mole) using selected ΔG°_f values for Ca^{2+} and F^- .

Smith and Martell (1976) reported $\text{p}K = 1.80$ for the reaction:

We calculated $\Delta G^\circ_f = -750.60$ kJ/mole (-179.40 kcal/mole) for MgF^+ species using selected ΔG°_f values for Mg^{2+} and F^- .

Sposito and Mattigod (1980) reported $\log K^\circ = -0.60$ for the reaction:

No other information was available. We calculated $\Delta G^\circ_f = -851.44$ kJ/mole (-203.50 kcal/mole) for SrF^+ species using equation (8) and selected ΔG°_f values for Sr^{2+} and F^- .

Wagman et al. (1982) reported $\Delta G^\circ_f = -111.15$ kJ/mole (-265.57 kcal/mole) from $\Delta H^\circ_f = -1208.09$ kJ/mole (-288.74 kcal/mole) and $S^\circ = -80.8$ J/mole (-19.31 cal/mole). We adopted these values for CaF_2° species and selected $\Delta G^\circ_f = -1111.15$ kJ/mole (-265.57 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) calculated $\Delta G^\circ_f = -464.90$ kJ/mole (-111.11 kcal/mole) from $\Delta H^\circ_f = -536.80$ kJ/mole (-128.30 kcal/mole) and $s^\circ = -226.00$ J/mole (-54.01 cal/mole). We adopted $\Delta G^\circ_f = -464.90$ kJ/mole (-111.11 kcal/mole) for GaF^{2+} species.

Wagman et al. (1982) reported $\Delta G^\circ_f = -764.80$ kJ/mole (-182.80 kcal/mole) for GaF_2^+ species from $\Delta H^\circ_f = -863.20$ kJ/mole (-206.30 kcal/mole) and $s^\circ = -146.00$ J/mole (-34.90 cal/mole). We selected $\Delta G^\circ_f = -764.80$ kJ/mole (-182.80 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = -311.19$ kJ/mole (74.37 kcal/mole) from $\Delta H^\circ_f = -327.27$ kJ/mole (-78.22 kcal/mole) and $s^\circ = 111.70$ J/mole (+26.70 cal/mole). We selected $\Delta G^\circ_f = -311.19$ kJ/mole (-74.37 kcal/mole) for TlF° species.

Wagman et al. (1982) calculated $\Delta G^\circ_f = -201.69$ kJ/mole (-48.20 kcal/mole) from $\Delta H^\circ_f = -227.07$ kJ/mole (-54.27 kcal/mole) and $s^\circ = 59.00$ J/mole (14.10 cal/mole). We adopted $\Delta G^\circ_f = -201.69$ kJ/mole (-48.20 kcal/mole) for AgF° species after Wagman et al. (1982).

Wagman et al. (1982) calculated $\Delta G^\circ_f = -603.30$ kJ/mole (-144.20 kcal/mole) from $\Delta H^\circ_f = -719.20$ kJ/mole (-171.90 kcal/mole) and $s^\circ = -156.5$ J/mole (-37.40 cal/mole). We selected $\Delta G^\circ_f = -603.30$ kJ/mole (-144.20 kcal/mole) for NiF_2° species after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = -1118.35$ kJ/mole (-267.30 kcal/mole) from $\Delta H^\circ_f = -1202.90$ kJ/mole (-287.50 kcal/mole) and $s^\circ = -18.00$ J/mole (-4.30 cal/mole). We selected $\Delta G^\circ_f = -1118.35$ kJ/mole (-267.30 kcal/mole) for BaF_2° species after Wagman et al. (1982).

Naumov et al. (1971) reported $\Delta H^\circ_f = -1510.42$ kJ/mole (-361.00 kcal/mole) after Rudzites et al. (1967) and $s^\circ = 66.48$ J/mole (15.89 cal/mole) after King (1957). Wagman et al. (1982) calculated $\Delta G^\circ_f = -1425.00$ kJ/mole (-340.58 kcal/mole) from $\Delta H^\circ_f = -1504.10$ kJ/mole (-359.50 kcal/mole) and $s^\circ = -66.44$ J/mole (15.90 cal/mole). Stull et al. (1971) and CODATA (1978) listed $\Delta H^\circ_f = -1510.42$ kJ/mole (-361.00 kcal/mole) and $s^\circ = 66.48$ J/mole (15.89 cal/mole) for $\text{AlF}_3(\text{c})$ compound.

Elrashidi and Lindsay (1984) calculated $\Delta G^\circ_f = -1444.06$ kJ/mole (-345.14 kcal/mole) from $\Delta H^\circ_f = -1510.42$ kJ/mole (-361.00 kcal/mole) and $s^\circ = 66.48$ J/mole (15.89 cal/mole) after CODATA (1978). In this report, we selected $\Delta G^\circ_f = -1444.06$ kJ/mole (-345.14 kcal/mole) after Elrashidi and Lindsay (1984).

Wagman et al. (1982) reported $\Delta G^\circ_f = -647.70$ kJ/mole (-154.80 kcal/mole) from $\Delta H^\circ_f = -700.40$ kJ/mole (-167.40 kcal/mole) and $s^\circ = -77.40$ J/mole (18.50 cal/mole). Karapet'yants and Karapet'yants (1970) calculated $\Delta G^\circ_f = -649.35$ kJ/mole (-155.20 kcal/mole) from $\Delta H^\circ_f = -700.36$ kJ/mole (-167.39 kcal/mole) and $s^\circ = 83.26$ J/mole (19.90 cal/mole).

Naumov et al. (1971) reported $\Delta G^\circ_f = -651.07$ kJ/mole (-155.61 kcal/mole) from $\Delta H^\circ_f = -700.36$ kJ/mole (-167.39 kcal/mole) and $s^\circ = 89.12$ J/mole (21.30 cal/mole). In general, the reported ΔG°_f values for $\text{CdF}_2(\text{c})$ were reasonably close. We selected $\Delta G^\circ_f = -647.70$ kJ/mole (-154.80 kcal/mole) after Wagman et al. (1982) for $\text{CdF}_2(\text{c})$.

$\text{CuF}_2 \cdot 2\text{H}_2\text{O}(\text{c})$

Wagman et al. (1982) reported $\Delta G^\circ_f = -981.40$ kJ/mole (-234.56 kcal/mole). But no values for ΔH°_f or s° were recommended. We selected available $\Delta G^\circ_f = -981.40$ kJ/mole (-234.56 kcal/mole) for $\text{CuF}_2 \cdot 2\text{H}_2\text{O}(\text{c})$ after Wagman et al. (1982).

$\text{FeF}_3(\text{c})$

Stull et al. (1970) calculated $\Delta G^\circ_f = -972.33$ kJ/mole (-232.40 kcal/mole) from ΔH°_f and s° values. Elrashidi and Lindsay (1984) reported $\Delta G^\circ_f = -979.71$ kJ/mole (-234.16 kcal/mole) from $\Delta H^\circ_f = -1041.82$ kJ/mole (-249.00 kcal/mole) and $s^\circ = 98.32$ J/mole (23.50 cal/mole). We selected $\Delta G^\circ_f = -979.71$ kJ/mole (-234.16 kcal/mole) for $\text{FeF}_3(\text{c})$ after Elrashidi and Lindsay (1984).

$\text{Hg}_2\text{F}_2(\text{c})$

Stull et al. (1971) reported $\Delta G^\circ_f = -427.47$ kJ/mole (-102.17 kcal/mole) from the cell measurements of Koerber and Devries (1952). Sadiq and Lindsay (1979) recommended $\Delta G^\circ_f = -427.48$ kJ/mole (-102.17 kcal/mole) from $\Delta H^\circ_f = -485.34$ kJ/mole (-116.00 kcal/mole) and $s^\circ = -160.66$ J/mole (38.40 cal/mole). In this report, we selected $\Delta G^\circ_f = -427.48$ kJ/mole (-102.17 kcal/mole) for $\text{Hg}_2\text{F}_2(\text{c})$ after Sadiq and Lindsay (1979).

KF(c)

Wagman et al. (1982) reported $\Delta G^\circ_f = -537.75$ kJ/mole (-128.52 kcal/mole) from $\Delta H^\circ_f = -567.27$ kJ/mole (-135.58 kcal/mole) and $s^\circ = 66.57$ J/mole (15.91 cal/mole). Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ_f = -537.70$ kJ/mole (-128.51 kcal/mole) from $\Delta H^\circ_f = -567.35$ kJ/mole (-135.60 kcal/mole) and $s^\circ = 66.60$ J/mole (15.92 cal/mole). Naumov et al. (1971) reported $\Delta G^\circ_f = -538.95$ kJ/mole (-128.81 kcal/mole) from $\Delta H^\circ_f = -568.44$ kJ/mole (-135.86 kcal/mole) and $s^\circ = 66.57$ J/mole (15.91 cal/mole).

We selected $\Delta G^\circ_f = -537.75$ kJ/mole (-128.52 kcal/mole) for KF(c) after Wagman et al. (1982).

MgF₂(c)

Wagman et al. (1982) reported $\Delta G^\circ_f = -1070.20$ kJ/mole (-255.78 kcal/mole) from $\Delta H^\circ_f = -1123.40$ kJ/mole (-268.50 kcal/mole) and $s^\circ = 57.24$ J/mole (13.68 cal/mole). Naumov et al. (1971) calculated $\Delta G^\circ_f = -1071.10$ kJ/mole (-256.00 kcal/mole) from $\Delta H^\circ_f = -1124.24$ kJ/mole (-268.70 kcal/mole) and $s^\circ = 57.23$ J/mole (13.68 cal/mole). Stull et al. (1971) reported $\Delta G^\circ_f = -1071.10$ kJ/mole (-256.00 kcal/mole) from similar ΔH°_f and s° values as reported by Naumov et al. (1971).

CODATA (1978) also reported similar $\Delta H^\circ_f = -1124.24$ kJ/mole (-268.70 kcal/mole) and $s^\circ = 57.23$ kJ/mole (13.68 cal/mole) values for MgF₂(c). We selected $\Delta G^\circ_f = -1070.20$ kJ/mole (-255.78 kcal/mole) after Wagman et al. (1982).

NaF(c)

Robie and Waldbaum (1968) reported $\Delta G^\circ_f = -543.13$ kJ/mole (-129.81 kcal/mole) from $\Delta H^\circ_f = -573.33$ kJ/mole (-137.03 kcal/mole) and $s^\circ =$

-51.30 J/mole (12.26 cal/mole). Wagman et al. (1982) calculated $\Delta G^\circ_f = -543.50$ kJ/mole (-129.90 kcal/mole) from $\Delta H^\circ_f = -573.65$ kJ/mole (-137.10 kcal/mole) and $s^\circ = 51.46$ J/mole (12.30 cal/mole). Naumov et al. (1971) calculated $\Delta G^\circ_f = -546.51$ kJ/mole (-130.62 cal/mole) from $\Delta H^\circ_f = -575.26$ kJ/mole (-137.49 kcal/mole) and $s^\circ = 51.30$ J/mole (12.26 cal/mole).

We adopted $\Delta G^\circ_f = -543.50$ kJ/mole (-129.90 kcal/mole) after Wagman et al. (1982) for NaF(c).

PbF₂(c)

Wagman et al. (1982) reported $\Delta G^\circ_f = -617.10$ kJ/mole (-147.49 kcal/mole) from $\Delta H^\circ_f = -664.00$ kJ/mole (-158.70 kcal/mole) and $s^\circ = 110.50$ J/mole (26.41 cal/mole). Naumov et al. (1971) calculated $\Delta G^\circ_f = -627.60$ kJ/mole (-150.00 kcal/mole) from $\Delta H^\circ_f = -678.64$ kJ/mole (-162.20 kcal/mole) and $s^\circ = 96.23$ J/mole (23.00 cal/mole). Karapet'yants and Karapet'yants (1970) calculated $\Delta G^\circ_f = -715.88$ kJ/mole (-148.10 kcal/mole) from $\Delta H^\circ_f = -662.32$ kJ/mole (158.30 kcal/mole) and $s^\circ = 112.97$ J/mole (27.00 cal/mole).

In this report, we selected $\Delta G^\circ_f = -617.10$ kJ/mole (147.49 kcal/mole) after Wagman et al. (1982) for PbF₂(c).

ZnF₂(c)

Wagman et al. (1982) reported $\Delta G^\circ_f = -713.30$ kJ/mole (-170.48 kcal/mole) from $\Delta H^\circ_f = -764.40$ kJ/mole (-186.70 kcal/mole) and $s^\circ = 73.68$ J/mole (17.60 cal/mole). Karapet'yants and Karapet'yants (1971) and Naumov et al. (1971) also reported similar ΔG°_f values for ZnF₂(c). We selected $\Delta G^\circ_f = -713.30$ kJ/mole (-170.48 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = -2754.20$ kJ/mole (658.27 kcal/mole) from $\Delta H^\circ_f = -2909.60$ kJ/mole (-695.41 kcal/mole) and $s^\circ = 207.10$ J/mole (49.50 cal/mole). Karapet'yants and Karapet'yants (1971) listed $\Delta G^\circ_f = -2553.91$ kJ/mole (-610.40 kcal/mole) from $\Delta H^\circ_f = -2849.72$ kJ/mole (-681.10 kcal/mole) and $s^\circ = 214.64$ J/mole (51.30 cal/mole) after Latimer (1952). Naumov et al. (1972) calculated $\Delta G^\circ_f = -2757.25$ kJ/mole from $\Delta H^\circ_f = -2917.80$ kJ/mole (-697.37 kcal/mole) and $s^\circ = 190.80$ J/mole (45.60 cal/mole).

We accepted $\Delta G^\circ_f = -2754.20$ kJ/mole (-658.27 cal/mole) for $\text{Na}_2\text{SiF}_6(\text{c})$ after Wagman et al. (1982).

Naumov et al. (1971) calculated $\Delta G^\circ_f = -3152.64$ kJ/mole (-753.50 kcal/mole) from $\Delta H^\circ_f = -3322.51$ kJ/mole (-794.10 kcal/mole) and $s^\circ = 238.49$ J/mole (57.00 cal/mole). Robie and Waldbaum (1968) listed $\Delta G^\circ_f = -3140.90$ kJ/mole (-750.69 kcal/mole) from $\Delta H^\circ_f = -3305.36$ kJ/mole (-759.00 kcal/mole) after Stull et al. (1960) and $s^\circ = +238.40$ J/mole (56.98 cal/mole) after Kelly and King (1961). Wagman et al. (1982) reported $\Delta G^\circ_f = -3136.60$ kJ/mole (-749.67 kcal/mole) from $\Delta H^\circ_f = -3301.20$ kJ/mole (-789.00 kcal/mole) and $s^\circ = 238.50$ J/mole (57.00 cal/mole).

Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ_f = -3015.82$ kJ/mole (-720.80 kcal/mole) from $\Delta H^\circ_f = -3283.60$ kJ/mole (-784.80 kcal/mole) after Coughlin (1958) and $s^\circ = 238.40$ J/mole (56.98 cal/mole). In this report, we adopted $\Delta G^\circ_f = -3136.60$ kJ/mole (-739.67 kcal/mole) for $\text{Na}_3\text{AlF}_6(\text{c})$ after Wagman et al. (1982).

Westerich and Navrotsky (1981) calculated $\Delta G^\circ_f = -12117.78$ kJ/mole (-2896.22 kcal/mole) from $\Delta H^\circ_f = -12799.48$ kJ/mole (-3059.15 kcal/mole) and $s^\circ = 2287.60$ J/mole (546.75 cal/mole). They used $\Delta H^\circ_r = -349.36$ kJ/mole (-83.50 kcal/mole) for the reaction:

using the volume-corrected algorithm method described by Helgeson et al. (1978), authors determined $s^\circ = 2287.60$ J/mole (546.75 cal/mole) for this mineral. We adopted $\Delta G^\circ_f = -12117.78$ kJ/mole (-2896.22 kcal/mole) after Westrich and Navrotsky (1981).

Wagman et al. (1982) listed $\Delta G^\circ_f = -2006.10$ kJ/mole (-479.47 kcal/mole) from $\Delta H^\circ_f = -2180.30$ kJ/mole (-521.10 kcal/mole) and $s^\circ = 205.00$ J/mole (49.00 cal/mole). No other compiler listed thermodynamic data for this compound.

We adopted the only available $\Delta G^\circ_f = -2006.10$ kJ/mole (-479.47 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) listed $\Delta G^\circ_f = -2798.60$ kJ/mole (-668.88 kcal/mole) from $\Delta H^\circ_f = -2956.00$ kJ/mole (-706.50 kcal/mole) and $s^\circ = 225.90$ J/mole (53.99 cal/mole). Karapet'yants and Karapet'yants (1970) recommended $\Delta G^\circ_f = -2723.78$ kJ/mole (-651.00 kcal/mole) and $s^\circ = 228.86$ J/mole (54.70 cal/mole) for this mineral after Latimer (1952). Authors did not list any ΔH°_f values for this mineral.

Naumov et al. (1971) recommended $\Delta G^\circ_f = -2810.40$ kJ/mole (-671.70 kcal/mole), $\Delta H^\circ_f = -2965.62$ kJ/mole (708.80 kcal/mole), and $s^\circ = 235.56$ J/mole (56.30 cal/mole) from $pK = 6.47$ for the reaction:

In this report, we selected $\Delta G^\circ_f = -2798.60$ kJ/mole (-668.88 kcal/mole) after Wagman et al. (1982) for K_2SiF_6 (hieratite) mineral.

$KMg_3AlSi_3O_{10}F_2$ (fluorophlogopite)

The standard free energy of formation (ΔG°_f) reported by different investigators are listed below:

Investigator	ΔG°_f	
	(kJ/mole)	(kcal/mole)
Wagman et al. (1982)	-6044.00	-1444.55
Naumov et al. (1971)	-6026.21	-1440.30
Robie and Waldbaum (1968)	-6022.95	-1439.52
Sadiq and Lindsay (1979)	-6115.46	-1461.63
Westrich and Navrotsky (1981)	-6019.68	-1438.74

Kelly et al. (1959) reported $\Delta H^\circ_f = -31.21$ kJ/mole for the reaction:

This source was adopted by almost all the compilers using new available data. However, Sadiq and Lindsay (1979) made critical evaluation of ΔG°_f of this mineral. They used $\Delta H^\circ_f = -6392.90$ kJ/mole (-1527.94

kcal/mole) and $s^\circ = 336.30$ J/mole (80.38 cal/mole) for fluorphlogopite after Hemingway and Robie (1977) to calculate $\Delta G^\circ f$ value for flurphlogopite mineral.

In this report, we accepted $\Delta G^\circ f = -6115.46$ kJ/mole (-1461.63 kcal/mole) for this mineral after Sadiq and Lindsay (1979).

$\text{Ca}_5(\text{PO}_4)_3\text{F}$ (fluorapatite)

The standard free energy of formation ($\Delta G^\circ f$) reported by different compiling for $\text{Ca}_5(\text{PO}_4)_3\text{F}$ are listed below:

Compiler	$\Delta G^\circ f$	
	(kJ/mole)	(kcal/mole)
Parker et al. (1971)	-6491.47	-1551.50
Naumov et al. (1971)	-6507.37	-1555.30
Sadiq and Lindsay (1979)	-6474.19	-1547.37
Westrich and Navrotsky (1981)	-6501.51	-1553.90

Parker et al. (1971) and Naumov et al. (1971) reported $\Delta G^\circ f$ values for fluorapatite from $\Delta H^\circ f$ and s° values. Fan et al. (1962) reported $\text{pk} = 120.86$ on the reaction:

which determined $\Delta G^\circ f = -12952.87$ kJ/mole (-3095.81 kcal/mole) for $\text{Ca}_{10}\text{F}_2(\text{PO}_4)_6(\text{c})$ and $\Delta G^\circ f = -6476.43$ kJ/mole (-1547.90 kcal/mole) for $\text{Ca}_5(\text{PO}_4)_3\text{F}$.

Chien and Black (1976) recommended $\text{pk} = 119.20$ for the same equation which determined $\Delta G^\circ f = -12948.35$ kJ/mole (-3094.73 kcal/mole) for $\text{Ca}_{10}(\text{PO}_4)_6\text{F}_2(\text{c})$ and $\Delta G^\circ f = -6474.17$ kJ/mole (-1547.36 kcal/mole for

$\text{Ca}_5(\text{PO}_4)_3\text{F}$. These values are similar to that calculated from Farr et al. (1962) solubility data. Sadiq and Lindsay (1979) accepted solubility data of Chien and Black (1976) and recommended $\Delta G^\circ_f = -6474.19$ kJ/mole (-1547.37 kcal/mole) for $\text{Ca}_5(\text{PO}_4)_3(\text{c})$.

In this report, we selected $\Delta G^\circ_f = -6474.19$ kJ/mole (-1547.37 kcal/mole) for $\text{Ca}_5(\text{PO}_4)_3\text{F}(\text{c})$ after Sadiq and Lindsay (1979).

$\text{Ca}_4\text{Si}_2\text{O}_7\text{F}_2$ (cuspidine)

Naumov et al. (1971) listed $\Delta G^\circ_f = -4988.58$ kJ/mole (-1192.30 kcal/mole) from $\Delta H^\circ_f = -5240.46$ kJ/mole (-1252.50 kcal/mole) and $s^\circ = 279.90$ J/mole (66.90 cal/mole) for $\text{Ca}_4\text{Si}_2\text{O}_7\text{F}_2$ mineral. No other information was available for $\text{Ca}_4\text{Si}_2\text{O}_7\text{F}_2$ mineral.

We selected only available $\Delta G^\circ_f = -4988.58$ kJ/mole (-1192.30 kcal/mole) for cuspidine mineral after Naumov et al. (1971).

$(\text{NH}_4)_2\text{SiF}_6$ (bararite)

Naumov et al. (1971) calculated $\Delta G^\circ_f = -2372.24$ kJ/mole (-566.98 kcal/mole) from $\Delta H^\circ_f = -2688.43$ kJ/mole (-642.55 kcal/mole) and $s^\circ = 280.24$ J/mole (66.98 cal/mole). No other information was available. We accepted $\Delta G^\circ_f = -2372.24$ kJ/mole (-566.98 kcal/mole) for bararite mineral after Naumov et al. (1971).

$\text{Pb}_5(\text{PO}_4)_3\text{F}$ (fluoropyromorphite)

Nriagu (1973) studied the reaction:

and reported $\text{pk} = 71.60$ for this reaction. Sadiq and Lindsay (1979) adopted this pk value and reported $\Delta G^\circ_f = -3893.75$ kJ/mole (-930.63

kcal/mole) for this mineral. We adopted $\Delta G^\circ_f = -3893.75$ kJ/mole (930.63 kcal/mole) for $\text{Pb}_5(\text{PO}_4)_3\text{F}$ mineral after Sadiq and Lindsay (1979).

CaF_2 (fluorite)

The standard free energy of formation of CaF_2 reported by different investigators are listed below:

Investigator	ΔG°_f	
	(kJ/mole)	(kcal/mole)
Wagman et al. (1982)	-1167.30	-278.99
Helgeson et al. (1978)	-1173.58	-280.49
Stull et al. (1971)	-1173.53	-280.48
Naumov et al. (1971)	-1175.99	-281.07
Karapet'yants and Karapet'yants (1970)	-1163.15	-278.00
Robie and Waldbaum (1968)	-1162.31	-277.80
Sadiq and Lindsay (1979)	-1182.31	-282.58

Naumov et al. (1971) reported ΔG°_f value for CaF_2 (fluorite) from $\text{pk} = 11.09$ for the reaction:

Smith and Martell (1976) reported $\text{pk} = 10.41$ for the same reaction which corresponds to $\Delta G^\circ_f = -1182.31$ kJ/mole (-282.58 kcal/mole). Elrashidi and Lindsay (1984) reported $\Delta G^\circ_f = -1182.31$ kJ/mole (-282.5 kcal/mole) from $\text{pk} = 11.41$ for the above reaction after Smith and Martell (1976).

Recently, Street and Elwali (1983) confirmed the solubility data reported by Smith and Martell (1976). Sadiq and Lindsay critically

evaluated available thermodynamic data for $\text{CaF}_2(\text{c})$ and reported similar $\Delta G^\circ_f = -1182.31 \text{ kJ/mole}$ ($-282.58 \text{ kcal/mole}$). In this report, we adopted $\Delta G^\circ_f = -1182.31 \text{ kJ/mole}$ ($-282.58 \text{ kcal/mole}$) for CaF_2 (fluorite) after Elrashidi and Lindsay (1984).

MOLYBDENUM

Wagman et al. (1982) reported $\Delta G^\circ_f = -836.30 \text{ kJ/mole}$ ($-199.88 \text{ kcal/mole}$) from $\Delta H^\circ_f = -997.70 \text{ kJ/mole}$ ($-238.45 \text{ kcal/mole}$) and $s^\circ = 27.20 \text{ J/mole}$ (6.50 cal/mole). Sadiq and Lindsay (1979) critically evaluated ΔG°_f values for MoO_4^{2-} and recommended $\Delta G^\circ_f = -836.13 \text{ kJ/mole}$ ($-199.84 \text{ kcal/mole}$) from $\text{pk} = 12.10$ for the reaction:

after Smith and Martell (1976). Sadiq and Lindsay (1979) calculated ΔG°_f value for MoO_4^{2-} is in good agreement with Wagman et al. (1982). Therefore, we selected $\Delta G^\circ_f = -836.30 \text{ kJ/mole}$ ($-199.88 \text{ kcal/mole}$) for MoO_4 species after Wagman et al. (1982).

Naumov et al. (1971) recommended $\Delta G^\circ_f = -411.28 \text{ kJ/mole}$ (-98.30 kcal/mole) from $\text{pk} = 3.45$ for the reaction:

No other information was available. Therefore, we adopted the available value after Naumov et al. (1971) for MoO_2^{2+} species.

Naumov et al. (1971) reported $\Delta G^\circ_f = -645.88$ kJ/mole (-154.37 kcal/mole). Authors based their calculation on $\text{pk} = 0.45$ for the reaction:

Sadiq and Lindsay (1979) calculated $\Delta G^\circ_f = -645.75$ kJ/mole (-154.34 kcal/mole) from the above pk value. No other information was available. We selected $\Delta G^\circ_f = -645.75$ kJ/mole (-154.34 kcal/mole) for $\text{MoO}_2(\text{OH})^+$ species after Sadiq and Lindsay (1979).

Naumov et al. (1971) reported $\Delta G^\circ_f = -866.63$ kJ/mole (-207.13 kcal/mole). Garrels and Christ (1965) listed $\Delta G^\circ_f = -893.70$ kJ/mole (-213.60 kcal/mole) from ΔH°_f and s° values. Sadiq and Lindsay (1979) calculated $\Delta G^\circ_f = -860.31$ kJ/mole (-205.62 kcal/mole) from $\text{pk} = -4.24$ for the reaction:

after Rohwer and Cruywagen (1963) and Smith and Martell (1976). No other information was available. We selected $\text{pk} = -4.24$ (Smith and Martell, 1976) and calculated $\Delta G^\circ_f = -860.48$ kJ/mole (-205.66 kcal/mole) for HMoO_4^{2-} species.

Latimer (1952) reported $\Delta G^\circ_f = -949.76$ kJ/mole (-227.00 kcal/mole) from estimated $\Delta H^\circ_f = -1072.77$ kJ/mole (-256.40 kcal/mole) and $s^\circ =$

150.62 J/mole (36.00 cal/mole). Naumov et al. (1971) reported $\Delta G^\circ_f = -877.13$ kJ/mole (-209.64 kcal/mole) from ΔH°_f and s° values.

Wagman et al. (1982) listed $\Delta H^\circ_f = -1007.50$ kJ/mole (-240.80 kcal/mole). But the author did not list any ΔG°_f or s° values for this species.

Sadiq and Lindsay (1979) calculated $\Delta G^\circ_f = -883.15$ kJ/mole (-211.08 kcal/mole) from $pK = -4.0$ for the reaction:

after Rohwer and Cruywagen (1963). No other information was available. We calculated $\Delta G^\circ_f = -883.28$ kJ/mole (-211.11 kcal/mole) using $pK = -4.0$ for the above equation.

MoO_3 (molybdate)

Wagman et al. (1982) listed $\Delta G^\circ_f = -667.97$ kJ/mole (-159.64 kcal/mole) from $\Delta H^\circ_f = -745.09$ kJ/mole (-178.08 kcal/mole) and $s^\circ = 77.74$ J/mole (18.58 cal/mole). Stull et al. (1971) reported $\Delta G^\circ_f = -668.10$ kJ/mole (-159.68 kcal/mole) from $\Delta H^\circ_f = -745.17$ kJ/mole (-178.10 kcal/mole) and $s^\circ = 77.73$ J/mole (18.58 cal/mole).

Sadiq and Lindsay (1979) calculated $\Delta G^\circ_f = -668.01$ kJ/mole (-159.66 kcal/mole) from $\Delta H^\circ_f = -745.08$ kJ/mole (-178.08 kcal/mole) after Mah (1957) and Staskiewicz et al. (1955) and $s^\circ = 77.73$ J/mole (18.58 cal/mole) after Kelley and King (1961).

Listed ΔG°_f values for MoO_3 (molybdate) by different investigators are in agreement. Therefore, we selected $\Delta G^\circ_f = -667.97$ kJ/mole (-159.64 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta H^\circ_f = -1046.00$ kJ/mole (-250.00 kcal/mole). But the authors did not list any ΔG°_f or s° values for this species. Sadiq and Lindsay (1979) calculated $\Delta G^\circ_f = -912.44$ kJ/mole (-218.08 kcal/mole) from $\Delta H^\circ_f = -1046.00$ kJ/mole (-250.00 kcal/mole) after Graham and Hepler (1956) and $s^\circ = 121.33$ J/mole (29.00 cal/mole) after Dellien et al. (1976).

No other information was available. Therefore, we selected $\Delta G^\circ_f = -912.44$ kJ/mole (-218.08 kcal/mole) after Sadiq and Lindsay (1979).

Latimer (1952) reported $\Delta G^\circ_f = -225.09$ kJ/mole (-53.80 kcal/mole) from $\Delta H^\circ_f = -232.21$ kJ/mole (-55.50 kcal/mole) and $s^\circ = 63.17$ J/mole (15.10 cal/mole). Wagman et al. (1982) listed $\Delta G^\circ_f = -225.90$ kJ/mole (-53.99 kcal/mole) from $\Delta H^\circ_f = -235.10$ kJ/mole (-56.19 kcal/mole) and $s^\circ = 62.59$ J/mole (14.96 cal/mole). Sadiq and Lindsay (1979) critically evaluated ΔH°_f and s° values for MoS_2 (molybdenite) and calculated $\Delta G^\circ_f = -266.47$ kJ/mole (-63.69 kcal/mole). The authors adopted $\Delta H^\circ_f = -275.30$ kJ/mole (-65.80 kcal/mole) after O'Hare et al. (1970) and $s^\circ = 62.59$ J/mole (14.96 cal/mole) after Westrum and McBride (1955). Recently, Chase et al. (1982) reported $\Delta G^\circ_f = -267.14$ kJ/mole (-63.85 kcal/mole) which is similar to Sadiq and Lindsay (1979) selection.

In this report, we selected $\Delta G^\circ_f = -266.47$ kJ/mole (-63.69 kcal/mole) for MoO_2 species after Sadiq and Lindsay (1979).

Sadiq and Lindsay (1979) calculated $\Delta G^\circ_f = -747.89$ kJ/mole (-178.75 kcal/mole) from $\text{pK} = 11.55$ for the reaction:

after Smith and Martell (1976). Similar pk values for the above reaction were reported by Muldrew and Hepler (1956) and Pan (1954).

Latimer (1952) reported $\Delta G^\circ_f = -821.73$ kJ/mole (-196.40 kcal/mole). But the author did not report any ΔH°_f or s° values.

The equilibrium constant ($\log k^\circ$) for the following reaction:

reported by various investigators and geochemical models are summarized below:

Investigator/Geochemical Model	$\log k^\circ$
Smith and Martell (1976)	-11.55
Muldrew and Hepler (1956)	-11.55
Pan (1954)	-11.55
Ricci and Linke (1951)	-10.51
Lindsay (1979)	-11.55
WATEQFC (Runnells and Lindberg, 1980)	-11.55
GEOCHEM (Sposito and Mattigod, 1980)	-11.42

Reported $\log k$ values are in good agreement except Ricci and Linke (1951). Therefore, we selected $\text{pk} = 11.55$ for the above reaction after Smith and Martell and calculated $\Delta G^\circ_f = -748.01$ kJ/mole (-178.78 kcal/mole) for $\text{Ag}_2\text{MoO}_4(\text{c})$.

BaMoO₄(c)

Latimer (1952) reported $\Delta G^\circ_f = -1075.28$ kJ/mole (-257.00 kcal/mole) from $\Delta H^\circ_f = -1179.88$ kJ/mole (-282.00 kcal/mole) and estimated $s^\circ = 153.97$ J/mole (36.80 cal/mole). Similar ΔG°_f , ΔH°_f and s° values reported by Garrels and Christ (1965).

Wagman et al. (1982) reported $\Delta G^\circ_f = -1439.60$ kJ/mole (-344.07 kcal/mole) from $\Delta H^\circ_f = -1548.00$ kJ/mole (-369.98 kcal/mole) and $s^\circ = 138.00$ J/mole (32.98 cal/mole). No other information was available. In this report, we selected $\Delta G^\circ_f = -1439.60$ kJ/mole (-344.07 kcal/mole) for BaMoO₄(c) after Wagman et al. (1982).

CaMoO₄(c)

Wagman et al. (1982) listed $\Delta G^\circ_f = -1434.60$ kJ/mole (-342.87 kcal/mole) from $\Delta H^\circ_f = -1541.40$ kJ/mole (-368.40 kcal/mole) and $s^\circ = 122.60$ J/mole (29.30 cal/mole). Sadiq and Lindsay (1979) reported $\Delta G^\circ_f = -1435.90$ kJ/mole (-343.19 kcal/mole) from $\Delta H^\circ_f = -1545.99$ kJ/mole (-369.50 kcal/mole) after Barany (1962) and $s^\circ = 122.59$ J/mole (29.30 cal/mole) after Weller and King (1963).

The equilibrium constant ($\log k^\circ$) for the following reaction:

reported by various investigators and geochemical models are summarized below:

Investigator/Geochemical Model	$\log k^\circ$
Smith and Martell (1976)	-8.00
Lindsay (1979)	-7.94
GEOCHEM (Sposito and Mattigod, 1980)	-7.41
WATEQFC (Runnells and Lindberg, 1980)	-8.36

The equilibrium constant reported by Lindsay (1979) calculated from selected ΔG°_f values of Sadiq and Lindsay (1979) is in good agreement with Smith and Martell (1979). In this report, we adopted $\log k^\circ = -7.94$ (Lindsay, 1979) for the above reaction and calculated $\Delta G^\circ_f = -1435.99$ kJ/mole (-343.21 kcal/mole) for $\text{CaMoO}_4(\text{c})$.

$\text{CuMoO}_4(\text{c})$

Latimer (1952) listed $\Delta H^\circ_f = -948.09$ kJ/mole (-266.60 kcal/mole) and estimated $s^\circ = 141.41$ J/mole (33.80 cal/mole) for $\text{CuMoO}_4(\text{c})$.

Naumov et al. (1971) recommended $\Delta G^\circ_f = -809.60$ kJ/mole (-193.50 kcal/mole) from $\text{pk} = 6.48$ for the reaction:

No other information was available for this compound. Therefore, we adopted $\Delta G^\circ_f = -809.60$ kJ/mole (-193.50 kcal/mole) for $\text{CuMoO}_4(\text{c})$ after Naumov et al. (1971).

$\text{FeMoO}_4(\text{c})$

Latimer (1951) reported $\Delta G^\circ_f = -982.40$ kJ/mole (-234.80 kcal/mole) from $\Delta H^\circ_f = -1077.38$ kJ/mole (-257.50 kcal/mole) and estimated $s^\circ = 139.74$ J/mole (33.40 cal/mole). Garrels and Christ (1965) listed similar ΔG°_f , ΔH°_f , and s° values from Latimer (1951).

Wagman et al. (1982) recommended $\Delta G^\circ_f = -975.00$ kJ/mole (-233.03 kcal/mole) from $\Delta H^\circ_f = -1075.00$ kJ/mole (-256.93 kcal/mole) and $s^\circ = 129.30$ J/mole (30.90 cal/mole). Naumov et al. (1971) reported $\Delta G^\circ_f = -974.28$ kJ/mole (-232.86 kcal/mole) from $\text{pk} = 7.7$ for the reaction:

O'Hare et al. (1974) reported $p_k = 9.11$ for the same reaction, which determined $\Delta G^\circ_f = -979.38$ kJ/mole (-234.07 kcal/mole) for $\text{FeMoO}_4(\text{c})$.

Sadiq and Lindsay (1979) critically evaluated ΔG°_f for $\text{FeMoO}_4(\text{c})$ and reported that calorimetric data of Wagman et al. (1982) and Latimer (1951) and solubility measurements of O'Hare et al. (1974) had higher uncertainties. Therefore, authors selected $p_k = 7.7$ for the above reaction after Naumov et al. (1971) and calculated $\Delta G^\circ_f = -971.27$ kJ/mole (-232.14 kcal/mole) for $\text{FeMoO}_4(\text{c})$ to be internally consistent to their selection.

In this report, we selected $p_k = 7.7$ (Naumov et al., 1971) for the above reaction and calculated $\Delta G^\circ_f = -971.44$ kJ/mole (-232.18 kcal/mole) for $\text{FeMoO}_4(\text{c})$ to be internally consistent to our selection.

$\text{Li}_2\text{MoO}_4(\text{c})$

Wagman et al. (1982) listed $\Delta G^\circ_f = -1409.50$ kJ/mole (336.87 kcal/mole) from $\Delta H^\circ_f = -1520.30$ kJ/mole (-363.36 kcal/mole) and $s^\circ = 126.00$ J/mole (-30.11 cal/mole). No other ingredients was available. We selected the available ΔG°_f value for $\text{Li}_2\text{MoO}_4(\text{c})$.

$\text{MgMoO}_4(\text{c})$

Wagman et al. (1982) recommended $\Delta G^\circ_f = -1295.68$ kJ/mole (-309.67 kcal/mole) from $\Delta H^\circ_f = -1400.85$ kJ/mole (-334.81 kcal/mole) and $s^\circ = 118.80$ J/mole (28.39 cal/mole). Naumov et al. (1971) reported $\Delta G^\circ_f = -1295.78$ kJ/mole (-309.70 kcal/mole) from $\Delta H^\circ_f = -1400.88$ kJ/mole (-334.82 kcal/mole) after Barany (1962) and $s^\circ = 118.82$ J/mole (28.40 cal/mole) after Weller and King (1963). Dellien et al. (1976) reported similar values for $\text{MgMoO}_4(\text{c})$. Sadiq and Lindsay (1979) adopted Naumov et al. (1971) values.

Reported ΔG°_f values for $\text{MgMoO}_4(\text{c})$ are in good agreement. Therefore, we selected $\Delta G^\circ_f = -1295.68 \text{ kJ/mole}$ ($-309.67 \text{ kcal/mole}$) for $\text{MgMoO}_4(\text{c})$ after Wagman et al. (1982).

$\text{MnMoO}_4(\text{c})$

Sadiq and Lindsay (1979) recommended $\Delta G^\circ_f = -1090.30 \text{ kJ/mole}$ ($-260.59 \text{ kcal/mole}$) from $\Delta H^\circ_f = -1191.35 \text{ kJ/mole}$ ($-284.74 \text{ kcal/mole}$) after Barany (1965) and $s^\circ = 131.79 \text{ J/mole}$ (31.50 cal/mole) after Naumov et al. (1971). Wagman et al. (1982) reported $\Delta H^\circ_f = -1191.31 \text{ kJ/mole}$ ($-284.73 \text{ kcal/mole}$), which is similar to Barany (1965). But the authors did not list ΔG°_f or s° values for $\text{MnMoO}_4(\text{c})$.

Naumov et al. (1971) reported $\Delta G^\circ_f = -1090.39 \text{ kJ/mole}$ ($-260.61 \text{ kcal/mole}$) from ΔH°_r for the reaction:

In this report, we selected $\Delta G^\circ_f = -1090.39 \text{ kJ/mole}$ ($-260.61 \text{ kcal/mole}$) for $\text{MnMoO}_4(\text{c})$ compound after Naumov et al. (1971).

$\text{Na}_2\text{MoO}_4(\text{c})$

Wagman et al. (1982) reported $\Delta G^\circ_f = -1354.34 \text{ kJ/mole}$ ($-323.69 \text{ kcal/mole}$) from $\Delta H^\circ_f = -1468.12 \text{ kJ/mole}$ ($-350.89 \text{ kcal/mole}$) and $s^\circ = 159.70 \text{ J/mole}$ (38.17 cal/mole). WATEQFC (Runnells and Lindberg, 1980) reported $\log K^\circ = 1.18$ for the reaction:

This equilibrium constant yield $\Delta G^\circ_f = -1353.31 \text{ kJ/mole}$ ($-323.45 \text{ kcal/mole}$) which is in good agreement with ΔG°_f value reported by Wagman

et al. (1982). Therefore, we selected $\Delta G^\circ_f = -1354.34$ kJ/mole (-323.69 kcal/mole) for $\text{Na}_2\text{MoO}_4(\text{c})$ after Wagman et al. (1982).

Wagman et al. (1982) listed $\Delta G^\circ_f = -681.90$ kJ/mole (-162.97 kcal/mole) from $\Delta H^\circ_f = -786.60$ kJ/mole (-188.00 kcal/mole) and $s^\circ = 172.80$ J/mole (41.30 cal/mole). No other information was available. We adopted only available ΔG°_f value for $\text{Ag}_2\text{MoO}_4^\circ$.

Wagman et al. (1982) recommended $\Delta G^\circ_f = -1389.90$ kJ/mole (-332.19 kcal/mole) from $\Delta H^\circ_f = -154.50$ kJ/mole (-368.18 kcal/mole) and $s^\circ = 25.90$ J/mole (6.19 cal/mole). We adopted the only available ΔG°_f value for CaMoO_4° .

Wagman et al. (1982) recommended $\Delta G^\circ_f = -1360.20$ kJ/mole (-325.09 kcal/mole) from $\Delta H^\circ_f = -1478.20$ kJ/mole (-353.30 kcal/mole) and $s^\circ = 145.20$ J/mole (34.70 cal/mole). No other information was available. We selected the only available ΔG°_f value for $\text{Na}_2\text{MoO}_4^\circ$.

Wagman et al. (1982) listed $\Delta G^\circ_f = -1402.80$ kJ/mole (-335.27 kcal/mole) from $\Delta H^\circ_f = -1502.50$ kJ/mole (-359.10 kcal/mole) and $s^\circ = 232.20$ J/mole (55.49 cal/mole). No other information was available. We adopted the available ΔG°_f value for $\text{K}_2\text{MoO}_4^\circ$.

Wagman et al. (1982) reported $\Delta G^\circ_f = -951.40$ kJ/mole (-227.39 kcal/mole) from $\Delta H^\circ_f = -1051.90$ kJ/mole (-251.41 kcal/mole) and $s^\circ =$

166.10 J/mole (39.70 cal/mole). Latimer (1952) listed $pK = 5.39$ for the reaction:

Smith and Martell (1976) reported $pK = 13.0$ for the same reaction from Muldrow and Hepler (1958). But the authors considered this pK value to be questionable because of the difficulties associated with measuring of solubility of $\text{PbMoO}_4(\text{c})$. GEOCHEM (Runnells and Lindberg, 1980) and WATEQFC (Sposito and Mattigod, 1980) reported $pK = 13.0$ and 15.07 , respectively.

Sadiq and Lindsay (1979) calculated $\Delta G^\circ_f = -952.36$ kJ/mole (-227.62 kcal/mole) from $\Delta H^\circ_f = -1052.94$ kJ/mole (-251.66 kcal/mole) after Dillien et al. (1976) and $s^\circ = 166.10$ J/mole (39.70 cal/mole) after Weller and Kelley (1964). These values are similar to values reported by Wagman et al. (1982).

In this report, we selected $\Delta G^\circ_f = -952.36$ kJ/mole (-227.62 kcal/mole) after Sadiq and Lindsay (1979).

Naumov et al. (1971) recommended $\Delta G^\circ_f = -1010.85$ kJ/mole (-241.60 kcal/mole) from $pK = 4.49$ for the reaction:

No other information was available. Therefore, we selected $pK = 4.49$ for the above reaction after Naumov et al. (1971) and calculated $\Delta G^\circ_f = -1009.09$ kJ/mole (-241.18 kcal/mole) for $\text{ZnMoO}_4(\text{c})$ to be internally consistent to our selection.

SELENIUM

Wagman et al. (1982) reported $\Delta G^\circ_f = -129.30$ kJ/mole (-30.90 kcal/mole). Authors did not list ΔH°_f and s° values for this species. Naumov et al. (1971) listed $\Delta G^\circ_f = -129.30$ kJ/mole (-30.90 kcal/mole) from $\Delta H^\circ_f = 64.01$ kJ/mole (15.30 kcal/mole) and $s^\circ = -46.02$ J/mole (-11.00 cal/mole). Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ_f = -129.30$ kJ/mole (-30.90 kcal/mole) from $\Delta H^\circ_f = 74.05$ kJ/mole (17.70 kcal/mole) and $s^\circ = 173.63$ J/mole (41.50 cal/mole). The reported ΔH°_f and s° values differ significantly for Se^{2-} species. However, ΔG°_f values agree very well. Therefore, we selected $\Delta G^\circ_f = -129.30$ kJ/mole (-30.90 kcal/mole) for Se^{2-} after Wagman et al. (1982).

Naumov et al. (1971) listed $\Delta G^\circ_f = -363.80$ kJ/mole (-86.95 kcal/mole) from $\Delta H^\circ_f = -509.19$ kJ/mole (-121.70 kcal/mole) and $s^\circ = -7.12$ J/mole (-1.7 cal/mole). Garrels and Christ (1965) listed $\Delta G^\circ_f = -373.76$ kJ/mole (-89.33 cal/mole) from $\Delta H^\circ_f = -512.08$ kJ/mole (-122.39 kcal/mole) and $s^\circ = 16.31$ J/mole (3.9 cal/mole). Wagman et al. (1982) reported $\Delta H^\circ_f = -369.78$ kJ/mole (-88.38 kcal/mole) from $\Delta H^\circ_f = -509.19$ kJ/mole (-121.70 kcal/mole) and $s^\circ = 12.97$ J/mole (3.10 cal/mole). Karapet'yants and Karapet'yants (1970) reported only $\Delta H^\circ_f = -518.39$ kJ/mole (-123.90 kcal/mole) and $s^\circ = 16.31$ J/mole (3.9 cal/mole) values for SeO_3^{2-} species. Even though the ΔH°_f and s° values did not agree well, the ΔG°_f values agree very well. We selected $\Delta G^\circ_f = -369.78$ kJ/mole (-88.38 kcal/mole) for SeO_3^{2-} species after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = -441.28$ kJ/mole (-105.47 kcal/mole) from $\Delta H^\circ_f = 599.15$ kJ/mole (-143.20 kcal/mole) and $s^\circ = 53.97$ J/mole (12.90 cal/mole). Naumov et al. (1971) listed $\Delta G^\circ_f = -441.41$ kJ/mole (-105.50 kcal/mole) from $\Delta H^\circ_f = -599.15$ kJ/mole (-143.20 kcal/mole) and $s^\circ = 53.97$ J/mole (12.90 cal/mole). No other information is available for SeO_4^{2-} species. Therefore, we selected $\Delta G^\circ_f = -441.28$ kJ/mole (-105.47 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) listed $\Delta G^\circ_f = 43.93$ kJ/mole (10.50 kcal/mole) from $\Delta H^\circ_f = 15.90$ kJ/mole (3.80 kcal/mole) and $s^\circ = 79.50$ J/mole (19.00 cal/mole). Naumov et al. (1971) reported similar ΔG°_f , ΔH°_f , and s° values. We selected $\Delta G^\circ_f = 43.93$ kJ/mole (10.50 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = 22.17$ kJ/mole (5.30 kcal/mole) from $\Delta H^\circ_f = 19.24$ kJ/mole (4.6 kcal/mole) and $s^\circ = 163.60$ J/mole (39.10 cal/mole). Similar ΔG°_f , ΔH°_f , and s° values were listed by Naumov et al. (1971). In this report, we selected $\Delta G^\circ_f = 22.17$ kJ/mole (5.30 kcal/mole) for $\text{H}_2\text{Se}^\circ$ after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = -452.16$ kJ/mole (-108.07 kcal/mole) from $\Delta H^\circ_f = -581.58$ kJ/mole (-139.00 kcal/mole). Naumov et al. (1971) listed $\Delta G^\circ_f = -450.87$ kJ/mole (-107.76 kcal/mole) from $\Delta H^\circ_f = -576.14$ kJ/mole (-137.70 kcal/mole) and $s^\circ = 162.76$ J/mole (38.90 cal/mole).

cal/mole). Reported ΔG°_f values for HSeO_4^- are in good agreement. We selected $\Delta G^\circ_f = -452.16$ kJ/mole (-108.07 kcal/mole) after Wagman et al. (1982).

Wagman et al. (1982) reported $\Delta G^\circ_f = -426.14$ kJ/mole (-101.85 kcal/mole) from $\Delta H^\circ_f = -507.48$ kJ/mole (-121.29 kcal/mole) and $s^\circ = 207.95$ J/mole (49.70 cal/mole). Similar ΔG°_f , ΔH°_f , s° values for $\text{H}_2\text{SeO}_3^\circ$ species were reported by Naumov et al. (1971). We selected $\Delta G^\circ_f = -426.14$ kJ/mole (-101.85 kcal/mole) after Wagman et al. (1981).

Garrels and Christ (1965) listed $\Delta G^\circ_f = -441.08$ kJ/mole (-105.42 kcal/mole) from $\Delta H^\circ_f = -607.94$ kJ/mole (-145.30 kcal/mole) and $s^\circ = 23.85$ J/mole (5.70 cal/mole). No other information is available for $\text{H}_2\text{SeO}_4^\circ$ species. Therefore, we selected available ΔG°_f of -441.08 kJ/mole (-105.42 kcal/mole) after Garrels and Christ (1965).

Wagman et al. (1982) reported $\Delta G^\circ_f = -968.18$ kJ/mole (-231.40 kcal/mole) from $\Delta H^\circ_f = -1040.56$ kJ/mole (-248.70 kcal/mole) and $s^\circ = 167.36$ J/mole (40.00 cal/mole). Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ_f = -971.95$ kJ/mole (-232.30 kcal/mole) from $\Delta H^\circ_f = -1043.11$ kJ/mole (-249.31 kcal/mole) and $s^\circ = 177.82$ J/mole (42.50 cal/mole). Reported ΔG°_f values for BaSeO_3 agree fairly well. Therefore, we selected $\Delta G^\circ_f = -968.18$ kJ/mole (-231.40 kcal/mole) after Wagman et al. (1982).

CaSe

Wagman et al. (1982) reported $\Delta G^\circ_f = -363.17$ kJ/mole (-86.80 kcal/mole) from $\Delta H^\circ_f = -368.20$ kJ/mole (-88.00 kcal/mole) and $s^\circ = 66.95$ J/mole (16.00 cal/mole). Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ_f = 75.32$ kJ/mole (18.00 kcal/mole). The agreement between ΔG°_f values for CaSe was very poor. In this report, we selected $\Delta G^\circ_f = -363.17$ kJ/mole (86.80 kcal/mole) after Wagman et al. (1982). Because the ΔG°_f value reported by Karapet'yants and Karapet'yants (1970) was derived from approximate calculations.

CaSe₃·2H₂O

Naumov et al. (1971) reported $\Delta G^\circ_f = -1423.40$ kJ/mole (-340.20 kcal/mole) from $\Delta H^\circ_f = -1609.60$ kJ/mole (-384.70 kcal/mole) $s^\circ = 233.05$ J/mole (55.70 cal/mole). Wagman et al. (1982) listed only ΔG°_f value of -1428.84 kJ/mole (-341.50 kcal/mole). Similar ΔG°_f value for CaSe₃·2H₂O was reported by Karapet'yants and Karapet'yants (1970). We selected Wagman et al. (1982) ΔG°_f value for CaSe₃·2H₂O.

CaSeO₄

No source gives a value of ΔG°_f for CaSeO₄. However, Smith and Martell (1976) reported equilibrium constant of $10^{3.09}$ for the following reaction:

Using $\Delta G^\circ_f = -554.46$ kJ/mole (-132.52 kcal/mole) for Ca^{2+} from Lindsay (1979) and $\Delta G^\circ_f = -441.28$ kJ/mole (-105.47 kcal/mole) for SeO_4^{2-} from Wagman et al. (1982), we calculated $\Delta G^\circ_f = -1013.50$ kJ/mole (-242.23 kcal/mole) for CaSeO₄ compound from the above reaction.

Wagman et al. (1982) reported $\Delta G^\circ_f = -1486.80$ kJ/mole (-355.35 kcal/mole) from $\Delta H^\circ_f = -1706.66$ kJ/mole (-407.90 kcal/mole) and $s^\circ = 221.75$ J/mole (53.00 cal/mole). Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ_f = -1402.40$ kJ/mole (-335.18 kcal/mole) from $\Delta H^\circ_f = -1727.03$ kJ/mole (-412.77 kcal/mole) and $s^\circ = 131.80$ J/mole (31.50 cal/mole). Naumov et al. (1971) reported $\Delta G^\circ_f = -1486.16$ kJ/mole (-335.20 kcal/mole) from $\Delta H^\circ_f = -1717.33$ kJ/mole (-410.45 kcal/mole) and $s^\circ = 184.94$ J/mole (44.20 cal/mole). Listed ΔG°_f values for $\text{CaSeO}_4 \cdot 2\text{H}_2\text{O}$ agree very well. Therefore, we adopted $\Delta G^\circ_f = 1486.80$ kJ/mole (-355.35 kcal/mole) for $\text{CaSeO}_4 \cdot 7\text{H}_2\text{O}$ after Wagman et al. (1982).

CuSe

Smith and Martell (1976) reported equilibrium constant of $10^{-48.10}$ for the following reaction:

Using $\Delta G^\circ_f = 65.57$ kJ/mole (15.67 kcal/mole) for Cu^{2+} from Lindsay (1979) and $\Delta G^\circ_f = 129.30$ kJ/mole (30.90 kcal/mole) for Se^{2-} from Wagman et al. (1982), we calculated $\Delta G^\circ_f = -79.50$ kJ/mole (-19.00 kcal/mole) for CuSe compound from the above reaction.

Cu_2Se

Smith and Martell (1976) listed equilibrium constant of $10^{-60.80}$ for the following reaction:

No other information is available for this compound. Therefore, we calculated $\Delta G^\circ_f = -116.44$ kJ/mole (-27.83 kcal/mole) for Cu_2Se using $= 50.63$ kJ/mole (12.10 kcal/mole) for Cu^+ (Lindsay, 1979) and $\Delta G^\circ_f = 129.30$ kJ/mole (30.90 kcal/mole) for Se^{2-} (Wagman et al. 1982) from reaction.

CuSeO_3

Wagman et al. (1982) reported $\Delta G^\circ_f = -348.07$ kJ/mole (-83.19 kcal/mole). No other information is available for this compound. Therefore, we selected available $\Delta G^\circ_f = -348.07$ kJ/mole (-83.19 kcal/mole) for CuSeO_3 after Wagman et al. (1982).

$\text{CuSeO}_3 \cdot 2\text{H}_2\text{O}$

Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ_f = -827.60$ kJ/mole (-197.80 kcal/mole) from $\Delta H^\circ_f = -1003.32$ kJ/mole (-239.80 kcal/mole) and $s^\circ = 258.57$ J/mole (61.80 cal/mole). Naumov et al. (1971) listed $\Delta G^\circ_f = -817.39$ kJ/mole (-195.36 kcal/mole) from $\Delta H^\circ_f = -983.66$ kJ/mole (-235.10 kcal/mole) and $s^\circ = 292.46$ J/mole (69.90 cal/mole).

Smith and Martell (1976) reported a equilibrium constant of $10^{-7.78}$ for the following reaction at 20°C :

using $\Delta G^\circ_f = 65.56$ kJ/mole (15.67 kcal/mole) for Cu^{2+} (Lindsay, 1979) and $\Delta G^\circ_f = 369.78$ kJ/mole (-88.38 kcal/mole) for SeO_3^{2-} (Wagman et al., 1982) from the above reaction, we estimated $\Delta G^\circ_f = -823.00$ kJ/mole (-196.70 kcal/mole) for $\text{CuSeO}_3 \cdot 2\text{H}_2\text{O}$ compound. This estimated value for $\text{CuSeO}_3 \cdot 2\text{H}_2\text{O}$ agrees well with Karapet'yants and Karapet'yants (1970).

Therefore, we adopted $\Delta G^\circ_f = -827.60$ kJ/mole (-197.80 kcal/mole) for $\text{CuSeO}_3 \cdot 2\text{H}_2\text{O}$ after Karapet'yants and Karapet'yants (1970).

FeSe

Garrels and Christ (1965) reported $\Delta G^\circ_f = -58.16$ kJ/mole (-13.90 kcal/mole) from $\Delta H^\circ_f = -69.03$ kJ/mole (-16.50 kcal/mole). However, authors did not list s° values. Karapet'yants and Karapet'yants (1970) reported a range of ΔG°_f values from -58.16 kJ/mole (-13.90 kcal/mole) to -74.06 kJ/mole (-17.70 kcal/mole). Smith and Martell (1976) reported an equilibrium constant of $10^{-26.00}$ for the following reaction:

using $\Delta G^\circ_f = -91.21$ kJ/mole (-21.80 kcal/mole) for Fe^{2+} (Lindsay, 1979) and $\Delta G^\circ_f = -129.28$ kJ/mole (-30.90 kcal/mole) for Se^{2-} (Wagman et al., 1982). We calculated $\Delta G^\circ_f = -110.29$ kJ/mole (-26.36 kcal/mole) for FeSe from the above reaction.

$\text{Fe}_2(\text{SeO}_3)_3$

Garrels and Christ (1965) reported equilibrium constant of $10^{-33.00}$ for the following reaction:

No other information is available for this compound.

Therefore, we calculated $\Delta G^\circ_f = -1331.56$ kJ/mole (-318.25 kcal/mole) for $\text{Fe}_2(\text{SeO}_3)_3$ from the above reaction using $\Delta G^\circ_f = -16.82$ kJ/mole (-4.02 kcal/mole) for Fe^{3+} (Lindsay, 1979) and $\Delta G^\circ_f = -369.78$ kJ/mole (-88.38 kcal/mole) for SeO_3^{2-} (Wagman et al., 1982).

Garrels and Christ (1965) reported equilibrium constant of $10^{62.70}$ for the following reaction:

No other information is available for this compound. Therefore, we calculated $\Delta G^\circ_f = -1390.56$ kJ/mole (-332.35 kcal/mole) for $\text{Fe}_3(\text{OH})_4\text{SeO}_3$ from the above reaction, using $\Delta G^\circ_f = -16.82$ kJ/mole (-4.02 kcal/mole) for Fe^{3+} , $\Delta G^\circ_f = -157.30$ kJ/mole (-37.594 kcal/mole) for OH^- (Lindsay, 1979), and $\Delta G^\circ_f = -369.78$ kJ/mole (-88.38 kcal/mole) for SeO_3^{2-} (Wagman et al., 1982).

MnSe

Wagman et al. (1982) reported $\Delta G^\circ_f = -111.71$ kJ/mole (-26.70 kcal/mole) from $\Delta H^\circ_f = -106.70$ kJ/mole (-25.50 kcal/mole) and $s^\circ = 90.79$ J/mole (21.70 cal/mole). Naumov et al. (1971) listed $\Delta G^\circ_f = -153.55$ kJ/mole (-36.70 kcal/mole) from $\Delta H^\circ_f = 148.53$ kJ/mole (-35.50 kcal/mole) and $s^\circ = 90.79$ J/mole (21.70 cal/mole). Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ_f = -122.30$ kJ/mole (-29.25 kcal/mole) from $\Delta H^\circ_f = -157.73$ kJ/mole (-37.70 kcal/mole). However, authors did not list s° values. Smith and Martel (1976) reported equilibrium constant of $10^{-11.50}$ for the following reaction:

Since reported ΔG°_f values for MnSe agree poorly, we calculated $\Delta G^\circ_f = -166.94$ kJ/mole (-39.90 kcal/mole) from the above reaction using $\Delta G^\circ_f = -230.58$ kJ/mole (-55.11 kcal/mole) for Mn^{2+} (Lindsay, 1979) and $\Delta G^\circ_f = -129.30$ kJ/mole (-30.90 kcal/mole) for Se^{2-} (Wagman et al., 1982).

PbSe

Garrels and Christ (1965) reported $\Delta G^\circ_f = -64.43$ kJ/mole (-15.40 kcal/mole) from $\Delta H^\circ_f = -75.31$ kJ/mole (-18.00 kcal/mole) and $s^\circ = 112.55$ J/mole (26.90 cal/mole). Karapet'yants and Karapet'yants (1970) reported a range of ΔG°_f values from -64.43 kJ/mole (-15.40 kcal/mole) to -73.64 kJ/mole (-17.60 kcal/mole). These authors calculated ΔG°_f values from $\Delta H^\circ_f = -75.31$ kJ/mole (-18.00 kcal/mole) and $s^\circ = 96.23$ J/mole (23.00 cal/mole) and also from $s^\circ = 112.55$ J/mole (26.90 cal/mole). Smith and Martell (1976) reported equilibrium constant of $10^{-42.10}$ for the following reactions:

Since reported ΔG°_f values for PbSe compound agree poorly, we calculated $\Delta G^\circ_f = -131.88$ kJ/mole (-31.52 kcal/mole) from above reaction using $\Delta G^\circ_f = -24.68$ kJ/mole (-5.90 kcal/mole) for Pb^{2+} (Lindsay, 1979) and $\Delta G^\circ_f = -129.30$ kJ/mole (-30.90 kcal/mole) for Se^{2-} (Wagman et al. 1982).

PbSeO₃

Karapet'yants and Karapet'yants (1970) reported $\Delta G^\circ_f = -463.80$ kJ/mole (-110.85 kcal/mole) from $\Delta H^\circ_f = -533.04$ kJ/mole (-127.40 kcal/mole) and $s^\circ = 181.87$ J/mole (43.47 cal/mole). Since no other information is available, we adopted the Karapet'yants and Karapet'yants value for PbSeO₃.

PbSeO₄

Wagman et al. (1982) reported $\Delta G^\circ_f = -504.88$ kJ/mole (-120.67 kcal/mole) from $\Delta H^\circ_f = 609.20$ kJ/mole (-145.60 kcal/mole) and $s^\circ = 167.78$ J/mole (40.10 cal/mole). Karapet'yants and Karapet'yants (1970)

listed $\Delta G^\circ_f = 497.90$ kJ/mole (-119.00 kcal/mole) from $\Delta H^\circ_f = 622.16$ kJ/mole (-148.70 kcal/mole) and $s^\circ = 103.35$ J/mole (24.7 cal/mole). Naumov et al. (1971) reported $\Delta G^\circ_f = -504.84$ kJ/mole (-120.88 kcal/mole) from $\Delta H^\circ_f = 615.05$ kJ/mole (-147.00 kcal/mole) and $s^\circ = 142.25$ J/mole (34.00 cal/mole). Reported ΔG°_f values for PbSeO_4 agree fairly well. Therefore, we selected $\Delta G^\circ_f = -504.88$ kJ/mole (-120.67 kcal/mole) after Wagman et al. (1982).

ZnSe

Garrels and Christ (1965) reported $\Delta G^\circ_f = 145.18$ kJ/mole (-34.70 kcal/mole) from $\Delta H^\circ_f = -142.25$ kJ/mole (-34.00 kcal/mole) and $s^\circ = 93.30$ J/mole (23.30 cal/mole). Wagman et al. (1982) reported $\Delta G^\circ_f = -163.00$ kJ/mole (-38.96 kcal/mole) from $\Delta H^\circ_f = -163.00$ kJ/mole (-38.96 kcal/mole) and $s^\circ = 83.68$ J/mole (20.00 cal/mole). Karapet'yants and Karapet'yants (1970) listed $\Delta G^\circ_f = -145.18$ kJ/mole (-34.70 kcal/mole) from $\Delta H^\circ_f = -129.70$ kJ/mole (-31.00 kcal/mole) and $s^\circ = 61.08$ J/mole (14.60 cal/mole). Smith and Martell (1976) reported equilibrium constant of $10^{-29.40}$ for the following reaction:

Since reported ΔG°_f values for ZnSe compound agree poorly, we calculated $\Delta G^\circ_f = -185.72$ kJ/mole (-44.39 kcal/mole) from the above reaction using $\Delta G^\circ_f = -147.22$ kJ/mole (-35.18 kcal/mole) for Zn^{2+} (Lindsay, 1979) and $\Delta G^\circ_f = -129.20$ kJ/mole (-30.90 kcal/mole) for Se^{2-} (Wagman et al., 1982).

$\text{ZnSe}_3 \cdot \text{H}_2\text{O}$

Wagman et al. (1982) reported $\Delta G^\circ_f = -729.80$ kJ/mole (-174.43 kcal/mole) from $\Delta H^\circ_f = -930.90$ kJ/mole (-222.490 kcal/mole) and $s^\circ =$

163.00 J/mole (38.96 cal/mole). No other information is available for this compound. Therefore, we adopted available ΔG°_f value after Wagman et al. (1982).

Smith and Martell (1976) reported equilibrium constant of $10^{2.19}$ for the following reaction:

No other information is available for this compound. Therefore, we calculated $\Delta G^\circ_f = -601.12$ kJ/mole (-143.67 kcal/mole) for ZnSeO_4 from the above reaction using $\Delta G^\circ_f = -147.22$ kJ/mole (-35.19 kcal/mole) for Zn^{2+} (Lindsay, 1979) and $\Delta G^\circ_f = -441.28$ kJ/mole (-105.47 kcal/mole) for SeO_4^{2-} (Wagman et al. 1982).

Table 4. Summary of Collected ΔG°_f (kJ/mole) values for Strontium Species. Values in Parenthesis are kcal/mole.

No.	Species	Source*									
		1	2	3	4	5	6	7	8	9	10
1.	Sr^{2+}	-559.47 (-133.72)	-559.44 (-133.71)	---	-571.44 (-136.58)	---	---	-563.83 (-134.76)	-559.43 (-133.70)	---	---
2.	$\text{SrSO}_4(\text{c})$	-1340.89 (-320.48)	---	-1334.44 (-318.94)	-1353.35 (-323.46)	---	---	---	-1340.97 (-320.50)	---	-1340.68 (-320.43)
3.	$\text{SrO}(\text{c})$	-561.87 (-134.29)	---	-573.00 (-137.07)	-574.13 (-137.22)	-559.82 (-133.80)	---	-559.95 (-133.83)	-560.32 (-133.92)	-560.57 (-133.98)	---
4.	$\text{Sr}(\text{NO}_3)_2(\text{c})$	-780.02 (-186.43)	---	-778.22 (-186.00)	-790.40 (-188.91)	---	---	-783.28 (-187.21)	-779.06 (-186.20)	---	---
5.	$\text{SrBr}_2(\text{c})$	-697.10 (-166.61)	---	-695.80 (-166.30)	---	---	---	---	-695.89 (-166.32)	-699.77 (-167.25)	---
6.	$\text{SrHPO}_4(\text{c})$	-1688.60 (-403.58)	---	-1681.31 (-401.80)	---	-1672.34 (-399.70)	---	---	---	---	---
7.	$\text{SrF}_2(\text{c})$	-1164.57 (-278.34)	---	-1162.31 (-277.80)	-1180.56 (-282.16)	-1162.31 (-277.80)	---	---	---	-1164.74 (-278.38)	---
8.	$\text{SrCrO}_4(\text{c})$	---	---	---	-1318.37 (-315.10)	---	-1319.21 (-315.30)	---	---	---	---
9.	$\text{SrSeO}_3(\text{c})$	---	---	-965.83 (-230.84)	-969.43 (-231.70)	---	---	---	---	---	---
10.	$\text{Sr}_2\text{TiO}_4(\text{c})$	-2172.30 (-519.19)	-2178.60 (-520.70)	---	-2196.01 (-524.86)	---	---	---	---	---	---
11.	SrOH^+	-721.32 (-172.40)	-721.32 (-172.40)	---	-733.45 (-175.30)	---	---	---	---	---	---

Table 4. Summary of Collected ΔG°_f (kJ/mole) values for Strontium Species. Values in Parenthesis are kcal/mole. (cont.)

No.	Species	Source*									
		1	2	3	4	5	6	7	8	9	10
12.	SrSO_4°	-1304.03 (-311.67)	---	---	---	---	---	---	---	---	---
13.	$\text{SrCO}_3(\text{c})$	-1140.10 (-272.49)	---	-1138.13 (-272.02)	-1152.31 (-275.40)	---	---	---	-1137.63 (-271.90)	---	---
14.	$\text{SrSiO}_3(\text{c})$	-1549.70 (-370.39)	---	-1467.75 (-350.80)	-1561.64 (-373.24)	---	---	---	---	---	---
15.	$\text{Sr}_2\text{SiO}_4(\text{c})$	-2191.10 (-523.68)	---	-2074.00 (-495.70)	-2215.09 (-529.68)	-2074.00 (-495.70)	---	---	---	---	---
73 16.	$\text{Sr}_3(\text{PO}_4)_2(\text{c})$	---	---	---	---	-3899.90 (-932.10)	---	---	---	---	---
17.	$\text{Sr}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}(\text{c})$	---	---	-1725.48 (-412.40)	---	---	---	-1734.19 (-414.48)	---	---	---
18.	$\text{SrCl}_2(\text{c})$	-781.10 (-186.69)	---	---	---	-781.15 (-186.70)	-781.15 (-186.70)	-785.00 (-187.62)	---	-781.02 (-186.67)	---
19.	$\text{SrCl}_2 \cdot \text{H}_2\text{O}(\text{c})$	-1036.30 (-247.68)	---	-1038.47 (-248.20)	---	---	---	---	---	---	---
20.	$\text{SrBr}_2 \cdot \text{H}_2\text{O}(\text{c})$	-954.30 (-228.08)	---	---	---	---	---	---	---	---	---
21.	$\text{Sr}_3(\text{ASO}_4)_2(\text{c})$	-3080.10 (-736.16)	---	---	---	---	-3222.10 (-770.10)	---	---	---	---
22.	$\text{SrSeO}_4(\text{c})$	---	---	-1023.87 (-244.71)	-1039.14 (-248.36)	---	---	---	---	---	---

Summary of Collected ΔG°_f (kJ/mole) values for Strontium Species. Values in Parenthesis are kcal/mole. (cont.)

[illegible]

Table 4. Summary of collected ΔG°_f (kJ/mole) values for Strontium
Species. Values in parenthesis are kcal/mole. (cont.)

Source*

1. Wagman et al. (1982)
2. Parker et al. (1971)
3. Karapet'yants and Karapet'yants (1970)
4. Naumov et al. (1971)
5. Garrels and Christ (1968)
6. Latimer (1952)
7. Busenberg et al. (1984)
8. Rcbie et al. (1978)
9. Pankratz (1984)
10. Helgeson et al. (1978)

Table 5. Summary of Selected ΔG°_f of Strontium Species.

No.	Species	ΔG°_f		Source	Remarks
		(kJ/mole)	(kcal/mole)		
1.	Sr^{2+}	-563.83	-134.76	Busenberg et al. (1984)	pk
2.	$\text{SrSO}_4(\text{c})$	-1346.16	-321.74	Reardon and Armstrong (1987)	pk
3.	$\text{SrO}(\text{c})$	-559.95	-133.83	Busenberg et al. (1984)	pk
4.	$\text{Sr}(\text{NO}_3)(\text{c})$	-783.28	-187.21	Busenberg et al. (1984)	pk
5.	$\text{SrBr}_2(\text{c})$	-699.77	-167.25	Pankratz (1984)	ΔH°_f and s°
6.	$\text{SrHPO}_4(\text{c})$	-1688.60	-403.58	Wagman et al. (1982)	ΔH°_f and s°
7.	$\text{SrF}_2(\text{c})$	-1180.56	-282.16	Naumov et al. (1971)	ΔH°_f and s°
8.	$\text{SrCrO}_4(\text{c})$	-1318.37	-315.10	Naumov et al. (1971)	ΔH°_f and s°
9.	$\text{SrSeO}_3(\text{c})$	-969.43	-231.70	Naumov et al. (1971)	ΔH°_f and s°
10.	$\text{Sr}_2\text{TiO}_4(\text{c})$	-2196.01	-524.86	Naumov et al. (1971)	ΔH°_f and s°
11.	SrOH^+	-733.46	-175.30	Naumov et al. (1971)	ΔH°_f and s°
12.	SrSO_4°	-1320.89	-315.70	Smith and Martell (1978)	pk
13.	$\text{SrCO}_3(\text{c})$	-1144.63	-273.33	Busenberg et al. (1984)	pk
14.	$\text{SrSiO}_3(\text{c})$	-1561.64	-373.24	Naumov et al. (1971)	ΔH°_f and s°
15.	$\text{Sr}_2\text{SiO}_4(\text{c})$	-2191.10	-523.68	Wagman et al. (1982)	ΔH°_f and s°
16.	$\text{Sr}_3(\text{PO}_4)_2(\text{c})$	-3899.90	-932.10	Garrels and Christ (1968)	ΔH°_f and s°
17.	$\text{Sr}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}(\text{c})$	-1734.19	-414.48	Busenberg et al. (1984)	pk

Table 5. Summary of Selected ΔG°_f of Strontium Species.

No.	Species	ΔG°_f		Source	Remarks
		(kJ/mole)	(kcal/mole)		
18.	$\text{SrCl}_2(\text{c})$	-785.00	-187.62	Busenberg et al. (1984)	pk
19.	$\text{SrCl}_2 \cdot \text{H}_2\text{O}(\text{c})$	-1036.30	-247.68	Wagman et al. (1982)	ΔH°_f and s°
20.	$\text{SrBr}_2 \cdot \text{H}_2\text{O}(\text{c})$	-954.30	-228.08	Wagman et al. (1982)	ΔH°_f and s°
21.	$\text{Sr}_3(\text{ASO}_4)_2(\text{c})$	-3080.10	-736.16	Wagman et al. (1982)	ΔH°_f and s°
22.	$\text{SrSeO}_4(\text{c})$	-1039.14	-248.36	Naumov et al. (1971)	pk
23.	$\text{SrMoO}_4(\text{c})$	-1454.36	-347.60	Naumov et al. (1971)	pk
24.	$\text{Sr}(\text{OH})_2(\text{c})$	-870.27	-208.00	Karapet'yants and Karapet'yants (1970)	ΔH°_f and s°
25.	$\text{SrI}_2(\text{c})$	-558.71	-133.53	Pankratz (1984)	ΔH°_f and s°
26.	$\text{SrTiO}_3(\text{c})$	-1600.38	-382.50	Naumov et al. (1971)	ΔH°_f and s°
27.	$\text{SrZrO}_3(\text{c})$	-1682.77	-402.20	Wagman et al. (1982)	ΔH°_f and s°
28.	SrHCO_3^+	-1157.50	-276.65	Busenberg et al. (1984)	pk
29.	SrCO_3°	-1175.50	-280.95	Busenberg et al. (1984)	pk
30.	$\text{Sr}(\text{NO}_3)_2^\circ$	-781.99	-186.90	Wagman et al. (1982)	ΔH°_f and s°
31.	SrCl_2°	-821.90	-196.44	Wagman et al. (1982)	ΔH°_f and s°
32.	SrI_2°	-662.62	-158.37	Wagman et al. (1982)	ΔH°_f and s°
33.	SrBr_2°	-767.38	-183.41	Parker et al. (1971)	ΔH°_f and s°

Table 6. Equilibrium Reactions of Strontium.

No.	Reaction	logk°
I. Solid Phases		
1.	$\text{SrO(c)} + 2\text{H}^+ \rightleftharpoons \text{Sr}^{2+} + \text{H}_2\text{O}$	42.23
2.	$\text{Sr(OH)}_2\text{(c)} + 2\text{H}^+ \rightleftharpoons \text{Sr}^{2+} + 2\text{H}_2\text{O}$	29.42
3.	$\text{SrSiO}_3\text{(c)} + 2\text{H}^+ + \text{H}_2\text{O} \rightleftharpoons \text{Sr}^{2+} + \text{H}_4\text{SiO}_4^\circ$	12.82
4.	$\text{Sr}_2\text{SiO}_4\text{(c)} + 4\text{H}^+ \rightleftharpoons 2\text{Sr}^{2+} + \text{H}_4\text{SiO}_4^\circ$	42.88
5.	$\text{SrCO}_3\text{(c)} \rightleftharpoons \text{Sr}^{2+} + \text{CO}_3^{2-}$	-9.27
6.	$\text{SrSO}_4\text{(c)} \rightleftharpoons \text{Sr}^{2+} + \text{SO}_4^{2-}$	-6.63
7.	$\text{Sr(NO}_3)_2\text{(c)} \rightleftharpoons \text{Sr}^{2+} + 2\text{NO}_3^-$	0.61
8.	$\text{SrBr}_2\text{(c)} \rightleftharpoons \text{Sr}^{2+} + 2\text{Br}^-$	12.64
9.	$\text{SrHPO}_4\text{(c)} + \text{H}^+ \rightleftharpoons \text{Sr}^{2+} + \text{H}_2\text{PO}_4^-$	2.22
10.	$\text{Sr}_3(\text{PO}_4)_2\text{(c)} + 4\text{H}^+ \rightleftharpoons 3\text{Sr}^{2+} + 2\text{H}_2\text{PO}_4^-$	11.64
11.	$\text{Sr(NO}_3)_2 \cdot 4\text{H}_2\text{O(c)} \rightleftharpoons \text{Sr}^{2+} + 2\text{NO}_3^- + 4\text{H}_2\text{O}$	0.22
12.	$\text{SrF}_2\text{(c)} \rightleftharpoons \text{Sr}^{2+} + 2\text{F}^-$	-8.46
13.	$\text{SrCl}_2\text{(c)} \rightleftharpoons \text{Sr}^{2+} + 2\text{Cl}^-$	7.24
14.	$\text{SrCl}_2 \cdot \text{H}_2\text{O(c)} \rightleftharpoons \text{Sr}^{2+} + 2\text{Cl}^- + \text{H}_2\text{O}$	4.77
15.	$\text{SrBr}_2 \cdot \text{H}_2\text{O(c)} \rightleftharpoons \text{Sr}^{2+} + 2\text{Br}^- + \text{H}_2\text{O}$	9.60
16.	$\text{Sr}_3(\text{ASO}_4)_2\text{(c)} + 2\text{H}^+ \rightleftharpoons 3\text{Sr}^{2+} + 2\text{HASO}_4^{2-}$	5.46
17.	$\text{SrCrO}_4\text{(c)} \rightleftharpoons \text{Sr}^{2+} + \text{CrO}_4^{2-}\text{T}$	-4.70
18.	$\text{SrSeO}_3\text{(c)} \rightleftharpoons \text{Sr}^{2+} + \text{SeO}_3^{2-}\text{T}$	-6.27
19.	$\text{SrSeO}_4\text{(c)} \rightleftharpoons \text{Sr}^{2+} + \text{SeO}_4^{2-}$	-5.96
20.	$\text{SrMoO}_4\text{(c)} \rightleftharpoons \text{Sr}^{2+} + \text{MoO}_4^{2-}$	-9.53
21.	$\text{SrI}_2\text{(c)} \rightleftharpoons \text{Sr}^{2+} + 2\text{I}^-$	19.14
22.	$\text{Sr}^{2+} + \text{H}_2\text{O} \rightleftharpoons \text{SrOH}^+ + \text{H}^+$	-11.83
23.	$\text{Sr}^{2+} + \text{CO}_2\text{(g)} + \text{H}_2\text{O} \rightleftharpoons \text{SrHCO}_3^+ + \text{H}^+$	-6.64

Table 6. Equilibrium Reactions of Strontium. (cont.)

No.	Reaction		logk°
II. Solution Phases			
24.	$\text{Sr}^{2+} + \text{CO}_2(\text{g}) + \text{H}_2\text{O}$	$\rightleftharpoons \text{SrCO}_3^\circ + 2\text{H}^+$	-18.15
25.	$\text{Sr}^{2+} + \text{SO}_4^{2-}$	$\rightleftharpoons \text{SrSO}_4^\circ$	2.55
26.	$\text{Sr}^{2+} + 2\text{NO}_3^-$	$\rightleftharpoons \text{Sr}(\text{NO}_3)_2^\circ$	-0.84
27.	$\text{Sr}^{2+} + 2\text{Cl}^-$	$\rightleftharpoons \text{SrCl}_2^\circ$	-0.78
28.	$\text{Sr}^{2+} + 2\text{I}^-$	$\rightleftharpoons \text{SrI}_2^\circ$	-0.84
29.	$\text{Sr}^{2+} + 2\text{Br}^-$	$\rightleftharpoons \text{SrBr}_2^\circ$	-0.80

TΔG°f values for CrO_4^{2-} , SeO_3^{2-} , and SeO_4^{2-} , were selected from Wagman et al. (1982).

Table 7. Summary of Collected Standard Free Energies of Formation (ΔG°_f , kcal/mole) of F Species. Values in the Parenthesis are kcal/mole.

No.	Species	Source*													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	F^-	-278.79 (-66.63)	-284.22 (-67.93)	-----	-281.70 (-67.33)	-284.22 (-67.93)	-----	-----	-----	-----	-----	-----	-----	-----	-----
2.	HF°	-796.82 (-70.94)	-----	-----	-----	-----	-298.11 (-71.25)	-----	-----	-----	-----	-----	-----	-----	-----
3.	HF_2^-	-578.08 (-138.16)	-----	-----	-----	-----	-581.50 (-138.98)	-----	-----	-----	-----	-----	-----	-----	-----
4.	AlF_2°	-1113.00 (-266.01)	-1131.27 (-270.38)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
5.	AlF^{2+}	-803.00 (-191.92)	-814.96 (-194.78)	-----	-----	-----	-811.82 (-194.03)	-----	-----	-----	-----	-----	-----	-----	-----
6.	AlF_3°	-1414.00 (-337.95)	-1438.58 (-343.08)	-----	-----	-----	-1427.03 (-341.07)	-----	-----	-----	-----	-----	-1438.88 (-343.90)	-----	-----
7.	AlF_4^-	-----	-1736.40 (-415.01)	-----	-----	-----	-1720.63 (-411.24)	-----	-----	-----	-----	-----	-----	-----	-----
8.	FeF^{2+}	-322.60 (-77.10)	-335.00 (-80.14)	-----	-----	-----	-332.33 (-79.43)	-----	-----	-----	-----	-----	-----	-----	-----
9.	FeF_2°	-636.48 (-152.12)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
10.	FeF_2°	-628.40 (-150.19)	-637.76 (-152.43)	-----	-----	-645.55 (-154.29)	-----	-----	-----	-----	-----	-----	-----	-----	-----
11.	FeF_3°	-----	-936.25 (-223.77)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
12.	PbF°	-310.37 (-74.18)	-317.40 (-75.86)	-----	-----	-----	-311.70 (-74.50)	-----	-----	-----	-----	-----	-----	-----	-----
13.	PbF_2°	-596.60 (-142.60)	-606.09 (-144.86)	-----	-----	-----	-597.47 (-142.80)	-----	-----	-----	-----	-----	-----	-----	-----
14.	PbF_3^-	-----	-896.84 (-214.35)	-----	-----	-----	-884.08 (-211.80)	-----	-----	-----	-----	-----	-----	-----	-----
15.	PbF_4^{2-}	-----	-1179.26 (-281.85)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
16.	SiF_4°	-1607.40 (-384.18)	-----	-----	-----	-----	-1611.67 (-385.20)	-----	-----	-----	-----	-----	-----	-----	-----
17.	SiF_6^{2-}	-2207.06 (-525.67)	-----	-----	-----	-----	-2207.31 (-527.56)	-2138.24 (-511.00)	-----	-----	-----	-----	-----	-----	-----

Table 7. Summary of Collected Standard Free Energy of Formation (ΔG°_f , kJ/mole) of F Species. Values in the Parenthesis are kcal/mole. (cont.)

No.	Species	Source*															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
18.	ZnF ⁺	-433.00 (-103.49)	-----	-----	-437.98 (-104.68)	-434.38 (-103.82)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
19.	ZnF ₂ ⁺	-704.64 (-168.41)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
20.	NaF ⁺	-540.68 (-129.22)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
21.	KF ⁺	-562.06 (-134.34)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
22.	CuF ⁺	-220.50 (-52.70)	-----	-----	-----	-225.50 (-53.90)	-221.75 (53.00)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
23.	CdF ₂ ⁺	-635.18 (-151.81)	-----	-----	-----	-619.57 (-148.08)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
24.	HgF ⁺	-123.40 (-29.50)	-----	-----	-----	-128.66 (-30.75)	-----	-----	-----	-----	-----	-----	-128.64 (-30.74)	-128.40 (-30.69)	-128.40 (-30.69)	-----	-----
25.	HnF ⁺	-511.70 (-122.30)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
26.	GF ⁺	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-844.00 (-201.72)	-----	-----	-----	-----
27.	HgF ₂ ⁺	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-750.60 (-179.40)	-----	-----	-----	-----
28.	SrF ⁺	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-851.44 (-203.50)	-----
29.	CaF ₂ ⁺	-1111.15 (-265.57)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
30.	CaF ₂ ²⁺	-464.90 (-111.11)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
31.	CaF ₂ ⁺	-764.80 (-182.80)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
32.	TiF ⁺	-311.19 (-74.37)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
33.	AgF ⁺	-701.49 (-48.20)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
34.	NiF ₂ ⁺	-603.30 (-144.70)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Table 7. Summary of Collected Standard Free Energy of Formation (ΔG°_f , kJ/mole) of F Species. Values in the Parenthesis are kcal/mole. (cont.)

No.	Species	Source*													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
35.	BaF ₂ ^o	-1118.35 (-267.30)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
36.	AlF ₃ (c)	-1425.00 (-340.58)	-----	-----	-----	-1444.06 (-354.14)	-----	-----	-----	-----	-----	-----	-----	-----	-----
37.	CdF ₂ (c)	-547.70 (-154.80)	-----	-----	-----	-----	-651.07 (-155.61)	-649.35 (-155.20)	-----	-----	-----	-----	-----	-----	-----
38.	CuF ₂ ·2H ₂ O	-981.40 (-234.56)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
39.	FeF ₃ (c)	-----	-----	-----	-----	-979.71 (-234.16)	-----	-----	-972.33 (-232.40)	-----	-----	-----	-----	-----	-----
40.	Hg ₂ F ₂ (c)	-----	-427.48 (-102.17)	-----	-----	-----	-----	-----	-427.47 (-102.17)	-----	-----	-----	-----	-----	-----
41.	KF(c)	-537.75 (-128.52)	-----	-----	-----	-----	-538.95 (-128.81)	-537.70 (-128.51)	-----	-----	-----	-----	-----	-----	-----
42.	MgF ₂ (c)	-1070.20 (-255.78)	-----	-----	-----	-----	-1071.10 (-256.00)	-----	-1071.10 (-256.00)	-----	-----	-----	-----	-----	-----
43.	NaF(c)	-543.50 (-129.90)	-----	-----	-----	-----	-546.51 (-137.49)	-----	-----	-----	-543.11 (-129.81)	-----	-----	-----	-----
44.	PbF ₂ (c)	-617.10 (-147.49)	-----	-----	-----	-----	-627.60 (-150.00)	-715.88 (-148.10)	-----	-----	-----	-----	-----	-----	-----
45.	ZnF ₂ (c)	-713.30 (-170.48)	-----	-----	-----	-----	-713.30 (-170.48)	-713.30 (-170.48)	-----	-----	-----	-----	-----	-----	-----
46.	Na ₂ SiF ₆ (c)	-2754.20 (-658.27)	-----	-----	-----	-----	-2757.25 (-659.80)	-2553.91 (-610.40)	-----	-----	-----	-----	-----	-----	-----
47.	Na ₃ AlF ₆ (c)	-3136.60 (-749.67)	-----	-----	-----	-----	-3152.64 (-753.50)	-3015.82 (-720.80)	-----	-----	-3140.90 (-750.69)	-----	-----	-----	-----
48.	NaCa ₂ Mg ₄ Al ₅ Si ₆ O ₂₂ F ₂	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-12117.78 (-2896.22)	-----	-----	-----
49.	NaMoF ₇ (c)	-2006.10 (-479.47)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
50.	K ₂ SiF ₆	-2798.60 (-658.88)	-----	-----	-----	-----	-2810.40 (-671.70)	-2723.78 (-651.00)	-----	-----	-----	-----	-----	-----	-----
51.	KMg ₃ AlSi ₃ O ₁₀ F ₂	-6044.00 (-1444.55)	-6115.46 (-1461.63)	-----	-----	-----	-6026.21 (-1440.30)	-----	-----	-----	-6072.95 (-1439.52)	-6091.68 (-1438.74)	-----	-----	-----

Table 7. Summary of Collected Standard Free Energy of Formation (ΔG°_f , kJ/mole)
of F Species. Values in the Parenthesis are kcal/mole. (cont.)

No.	Species	Source*													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
52.	$\text{Ca}_5(\text{Po}_4)_3\text{F}$	-----	-6474.19 (-1547.37)	-----	-----	-----	-6507.37 (-1555.30)	-----	-----	-6491.47 (-1551.50)	-----	-6501.51 (-1553.90)	-----	-----	-----
53.	$\text{Ca}_4\text{Si}_2\text{O}_7\text{F}_2$	-----	-----	-----	-----	-----	-4988.58 (-1192.30)	-----	-----	-----	-----	-----	-----	-----	-----
54.	$(\text{Ni})_4\text{SiF}_6$	-----	-----	-----	-----	-----	-2372.24 (-566.98)	-----	-----	-----	-----	-----	-----	-----	-----
55.	$\text{Pb}_5(\text{Po}_4)_3\text{F}$	-----	-3893.75 (-930.63)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
56.	CaF_2	-1167.30 (-278.99)	-1162.31 (-282.58)	-----	-----	-1182.31 (-282.58)	-1175.99 (-281.07)	-1163.15 (-278.00)	-1173.53 (-280.48)	-----	-1162.31 (-277.80)	-----	-----	-----	-1173.58 (-280.49)

Source*

1. Wagman et al. (1982)
2. Sadiq and Lindsay (1979)
3. CODATA (1976)
4. Robie et al. (1978)
5. Elrashidi and Lindsay (1984)
6. Naumov et al. (1971)
7. Karapet'yants and Karapet'yants (1970)
8. Stull et al. (1971)
9. Parker et al. (1971)
10. Robie and Waldbaum (1968)
11. Westrich and Navrotsky (1981)
12. Smith and Martell (1976)
13. Hepler and Olofson (1975)
14. Paul (1955)
15. Sposito and Mattigod (1980)
16. Helgeson et al. (1978)

Table 8. Selected Standard Free Energies of Formation (ΔG°_f) of F Species.

No.	Species	ΔG°_f		Source	Remarks
		(kJ/mole)	(kcal/mole)		
1.	F^-	-284.22	-67.93	Sadiq and Lindsay (1979)	$\Delta H^\circ_f, s^\circ$
2.	HF°	-296.82	-70.94	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
3.	HF_2^-	-578.08	-138.16	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
4.	AlF_2^+	-1131.27	-270.38	Sadiq and Lindsay (1979)	pk
5.	AlF^{2+}	-814.96	-194.78	Sadiq and Lindsay (1979)	pk
6.	AlF_3°	-1438.58	-343.83	Sadiq and Lindsay (1979)	pk
7.	AlF_4^-	-1736.40	-415.01	Sadiq and Lindsay (1979)	pk
8.	FeF^{2+}	-335.30	-80.14	Sadiq and Lindsay (1979)	pk
9.	FeF_2°	-636.48	-152.12	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
10.	FeF_2^+	-637.76	-152.43	Sadiq and Lindsay (1979)	pk
11.	FeF_3°	-936.25	-223.77	Sadiq and Lindsay (1979)	pk
12.	PbF^+	-317.40	-75.86	Sadiq and Lindsay (1979)	pk
13.	PbF_2°	-606.09	-144.86	Sadiq and Lindsay (1979)	K°
14.	PbF_3^-	-896.84	-216.35	Sadiq and Lindsay (1979)	pk
15.	PbF_4^{2-}	-1179.26	-281.85	Sadiq and Lindsay (1979)	pk
16.	SiF_4°	-1607.40	-384.18	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$

Table 8. Selected Standard Free Energies of Formation (ΔG°_f) of F Species. (cont.)

No.	Species	ΔG°_f		Source	Remarks
		(kJ/mole)	(kcal/mole)		
17.	SiF_6^{2-}	-2199.40	-525.67	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
18.	ZnF^+	-437.98	-104.68	Elrashidi and Lindsay (1979)	pk
19.	ZnF_2°	-704.64	-168.41	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
20.	NaF°	-540.68	-129.22	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
21.	KF°	-562.06	-134.34	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
22.	CuF^+	-225.52	-53.90	Elrashidi and Lindsay (1984)	pk
23.	CdF_2°	-635.18	-151.81	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
24.	HgF^+	-128.66	-30.75	Elrashidi and Lindsay (1979)	pk
25.	MnF^+	-511.70	-122.30	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
26.	CaF^+	-844.00	-201.72	Smith and Martell (1976)	pk
27.	MgF^+	-750.60	-179.40	Smith and Martell (1976)	pk
28.	SrF^+	-851.44	-203.50	Sposito and Mattigod (1980)	pk
29.	CaF_2°	-1111.15	-265.57	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
30.	GaF^{2+}	-464.90	-111.11	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
31.	GaF_2^+	-764.80	-182.80	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
32.	TlF°	-311.19	-74.37	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
33.	AgF°	-201.69	-48.20	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$

Table 8. Selected Standard Free Energies of Formation (ΔG°_f) of F Species. (cont.)

No.	Species	ΔG°_f		Source	Remarks
		(kJ/mole)	(kcal/mole)		
34.	NiF ₂ ^o	-603.30	-144.20	Wagman et al. (1982)	ΔH°_f , s ^o
35.	BaF ₂ ^o	-1118.35	-267.30	Wagman et al. (1982)	ΔH°_f , s ^o
36.	AlF ₃ (c)	-1444.06	-345.14	Elrashidi and Lindsay (1984)	ΔH°_f , s ^o
37.	CdF ₂ (c)	-647.70	-154.80	Wagman et al. (1982)	ΔH°_f , s ^o
38.	CuF ₂ ·2H ₂ O	-981.40	-234.56	Wagman et al. (1982)	ΔH°_f , s ^o
39.	Hg ₂ F ₂ (c)	-427.48	-102.17	Sadiq and Lindsay (1979)	ΔH°_f , s ^o
40.	FeF ₃ (c)	-979.71	-234.16	Elrashidi and Lindsay (1986)	ΔH°_f , s ^o
41.	KF(c)	-537.75	-128.52	Wagman et al. (1982)	ΔH°_f , s ^o
42.	MgF ₂ (c)	-1070.20	-255.78	Wagman et al. (1982)	ΔH°_f , s ^o
43.	NaF(c)	-543.50	-129.90	Wagman et al. (1982)	ΔH°_f , s ^o
44.	PbF ₂ (c)	-617.10	-147.49	Wagman et al. (1982)	ΔH°_f , s ^o
45.	ZnF ₂ (c)	-713.30	-170.48	Wagman et al. (1982)	ΔH°_f , s ^o
46.	Na ₂ SiF ₆ (c)	-2754.20	-658.27	Wagman et al. (1982)	ΔH°_f , s ^o
47.	Na ₃ AlF ₆ (c)	-3136.60	-749.67	Wagman et al. (1982)	ΔH°_f , s ^o
48.	NaCa ₂ Mg ₄ Al ₃ Si ₆ O ₂₂ F ₂	-12117.78	-2896.22	Westrich and Navrotsky (1981)	ΔH°_f , s ^o
49.	NaMoF ₇ (c)	-2006.10	-479.47	Wagman et al. (1982)	ΔH°_f , s ^o

Table 8. Selected Standard Free Energies of Formation (ΔG°_f) of F Species. (cont.)

No.	Species	ΔG°_f		Source	Remarks
		(kJ/mole)	(kcal/mole)		
50.	K_2SiF_6 (c) (hieratite)	-2798.60	-668.88	Wagman et al. (1982)	$\Delta H^\circ_f, s^\circ$
51.	$KMg_3AlSi_3O_{10}F_2$ (Fluorphlogopite)	-6115.46	-1461.63	Sadiq and Lindsay (1979)	$\Delta H^\circ_f, s^\circ$
52.	$Ca_5(PO_4)_3F$ (Fluorapatite)	-6474.19	-1547.37	Sadiq and Lindsay (1979)	pk
53.	$Ca_4Si_2O_7F_2$ (Cuspidine)	-4988.58	-1192.30	Naumov et al. (1971)	$\Delta H^\circ_f, s^\circ$
54.	$(NH_4)_2SiF_6$ (Bararite)	-2372.24	-566.98	Naumov et al. (1971)	$\Delta H^\circ_f, s^\circ$
55.	$Pb_5(PO_4)_3F$ (Fluoropyrrophite)	-3893.75	-930.63	Sadiq and Lindsay (1979)	pk
56.	CaF_2 (Fluorite)	-1182.31	-282.58	Elrashidi and Lindsay (1984)	pk

Table 9. Equilibrium Reactions of Fluoride.

No.	Reaction	logk°
<u>I. Solid Phases</u>		
1.	$\text{AlF}_3(\text{c}) \rightleftharpoons \text{Al}^{3+} + 3\text{F}^-$	-17.61
2.	$\text{CaF}_2(\text{fluorite}) \rightleftharpoons \text{Ca}^{2+} + 2\text{F}^-$	-10.42
3.	$\text{CdF}_2(\text{c}) \rightleftharpoons \text{Cd}^{2+} + 2\text{F}^-$	-0.24
4.	$\text{CuF}_2 \cdot 2\text{H}_2\text{O}(\text{c}) \rightleftharpoons \text{Cu}^{2+} + 2\text{F}^- + 2\text{H}_2\text{O}$	-0.73
5.	$\text{FeF}_3(\text{c}) \rightleftharpoons \text{Fe}^{3+} + 3\text{F}^-$	-19.31
6.	$\text{Hg}_2\text{F}_2(\text{c}) \rightleftharpoons \text{Hg}_2^{2+} + 2\text{F}^-$	-2.22
7.	$\text{KF}(\text{c}) \rightleftharpoons \text{K}^+ + \text{F}^-$	5.07
8.	$\text{MgF}_2(\text{sellaite}) \rightleftharpoons \text{Mg}^{2+} + 2\text{F}^-$	-8.01
9.	$\text{MgF}_2(\text{villiaumite}) \rightleftharpoons \text{Mg}^{2+} + 2\text{F}^-$	0.45
10.	$\text{PbF}_2(\text{c}) \rightleftharpoons \text{Pb}^{2+} + 2\text{F}^-$	-4.21
11.	$\text{ZnF}_2(\text{c}) \rightleftharpoons \text{Zn}^{2+} + 2\text{F}^-$	0.40
12.	$\text{Na}_2\text{SiF}_6 + 4\text{H}_2\text{O} \rightleftharpoons 2\text{Na}^+ + \text{H}_4\text{SiO}_4^\circ + 6\text{F}^- + 4\text{H}^+$ (malladrite)	-27.88
13.	$\text{Na}_3\text{AlF}_6(\text{cryolite}) \rightleftharpoons 3\text{Na}^+ + \text{Al}^{3+} + 6\text{F}^-$	-27.14
14.	$\text{NaCa}_2\text{Mg}_4\text{Al}_3\text{Si}_6\text{O}_{22}\text{F}_2 \rightleftharpoons \text{Na}^+ + 2\text{Ca}^{2+} + 4\text{Mg}^{2+} + 3\text{Al}^{3+} + 6\text{H}_4\text{SiO}_4^\circ + 2\text{F}^-$ $+ 2\text{H}_2\text{O} + 20\text{H}^+$	84.39
15.	$\text{NaMoF}_7(\text{c}) + 4\text{H}_2\text{O} \rightleftharpoons \text{Na}^+ + \text{H}_2\text{MoO}_4^\circ + 7\text{F}^- + 6\text{H}^+$	31.48
16.	$\text{K}_2\text{SiF}_6(\text{hieratite}) \rightleftharpoons 2\text{K}^+ + \text{H}_4\text{SiO}_4^\circ + 6\text{F}^- + 4\text{H}^+$ $+ 4\text{H}_2\text{O}$	-29.61
17.	$\text{KMg}_3\text{AlSi}_3\text{O}_{10}\text{F}_2 + 2\text{H}_2\text{O} \rightleftharpoons \text{K}^+ + 3\text{Mg}^{2+} + \text{Al}^{3+} + 3\text{H}_4\text{SiO}_4^\circ + 8\text{H}^+ + 2\text{F}^-$	7.85
18.	$\text{Ca}_5(\text{PO}_4)_3\text{F} + 6\text{H}^+ \rightleftharpoons 5\text{Ca}^{2+} + 3\text{H}_2\text{PO}_4^- + \text{F}^-$	-0.95
19.	$\text{Ca}_4\text{Si}_2\text{O}_7\text{F}_2 + \text{H}_2\text{O} + 6\text{H}^+ \rightleftharpoons 4\text{Ca}^{2+} + 2\text{H}_4\text{SiO}_4^\circ + 2\text{F}^-$	30.99

Table 9. Equilibrium Reactions of Fluoride. (cont).

No.	Reaction	logk°
20.	$(\text{NH}_4)_2\text{SiF}_6 + 4\text{H}_2\text{O} \rightleftharpoons 2\text{NH}_4^+ + \text{H}_4\text{SiO}_4^\circ + 6\text{F}^- + 4\text{H}^+$	-26.03
21.	$\text{Pb}_5(\text{PO}_4)_3\text{F} + 6\text{H}^+ \rightleftharpoons 5\text{Pb}^{2+} + 3\text{H}_2\text{PO}_4^- + \text{F}^-$	-12.98
II. Solution Complexes		
22.	$\text{HF}^\circ \rightleftharpoons \text{F}^- + \text{H}^+$	-2.21
23.	$\text{HF}_2^- \rightleftharpoons 2\text{F}^- + \text{H}^+$	-1.70
24.	$\text{AlF}^{2+} \rightleftharpoons \text{Al}^{3+} + \text{F}^-$	-6.98
25.	$\text{AlF}_2^+ \rightleftharpoons \text{Al}^{3+} + 2\text{F}^-$	-12.60
26.	$\text{AlF}_3^\circ \rightleftharpoons \text{Al}^{3+} + 3\text{F}^-$	-16.65
27.	$\text{AlF}_4^- \rightleftharpoons \text{Al}^{3+} + 4\text{F}^-$	-19.03
28.	$\text{FeF}_3^\circ \rightleftharpoons \text{Fe}^{3+} + 3\text{F}^-$	-11.70
29.	$\text{FeF}_2^+ \rightleftharpoons \text{Fe}^{3+} + 2\text{F}^-$	-9.20
30.	$\text{FeF}^{2+} \rightleftharpoons \text{Fe}^{3+} + \text{F}^-$	-6.00
31.	$\text{FeF}_2^\circ \rightleftharpoons \text{Fe}^{2+} + 2\text{F}^-$	-0.03
32.	$\text{PbF}_2^\circ \rightleftharpoons \text{Pb}^{2+} + 2\text{F}^-$	-2.27
33.	$\text{PbF}^+ \rightleftharpoons \text{Pb}^{2+} + \text{F}^-$	-1.49
34.	$\text{PbF}_3^- \rightleftharpoons \text{Pb}^{2+} + 3\text{F}^-$	-3.42
35.	$\text{PbF}_4^{2-} \rightleftharpoons \text{Pb}^{2+} + 4\text{F}^-$	-3.10
36.	$\text{SiF}_4^\circ + 4\text{H}_2\text{O} \rightleftharpoons \text{H}_4\text{SiO}_4^\circ + 4\text{F}^- + 4\text{H}^+$	-19.48
37.	$\text{SiF}_6^{2-} + 4\text{H}_2\text{O} \rightleftharpoons \text{H}_4\text{SiO}_4^\circ + 6\text{F}^- + 4\text{H}^+$	-23.61
38.	$\text{ZnF}_2^\circ \rightleftharpoons \text{Zn}^{2+} + 2\text{F}^-$	1.93
39.	$\text{ZnF}^+ \rightleftharpoons \text{Zn}^{2+} + \text{F}^-$	-0.27
40.	$\text{NaF}^\circ \rightleftharpoons \text{Na}^+ + \text{F}^-$	0.95
41.	$\text{KF}^\circ \rightleftharpoons \text{K}^+ + \text{F}^-$	0.81
42.	$\text{CuF}^+ \rightleftharpoons \text{Cu}^{2+} + \text{F}^-$	-0.32

Table 9. Equilibrium Reactions of Fluoride. (cont.)

No.		Reaction	logk°
43.	CdF_2°	$\text{Cu}^{2+} + 2\text{F}^-$	1.95
44.	HgF^+	$\text{Hg}^{2+} + \text{F}^-$	-1.56
45.	MnF^+	$\text{Mn}^{2+} + \text{F}^-$	0.54
46.	CaF^+	$\text{Ca}^{2+} + \text{F}^-$	-1.10
47.	MgF^+	$\text{Mg}^{2+} + \text{F}^-$	-1.80
48.	SrF^+	$\text{Sr}^{2+} + \text{F}^-$	-0.60
49.	GaF^{2+}	$\text{Ga}^{3+} + \text{F}^- \text{ TT}$	-3.79
50.	GaF_2^+	$\text{Ga}^{3+} + 2\text{F}^- \text{ TT}$	-6.55
51.	TlF°	$\text{Tl}^+ + \text{F}^- \text{ TT}$	0.95
52.	AgF°	$\text{Ag}^+ + \text{F}^- \text{ TT}$	0.96
53.	NiF_2°	$\text{Ni}^{2+} + 2\text{F}^- \text{ TT}$	1.87
54.	BaF_2°	$\text{Ba}^{2+} + 2\text{F}^- \text{ TT}$	1.89

TT Ga^{3+} , Tl^+ , Ag^+ , Ni^{2+} , and Ba^{2+} ΔG°_f values were taken from Wagman et al. (1982)

Table 10. Summary of Collected ΔG°_f (kJ/mole) Values for Molybdenum Species.
Values in the parenthesis are kcal/mole.

No.	Species	Source*						
		1	2	3	4	5	6	7
1.	MoO_4^{2-}	-836.30 (-199.88)	-836.13 (-199.84)	-----	-----	-----	-----	-----
2.	MoO_2^{2+}	-----	-----	-411.28 (-98.30)	-----	-----	-----	-----
3.	$\text{MoO}_2(\text{OH})^+$	-----	-645.75 (-154.34)	-645.88 (-154.37)	-----	-----	-----	-----
4.	HMoO_4^-	-----	-860.31 (-205.62)	-866.63 (-207.13)	-----	-----	-893.70 (-213.60)	-----
5.	$\text{H}_2\text{MoO}_4^\circ$	-----	-883.15 (-211.08)	-877.13 (-209.04)	-949.76 (-227.00)	-----	-----	-----
6.	MoO_3 (molybdate)	-667.97 (-159.64)	-668.01 (-159.66)	-----	-----	-668.10 (-159.64)	-----	-----
7.	$\text{H}_2\text{MoO}_4(\text{c})$	-----	-912.44 (-218.08)	-----	-----	-----	-----	-----
8.	$\text{MoS}_2(\text{c})$ (molybdenite)	-225.90 (-53.99)	-266.47 (-63.69)	-----	-255.09 (-53.80)	-----	-----	-267.14 (-63.85)
9.	$\text{Ag}_2\text{MoO}_4(\text{c})$	-----	-747.89 (-178.75)	-----	-821.73 (-196.40)	-----	-----	-----
10.	$\text{BaMoO}_4(\text{c})$	-1439.60 (-346.07)	-----	-----	-1075.28 (-257.00)	-----	-----	-----
11.	$\text{CaMoO}_4(\text{c})$	-1434.60 (-342.87)	-1435.90 (-343.19)	-----	-----	-----	-----	-----
12.	$\text{CuMoO}_4(\text{c})$	-----	-----	-809.60 (-193.50)	-----	-----	-----	-----

Table 10. Summary of Collected ΔG°_f (kJ/mole) Values for Molybdenum Species.
Values in the parenthesis are kcal/mole. (cont.)

No.	Species	Source*						
		1	2	3	4	5	6	7
13.	$\text{FeMoO}_4(\text{c})$	-975.00 (-233.03)	-971.27 (-232.14)	-974.28 (-232.86)	-982.40 (-234.80)	-----	-----	-----
14.	$\text{Li}_2\text{MoO}_4(\text{c})$	-1409.50 (-336.87)	-----	-----	-----	-----	-----	-----
15.	$\text{MgMoO}_4(\text{c})$	-1295.68 (-309.67)	-----	-1295.78 (-309.70)	-----	-----	-----	-----
16.	$\text{MnMoO}_4(\text{c})$	-----	-1090.30 (-260.59)	-1090.39 (-260.61)	-----	-----	-----	-----
17.	$\text{Na}_2\text{MoO}_4(\text{c})$	-1354.34 (-323.69)	-----	-----	-----	-----	-----	-----
18.	$\text{Ag}_2\text{MoO}_4^\circ$	-681.90 (-162.97)	-----	-----	-----	-----	-----	-----
19.	CaMoO_4°	-1389.90 (-332.19)	-----	-----	-----	-----	-----	-----
20.	$\text{Na}_2\text{MoO}_4^\circ$	-1360.20 (-325.09)	-----	-----	-----	-----	-----	-----
21.	$\text{K}_2\text{MoO}_4^\circ$	-1402.80 (-335.27)	-----	-----	-----	-----	-----	-----
22.	$\text{PbMoO}_4(\text{c})$	-951.40 (-227.39)	-952.36 (-227.62)	-----	-----	-----	-----	-----
23.	$\text{ZnMoO}_4(\text{c})$	-----	-----	-1010.35 (-241.60)	-----	-----	-----	-----

Table 10. Summary of Collected ΔG°_f (kJ/mole) Values for Molybdenum Species.
Values in the parenthesis are kcal/mole. (cont.)

*Source

1. Wagman et al. (1982)
2. Sadiq and Lindsay (1979)
3. Naumov et al. (1971)
4. Latimer (1952)
5. Stull et al. (1971)
6. Garrels and Christ (1965)
7. Chase et al. (1982)

Table 11. Selected ΔG°_f Values for Molybdenum Species.

No.	Species	ΔG°_f		Source	Remarks
		(kJ/mole)	(kcal/mole)		
1.	MoO_4^{2-}	-836.30	-199.88	Wagman et al. (1982)	ΔH°_f and s°
2.	MoO_2^{2+}	-411.28	-98.30	Naumov et al. (1971)	pk
3.	$\text{MoO}_2(\text{OH})^+$	-645.75	-154.34	Sadiq and Lindsay (1979)	pk
4.	HMoO_4^-	-860.48	-205.66	Smith and Martell (1976)	pk
5.	$\text{H}_2\text{MoO}_4^\circ$	-883.28	-211.11	Rohwer and Cruywagen (1963)	pk
6.	$\text{MoO}_3(\text{c})$ (molybdate)	-667.97	-159.64	Wagman et al. (1982)	ΔH°_f and s°
7.	$\text{H}_2\text{MoO}_4(\text{c})$	-912.44	-218.08	Sadiq and Lindsay (1979)	ΔH°_f and s°
8.	$\text{MoS}_2(\text{c})$ (molybdenite)	-266.47	-63.69	Sadiq and Lindsay (1979)	ΔH°_f and s°
9.	$\text{Ag}_2\text{MoO}_4(\text{c})$	-748.01	-178.78	Smith and Martell (1976)	pk
10.	$\text{BaMoO}_4(\text{c})$	-1439.60	-344.07	Wagman et al. (1982)	ΔH°_f and s°
11.	$\text{CaMoO}_4(\text{c})$	-1435.99	-343.21	Lindsay (1979)	pk
12.	$\text{CuMoO}_4(\text{c})$	-809.60	-193.50	Naumov et al. (1971)	pk
13.	$\text{FeMoO}_4(\text{c})$	-971.44	-232.18	Naumov et al. (1971)	pk
14.	$\text{Li}_2\text{MoO}_4(\text{c})$	-1409.50	-336.87	Wagman et al. (1982)	ΔH°_f and s°
15.	$\text{MgMoO}_4(\text{c})$	-1295.68	-309.67	Wagman et al. (1982)	ΔH°_f and s°
16.	$\text{MnMoO}_4(\text{c})$	-1090.39	-260.01	Naumov et al. (1971)	ΔH°_r
17.	$\text{Na}_2\text{MoO}_4(\text{c})$	-1354.34	-323.69	Wagman et al. (1982)	ΔH°_f and s°

Table 11. Selected ΔG°_f Values for Molybdenum Species. (cont.)

No.	Species	ΔG°_f		Source	Remarks
		(kJ/mole)	(kcal/mole)		
18.	$\text{Ag}_2\text{MoO}_4^\circ$	-681.90	-162.97	Wagman et al. (1982)	ΔH°_f and s°
19.	CaMoO_4°	-1389.90	-332.19	Wagman et al. (1982)	ΔH°_f and s°
20.	$\text{Na}_2\text{MoO}_4^\circ$	-1360.20	-325.09	Wagman et al. (1982)	ΔH°_f and s°
21.	$\text{K}_2\text{MoO}_4^\circ$	-1402.80	-335.27	Wagman et al. (1982)	ΔH°_f and s°
22.	$\text{PbMoO}_4(\text{c})$	-952.36	-227.62	Sadiq and Lindsay (1979)	ΔH°_f and s°
23.	$\text{ZnMoO}_4(\text{c})$	-1009.09	-241.18	Naumov et al. (1971)	pk

Table 12. Equilibrium Reactions of Molybdenum.

No.	Reaction	logk°
I. SOLID PHASES		
1. $\text{H}_2\text{MoO}_4(\text{c})$	$\rightleftharpoons 2\text{H}^+ + \text{MoO}_4^{2-}$	-13.34
2. $\text{MoO}_3(\text{molybdite}) + \text{H}_2\text{O}$	$\rightleftharpoons \text{MoO}_4^{2-} + 2\text{H}^+$	-12.05
3. $\text{Ag}_2\text{MoO}_4(\text{c})$	$\rightleftharpoons 2\text{Ag}^+ + \text{MoO}_4^{2-}$	-11.54
4. $\text{BaMoO}_4(\text{c})$	$\rightleftharpoons \text{Ba}^{2+} + \text{MoO}_4^{2-}$ T	-7.45
5. $\text{CaMoO}_4(\text{c})$	$\rightleftharpoons \text{Ca}^{2+} + \text{MoO}_4^{2-}$	-7.94
6. $\text{CuMoO}_4(\text{c})$	$\rightleftharpoons \text{Cu}^{2+} + \text{MoO}_4^{2-}$	-6.81
7. $\text{FeMoO}_4(\text{c})$	$\rightleftharpoons \text{Fe}^{2+} + \text{MoO}_4^{2-}$	-7.70
8. $\text{Li}_2\text{MoO}_4(\text{c})$	$\rightleftharpoons 2\text{Li}^+ + \text{MoO}_4^{2-}$ T	2.35
9. $\text{MgMoO}_4(\text{c})$	$\rightleftharpoons \text{Mg}^{2+} + \text{MoO}_4^{2-}$	-0.57
10. $\text{MnMoO}_4(\text{c})$	$\rightleftharpoons \text{Mn}^{2+} + \text{MoO}_4^{2-}$	-4.12
11. $\text{Na}_2\text{MoO}_4(\text{c})$	$\rightleftharpoons 2\text{Na}^+ + \text{MoO}_4^{2-}$	1.00
12. $\text{PbMoO}_4(\text{c})$	$\rightleftharpoons \text{Pb}^{2+} + \text{MoO}_4^{2-}$	-16.01
13. $\text{ZnMoO}_4(\text{c})$	$\rightleftharpoons \text{Zn}^{2+} + \text{MoO}_4^{2-}$	-4.48
14. $\text{MoS}_2(\text{molybdenite}) + 4\text{H}_2\text{O}$	$\rightleftharpoons \text{MoO}_4^{2-} + 2\text{S}^{2-} + 2\text{e}^- + 8\text{H}^+$	-96.43
II. SOLUTION PHASES		
15. $\text{H}_2\text{MoO}_4^\circ$	$\rightleftharpoons \text{H}^+ + \text{HMoO}_4^-$	-3.99
16. HMoO_4^-	$\rightleftharpoons \text{H}^+ + \text{MoO}_4^{2-}$	-4.23
17. $\text{H}_2\text{MoO}_4^\circ$	$\rightleftharpoons 2\text{H}^+ + \text{MoO}_4^{2-}$	-8.23
18. $\text{MoO}_2(\text{OH})^+ + \text{H}_2\text{O}$	$\rightleftharpoons \text{MoO}_4^{2-} + 3\text{H}^+$	-8.17
19. $\text{MoO}_2^{2+} + 2\text{H}_2\text{O}$	$\rightleftharpoons \text{MoO}_4^{2-} + 4\text{H}^+$	-8.64
20. $\text{Ag}_2\text{MoO}_4^\circ$	$\rightleftharpoons 2\text{Ag}^+ + \text{MoO}_4^{2-}$	0.05
21. CaMoO_4°	$\rightleftharpoons \text{Ca}^{2+} + \text{MoO}_4^{2-}$	0.14

Table 12. Equilibrium Reactions of Molybdenum. (cont.)

No.	Reaction	$\log k^\circ$
22. $\text{Na}_2\text{MoO}_4^\circ$	$\rightleftharpoons 2\text{Na}^+ + \text{MoO}_4^{2-}$	-0.02
23. $\text{K}_2\text{MoO}_4^\circ$	$\rightleftharpoons 2\text{K}^+ + \text{MoO}_4^{2-}$	-0.27

ΔG°_f values for Ba^{2+} and Li^+ were taken from Wagman et al. (1982).

Table 13. Summary of Collected Standard Free Energies of Formation (ΔG°_f , kJ/mole) of Se Species.
Values in the Parenthesis are kcal/mole.

Species	1	2	3	Source*	4	5	6
1. Se^{2-}	-129.30 (-30.90)	-129.30 (-30.90)	-129.30 (-30.90)		-	-	-
2. SeO_3^{2-}	-369.78 (-88.38)	-363.80 (-86.95)	-		-	-	-373.76 (-89.33)
3. SeO_4^{2-}	-441.28 (-105.47)	-441.41 (-105.50)	-		-	-	-
4. HS_e^-	43.93 (10.53)	43.93 (10.53)	-		-	-	-
5. $\text{H}_2\text{Se}^\circ$	22.17 (5.30)	22.17 (5.30)	-		-	-	-
6. HSeO_4^-	-452.16 (-108.07)	-450.87 (-107.76)	-		-	-	-
7. $\text{H}_2\text{SeO}_3^\circ$	-426.14 (-101.85)	-426.14 (-101.85)	-		-	-	-
8. $\text{H}_2\text{SeO}_4^\circ$	-	-	-		-	-	-441.08 (-105.42)
9. BaSeO_3	-968.18 (-231.40)	-	-971.95 (-232.30)		-	-	-
10. CaSe	-363.17 (-86.80)	-	75.32 (18.00)		-	-	-
11. $\text{CaSe}_3 \cdot 2\text{H}_2\text{O}$	-1428.84 (-341.50)	-1423.40 (-340.20)	-1428.84 (-341.50)		-	-	-

Table 13. Summary of Collected Standard Free Energies of Formation (ΔG°_f , kJ/mole) of Se Species.
Values in the Parenthesis are kcal/mole.

Species	Source*					
	1	2	3	4	5	6
12. CaSeO_4	-	-	-	-1013.50 (-242.23)	-	-
13. $\text{CaSeO}_4 \cdot 2\text{H}_2\text{O}$	-1486.80 (-355.35)	-1486.16 (-355.20)	-1402.40 (-335.18)	-	-	-
14. CuSe	-	-	-	-79.50 (-19.00)	-	-
15. Cu_2Se	-	-	-	-116.44 (-27.83)	-	-
16. CuSeO_3	-348.07 (-83.19)	-	-	-	-	-
17. $\text{CuSe}_3\text{O}_3 \cdot 2\text{H}_2\text{O}$	-	-817.39 (-195.36)	-827.60 (-197.80)	-823.00 (196.70)	-	-
18. FeSe	-	-	-58.16 to -74.06 (-13.90 to -17.70)	-110.29 (-26.36)	-	-58.16 (-13.90)
19. $\text{Fe}_2(\text{SeO}_3)_3$	-	-	-	-	-	-1331.56 (-318.25)
20. $\text{Fe}_3(\text{OH})_4\text{SeO}_3$	-	-	-	-	-	-1390.56 (-332.35)
21. MnSe	-111.71 (-26.70)	-153.55 (-36.70)	-122.30 (-157.73)	-166.94 (-39.90)	-	-

Table 13. Summary of Collected Standard Free Energies of Formation (ΔG°_f , kJ/mole) of Se Species. Values in the Parenthesis are kcal/mole.

Species	Source*					
	1	2	3	4	5	6
22. PbSe	-	-	-64.43 to -73.64 (-15.40 to -17.60	-131.88 (-31.52)	-	-64.43 (-15.40)
23. PbSeO ₃	-	-	-463.80 (-110.85)	-	-	-
24. PbSeO ₄	-504.88 (-120.67)	-504.84 (-120.88)	-497.90 (-119.00)	-	-	-
25. ZnSe	-163.00 (-38.96)	-	-145.18 (-34.70)	-185.72 (-44.39)	-	-145.18 (-34.00)
26. ZnSe ₃ ·H ₂ O	-729.80	-	-	-	-	-
27. ZnSeO ₄	-	-	-	-601.12 (-143.67)	-	-

*Source

1. Wagman et al. (1982)
2. Naumov et al. (1971)
3. Karapet'yants and Karapet'yants (1970)
4. Smith and Martell (1976)
5. Lindsay (1979)
6. Garrels and Christ (1965)

Table 14. Selected Standard Free Energies of Formation (ΔG°_f) of Se Species.

Species	ΔG°_f		Source	Remarks
	(kJ/mole)	(kcal/mole)		
1. Se^{2-}	-129.30	-30.90	Wagman et al. (1982)	ΔH°_f and s°
2. SeO_3^{2-}	-369.78	-88.38	Wagman et al. (1982)	ΔH°_f and s°
3. SeO_4^{2-}	-441.28	-105.47	Wagman et al. (1982)	ΔH°_f and s°
4. HSe^-	43.93	10.50	Wagman et al. (1982)	ΔH°_f and s°
5. H_2Se	22.17	5.30	Wagman et al. (1982)	ΔH°_f and s°
6. HSeO_4^-	-452.16	-108.07	Wagman et al. (1982)	ΔH°_f and s°
7. $\text{H}_2\text{SeO}_4^\circ$	-441.08	-105.42	Garrels and Christ (1965)	ΔH°_f and s°
8. BaSeO_3	-968.13	-231.40	Wagman et al. (1982)	ΔH°_f and s°
9. CaSe	-363.17	-86.80	Wagman et al. (1982)	ΔH°_f and s°
10. $\text{CaSe}_3 \cdot 2\text{H}_2\text{O}$	-1428.84	-341.50	Wagman et al. (1982)	ΔH°_f and s°
11. CaSeO_4	-1013.50	-242.23	Smith and Martell (1976)	pk
12. $\text{CaSeO}_4 \cdot 2\text{H}_2\text{O}$	-1486.80	-355.35	Wagman et al. (1982)	ΔH°_f and s°
13. CuSe	-79.50	-19.00	Smith and Martell (1976)	pk
14. Cu_2Se	-116.44	-27.83	Smith and Martell (1976)	pk
15. CuSeO_3	-348.07	-83.19	Wagman et al. (1982)	ΔH°_f and s°
16. $\text{CuSeO}_3 \cdot 2\text{H}_2\text{O}$	-827.60	-197.80	Karapet'yants & Karapet'yants (1970)	ΔH°_f and s°
17. FeSe	-110.29	-26.36	Smith and Martell (1976)	pk

Table 14. Selected Standard Free Energies of Formation (ΔG°_f) of Se Species. (cont.)

Species	ΔG°_f		Source	Remarks
	(kJ/mole)	(kcal/mole)		
18. $\text{Fe}_2(\text{SeO}_3)_3$	-1331.56	-318.25	Smith and Martell (1976)	pk
19. $\text{Fe}_3(\text{OH})_4\text{SeO}_3$	-1390.56	-332.35	Smith and Martell (1976)	pk
20. MnSe	-166.94	-39.90	Smith and Martell (1976)	pk
21. PbSe	-131.88	-31.52	Smith and Martell (1976)	pk
22. PbSeO_3	-463.80	-110.85	Karapet'yants & Karapet'yants (1970)	ΔH°_f and s°
23. PbSeO_4	-504.88	-120.67	Wagman et al. (1982)	ΔH°_f and s°
24. ZnSe	-185.72	-44.39	Smith and Martell (1976)	pk
25. $\text{ZnSe}_3 \cdot \text{H}_2\text{O}$	-729.80	-174.43	Wagman et al. (1982)	ΔH°_f and s°
26. ZnSeO_4	-601.12	-143.67	Smith and Martell (1976)	pk
27. $\text{H}_2\text{SeO}_3^\circ$	-426.14	-101.85	Wagman et al. (1982)	ΔH°_f and s°

Table 15. Equilibrium Reactions of Selenium.

No.	Equilibrium Reaction	logk°
<u>Redox Reactions</u>		
1.	$\text{SeO}_4^{2-} + 2\text{e}^- + 2\text{H}^+ \rightleftharpoons \text{SeO}_3^{2-} + \text{H}_2\text{O}$	29.02
2.	$\text{SeO}_4^{2-} + 6\text{e}^- + 8\text{H}^+ \rightleftharpoons \text{Se(c)} + 4\text{H}_2\text{O}$	88.89
3.	$\text{SeO}_4^{2-} + \text{Se}^- + 8\text{H}^+ \rightleftharpoons \text{Se}^{2-} + 4\text{H}_2\text{O}$	66.24
<u>Acids</u>		
4.	$\text{H}_2\text{SeO}_4^\circ \rightleftharpoons \text{H}^+ + \text{HSeO}_4^-$	1.96
5.	$\text{HSeO}_4^- \rightleftharpoons \text{SeO}_4^{2-} + \text{H}^+$	-1.91
6.	$\text{H}_2\text{SeO}_3^\circ \rightleftharpoons \text{HSeO}_3^- + \text{H}^+$	-2.57
7.	$\text{HSeO}_3^- \rightleftharpoons \text{H}^+ + \text{SeO}_3^{2-}$	-7.30
8.	$\text{H}_2\text{Se}^\circ \rightleftharpoons \text{HSe} + \text{H}^+$	-3.81
9.	$\text{HSe}^- \rightleftharpoons \text{Se}^{2-} + \text{H}^+$	-14.96
<u>Selenates</u>		
10.	$\text{BaSeO}_4 \text{ (c)} \rightleftharpoons \text{Ba}^{2+} + \text{SeO}_4^{2-}$	-7.46
11.	$\text{CaSeO}_4 \text{ (c)} \rightleftharpoons \text{Ca}^{2+} + \text{SeO}_4^{2-}$	-3.03
12.	$\text{CaSeO}_4 \cdot 2\text{H}_2\text{O (c)} \rightleftharpoons \text{Ca}^{2+} + \text{SeO}_4^{2-} + 2\text{H}_2\text{O}$	-2.94
13.	$\text{PbSeO}_4 \text{ (c)} \rightleftharpoons \text{Pb}^{2+} + \text{SeO}_4^{2-}$	-6.82
14.	$\text{ZnSeO}_4 \text{ (c)} \rightleftharpoons \text{Zn}^{2+} + \text{SeO}_4^{2-}$	-2.19

Table 15. Equilibrium Reactions of Selenium.

No.	Equilibrium Reaction	logk°
<u>Selenites</u>		
15.	$\text{BaSeO}_3 \text{ (c)} \rightleftharpoons \text{Ba}^{2+} + \text{SeO}_3^{2-}$	-6.57
16.	$\text{CaSeO}_3 \cdot 2\text{H}_2\text{O (c)} \rightleftharpoons \text{Ca}^{2+} + \text{SeO}_3^{2-} + 2\text{H}_2\text{O}$	-4.55
17.	$\text{CuSeO}_3 \text{ (c)} \rightleftharpoons \text{Cu}^{2+} + \text{SeO}_3^{2-}$	-7.68
18.	$\text{Fe}_2(\text{SeO}_3)_3 \text{ (c)} \rightleftharpoons 2\text{Fe}^{3+} + 3\text{SeO}_3^{2-}$	-33.00
19.	$\text{Fe}_2(\text{OH})_4\text{SeO}_3 \text{ (c)} \rightleftharpoons 2\text{Fe}^{3+} + 4\text{OH}^- + \text{SeO}_3^{2-}$	-62.70
20.	$\text{PbSeO}_3 \text{ (c)} \rightleftharpoons \text{Pb}^{2+} + \text{SeO}_3^{2-}$	-12.13
21.	$\text{ZnSeO}_3 \cdot \text{H}_2\text{O} \rightleftharpoons \text{Zn}^{2+} + \text{SeO}_3^{2-} + \text{H}_2\text{O}$	-6.77
<u>Selenides</u>		
22.	$\text{CaSe (c)} \rightleftharpoons \text{Ca}^{2+} + \text{Se}^{2-}$	10.80
23.	$\text{CuSe (c)} \rightleftharpoons \text{Cu}^{2+} + \text{Se}^{2-}$	-48.10
24.	$\text{Cu}_2\text{Se (c)} \rightleftharpoons 2\text{Cu}^+ + \text{Se}^{2-}$	-60.80
25.	$\text{FeSe (c)} \rightleftharpoons \text{Fe}^{2+} + \text{Se}^{2-}$	-26.00
26.	$\text{MnSe (c)} \rightleftharpoons \text{Mn}^{2+} + \text{Se}^{2-}$	-11.50
27.	$\text{PbSe (c)} \rightleftharpoons \text{Pb}^{2+} + \text{Se}^{2-}$	-42.10
28.	$\text{ZnSe (c)} \rightleftharpoons \text{Zn}^{2+} + \text{Se}^{2-}$	-29.40

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DOE/MC/11076-2443

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DISPOSAL OF PROCESSED OIL SHALE SOLID WASTE**

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