Chapter III

Selected thorium data

This chapter presents the chemical thermodynamic data set for thorium species that has been selected in this review. Table III-1 contains the recommended thermodynamic data of the thorium compounds and species, Table III-2 the recommended thermodynamic data of chemical equilibrium reactions by which the thorium compounds and complexes are formed, and Table II-3 the temperature coefficients of the heat capacity data of Table III-1 where available.

The species and reactions in the tables appear in standard order of arrangement. Table III-2 contains information only on those reactions for which primary data selections are made in Chapter V of this review. These selected reaction data are used, together with data for key thorium species and auxiliary data selected in this review, to derive the corresponding formation data in Table III-1. The uncertainties associated with values for key thorium species and the auxiliary data are in some cases substantial, leading to comparatively large uncertainties in the formation quantities derived in this manner.

The values of $\Delta_r G^\circ_m$ for many reactions are known more accurately than would be calculated directly from the uncertainties of the $\Delta_f G^\circ_m$ values in Table III-1 and auxiliary data. The inclusion of a table for reaction data (Table III-2) in this report allows the use of equilibrium constants with total uncertainties that are based directly on the experimental accuracies. This is the main reason for including both Table III-1 and Table III-2.

The selected thermal functions of the heat capacities, listed in Table II-3 refer to the relation

$$C^\circ_{p,m}(T) = a + b \times T + c \times T^2 + d \times T^{-1} + i \times T^{-1/2}$$

A detailed discussion of the selection procedure is presented in Chapter V. It may be noted that this chapter contains data on more species or compounds than are present in the tables of Chapter III. The main reasons for this situation are the lack of information for a proper extrapolation of the primary data to standard conditions in some systems and lack of solid primary data in others.

A warning: The addition of any aqueous species and their data to this internally consistent data base can result in a modified data set, which is no longer rigorous and can lead to erroneous results. The situation is similar when gases or solids are added.

Table III-1: Selected thermodynamic data for thorium compounds and complexes. All ionic species listed in this table are aqueous species. Unless noted otherwise, all data refer to the reference temperature of 298.15 K and to the standard state, *i.e.*, a pressure of 0.1 MPa and, for aqueous species, infinite dilution (I = 0). The uncertainties listed below each value represent total uncertainties and correspond in principle to the statistically defined 95% confidence interval. Values obtained from internal calculation, *cf.* footnotes (a) and (b), are rounded at the third digit after the decimal point and may therefore not be exactly identical to those given in Chapters V to XII. Systematically, all the values are presented with three digits after the decimal point, regardless of the significance of these digits. The data presented in this table are available on computer media from the OECD Nuclear Energy Agency.

Compound	$\Delta_f G_m^o$ (kJ·mol^{-1})	$\Delta_f H_m^o$ (kJ·mol^{-1})	S_m^o (J·K^{-1}·mol^{-1})	$C_{p,m}^o$ (J·K^{-1}·mol^{-1})
Th(cr, α) (fcc)	0.000	0.000	52.640 ±0.500	26.230 ±0.500
Th(g)	560.995 [(a)] ±6.002	602.000 ±6.000	190.170 ±0.010	20.790 ±0.005
Th^{4+}	– 704.783 [(a)] ±5.298	– 768.700 ±2.300	– 423.100 ±16.000	– 224.000 ±15.000
ThO(g)	– 51.299 [(a)] ±6.002	– 26.000 ±6.000	240.070 ±0.050	31.270 ±0.100
ThO_2(cr)	– 1168.988 [(a)] ±3.504	– 1226.400 ±3.500	65.230 ±0.200	61.740 ±0.150
ThO_2(g)	– 462.128 [(a)] ±15.430	– 455.000 [(b)] ±15.403	281.700 ±3.000	46.840 ±0.500
ThH(g)			233.500 ±5.000	29.600 ±4.000
ThH_2(cr)	– 105.468 [(a)] ±2.006	– 145.000 ±2.000	50.730 ±0.100	36.710 ±0.070
ThD_2(cr)			55.720 ±0.560	47.670 ±0.470
ThT_2(cr)			60.460 ±0.600	54.300 ±0.540
$ThH_{3.75}$(cr)	– 142.877 [(a)] ±8.001	– 215.400 ±8.000	54.420 ±0.110	51.320 ±0.100
$ThD_{3.75}$(cr)			63.970 ±0.640	69.710 ±0.700
$ThT_{3.75}$(cr)			72.650 ±0.730	81.490 ±0.810

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Table III-1 (Continued)

Compound	$\Delta_f G_m^o$ (kJ·mol^{-1})	$\Delta_f H_m^o$ (kJ·mol^{-1})	S_m^o (J·K^{-1}·mol^{-1})	$C_{p,m}^o$ (J·K^{-1}·mol^{-1})
$Th(OH)^{3+}$	– 927.653 [(b)] ±6.018	– 1010.330 [(b)] ±6.707	– 252.765 [(b)] ±28.180	
$Th(OH)_2^{2+}$	– 1143.673 [(b)] ±6.018	– 1254.660 [(b)] ±41.464	– 114.459 [(b)] ±140.102	
$Th(OH)_4(aq)$	– 1554.024 [(b)] ±6.638			
$Th_2(OH)_2^{6+}$	– 1850.168 [(b)] ±10.974	– 2050.760 [(b)] ±7.325	– 623.716 [(b)] ±38.485	
$Th_2(OH)_3^{5+}$	– 2082.171 [(b)] ±10.658			
$Th_4(OH)_8^{8+}$	– 4599.809 [(b)] ±21.317	– 5118.440 [(b)] ±23.204	– 708.329 [(b)] ±96.221	
$Th_4(OH)_{12}^{4+}$	– 5512.980 [(b)] ±21.228			
$Th_6(OH)_{14}^{10+}$	– 7338.604 [(b)] ±32.523			
$Th_6(OH)_{15}^{9+}$	– 7575.744 [(b)] ±32.927	– 8426.850 [(b)] ±25.977	– 608.102 [(b)] ±124.441	
ThF(g)	– 0.788 [(a)] ±15.422	30.000 ±15.000	257.300 ±12.000	34.700 ±6.000
ThF^{3+}	– 1036.936 [(b)] ±5.411	– 1104.450 [(b)] ±3.116	– 268.427 [(b)] ±17.604	
$ThF_2(g)$	– 601.857 [(a)] ±20.222	– 590.000 ±20.000	295.200 ±10.000	52.400 ±5.000
ThF_2^{2+}	– 1357.046 [(b)] ±5.631	– 1442.700 [(b)] ±2.672	– 162.534 [(b)] ±16.726	
$ThF_3(g)$	– 1159.774 [(a)] ±15.294	– 1165.000 ±15.000	339.300 ±10.000	73.300 ±5.000
ThF_3^+	– 1667.337 [(b)] ±5.763			
$ThF_4(cr)$	– 2005.736 [(a)] ±10.001	– 2100.000 ±10.000	142.060 ±0.170	110.710 ±0.130
$ThF_4(g)$	– 1719.328 [(a)] ±10.217	– 1750.700 [(b)] ±10.198	353.000 ±2.000	93.400 ±2.000
$ThF_4(aq)$	– 1976.887 [(b)] ±6.066			

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Table III-1 (Continued)

Compound	$\Delta_f G_m^o$ (kJ·mol^{-1})	$\Delta_f H_m^o$ (kJ·mol^{-1})	S_m^o (J·K^{-1}·mol^{-1})	$C_{p,m}^o$ (J·K^{-1}·mol^{-1})
ThOF(g)	– 566.186 [(a)] ±12.366	– 550.000 ±12.000	310.900 ±10.000	49.500 ±5.000
$ThOF_2$(cr)	– 1589.171 [(a)] ±7.948	– 1663.800 ±7.800	107.700 ±5.100	
ThCl(g)	215.688 [(a)] ±20.318	247.000 ±20.000	269.200 ±12.000	36.400 ±6.000
$ThCl^{3+}$	– 845.704 [(b)] ±5.330			
$ThCl_2$(g)	– 191.337 [(a)] ±22.202	– 179.000 ±22.000	317.100 ±10.000	55.300 ±5.000
$ThCl_3$(g)	– 563.764 [(a)] ±25.178	– 569.000 ±25.000	369.700 ±10.000	78.000 ±5.000
β-$ThCl_4$	– 1092.293 [(a)] ±1.984	– 1186.300 ±1.300	183.500 ±5.000	120.300 ±6.000
$ThCl_4\cdot 2\,H_2O$(cr)		– 1822.400 ±12.000		
$ThCl_4\cdot 4\,H_2O$(cr)		– 2456.200 ±12.000		
$ThCl_4\cdot 7\,H_2O$(cr)		– 3361.900 ±12.000		
$ThCl_4\cdot 8\,H_2O$(cr)		– 3661.300 ±12.000		
$ThCl_4$(g)	– 922.956 [(a)] ±5.304	– 951.400 [(b)] ±5.166	403.400 ±4.000	101.400 ±3.000
$ThOCl_2$(cr)	– 1153.564 [(a)] ±2.276	– 1231.500 ±2.100	116.900 ±2.900	
$ThClO_3^{3+}$	– 721.534 [(b)] ±5.515			
ThBr(g)	319.575 [(a)] ±20.318	365.000 ±20.000	281.100 ±12.000	37.400 ±6.000
$ThBr^{3+}$	– 816.510 [(b)] ±5.352			
$ThBr_2$(g)	– 0.027 [(a)] ±20.222	40.000 ±20.000	339.100 ±10.000	56.700 ±5.000
$ThBr_3$(g)	– 371.073 [(a)] ±15.295	– 334.000 ±15.000	405.300 ±10.000	80.800 ±5.000

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Table III-1 (Continued)

Compound	$\Delta_f G_m^o$ (kJ·mol^{-1})	$\Delta_f H_m^o$ (kJ·mol^{-1})	S_m^o (J·K^{-1}·mol^{-1})	$C_{p,m}^o$ (J·K^{-1}·mol^{-1})
β-$ThBr_4$	– 925.023 [(a)] ±2.505	– 963.800 ±2.000	227.000 ±5.000	125.200 ±6.000
$ThBr_4\cdot 7H_2O$(cr)		– 3163.900 ±12.000		
$ThBr_4\cdot 10H_2O$(cr)		– 4074.600 ±12.000		
$ThBr_4\cdot 12H_2O$(cr)		– 4677.800 ±12.000		
$ThBr_4$(g)	– 769.026 [(a)] ±5.593	– 742.300 [(b)] ±5.385	446.700 ±5.000	104.900 ±3.000
$ThOBr_2$(cr)		– 1129.800 ±5.400		
$ThBrO_3^{3+}$	– 696.558 [(b)] ±5.366			
ThI(g)			288.600 ±12.000	37.500 ±6.000
ThI_2(g)			355.600 ±10.000	57.400 ±5.000
ThI_3(g)			430.000 ±10.000	81.800 ±5.000
ThI_4(cr)	– 659.487 [(a)] ±2.668	– 669.600 ±2.200	251.000 ±5.000	137.100 ±10.000
ThI_4(g)	– 518.316 [(a)] ±5.753	– 460.600 [(b)] ±5.463	478.500 ±6.000	106.200 ±4.000
$ThOI_2$(cr)		– 996.600 ±2.300		
$ThIO_3^{3+}$	– 854.752 [(b)] ±5.385			
$Th(IO_3)_2^{2+}$	– 997.243 [(b)] ±5.565			
$Th(IO_3)_3^{+}$	– 1140.134 [(b)] ±5.825			
ThS(cr)	– 391.862 [(a)] ±6.205	– 396.300 ±6.200	69.810 ±0.700	47.720 ±0.500
ThS_2(cr)			96.230 ±1.700	70.290 ±0.500

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Table III-1 (Continued)

Compound	$\Delta_f G_m^o$ (kJ·mol^{-1})	$\Delta_f H_m^o$ (kJ·mol^{-1})	S_m^o (J·K^{-1}·mol^{-1})	$C_{p,m}^o$ (J·K^{-1}·mol^{-1})
$Th_2S_3(cr)$		– 1079.000 ±5.500		
ThOS(cr)			76.300 ±1.500	67.250 ±1.350
$ThSO_4^{2+}$	– 1484.006 (b) ±5.620	– 1657.120 (b) ±2.449	– 216.308 (b) ±17.316	
$Th(SO_4)_2(cr)$				173.500 ±5.000
$Th(SO_4)_2 \cdot 9 H_2O(cr)$	– 4391.269 (b) ±5.404			
$Th(SO_4)_2(aq)$	– 2248.102 (b) ±5.580	– 2547.000 (b) ±2.664	– 65.151 (b) ±17.219	
$Th(SO_4)_3^{2-}$	– 2998.147 (b) ±5.461			
ThOSe(cr)			93.500 ±1.900	72.650 ±1.500
ThN(cr)	– 353.638 (a) ±10.011	– 381.200 (b) ±10.000	56.000 ±1.500	45.000 ±1.100
ThN_3^{3+}	– 381.926 (b) ±6.739			
$Th(N_3)_2^{2+}$	– 57.415 (b) ±7.577			
$Th_3N_4(cr)$	– 1200.051 (a) ±15.659	– 1306.800 ±15.000	183.100 ±15.000	147.700 ±8.000
$Th(NO_3)_4 \cdot 4 H_2O(cr)$		– 2702.400 ±3.800		
$Th(NO_3)_4 \cdot 5 H_2O(cr)$	– 2322.651 (a) ±2.814	– 3005.400 ±2.800	543.100 ±0.800	480.700 ±0.800
$ThNO_3^{3+}$	– 822.997 (b) ±5.436			
$Th(NO_3)_2^{2+}$	– 939.499 (b) ±5.829			
$Th_4(PO_4)_4P_2O_7(cr)$				569.000 ±15.000
$ThH_2PO_4^{3+}$	– 1873.843 (b) ±5.822			

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Table III-1 (Continued)

Compound	$\Delta_f G_m^o$ (kJ·mol^{-1})	$\Delta_f H_m^o$ (kJ·mol^{-1})	S_m^o (J·K^{-1}·mol^{-1})	$C_{p,m}^o$ (J·K^{-1}·mol^{-1})
$ThH_3PO_4^{4+}$	– 1864.938 [(b)] ±5.804			
$Th(H_2PO_4)_2^{2+}$	– 3038.907 [(b)] ±6.430			
$Th(H_3PO_4)(H_2PO_4)^{3+}$	– 3034.455 [(b)] ±6.430			
ThAs(cr)			79.800 ±0.500	50.500 ±0.500
Th_3As_4(cr)			274.600 ±1.500	183.300 ±1.500
ThBi(cr)		– 162.300 ±4.200		
$ThBi_2$(cr)		– 207.100 ±6.300		
Th_3Bi_4(cr)		– 597.500 ±14.600		
Th_5Bi_3(cr)		– 532.200 ±16.700		
Th_5Sn_3(cr)		– 510.400 ±32.000		
$ThC_{0.97}$(cr)	– 124.466 [(a)] ±6.308	– 124.200 ±6.300	59.100 ±0.900	45.200 ±0.400
$ThC_{1.94}$(s)	– 126.705 [(a)] ±7.503	– 124.700 ±7.500	70.500 ±0.400	56.800 ±0.200
$Th(CO_3)_5^{6-}$	– 3521.231 [(b)] ±6.917			
$Th(OH)_2(CO_3)_2^{2-}$	– 2285.078 [(b)] ±6.070			
$ThOH(CO_3)_4^{5-}$	– 3176.808 [(b)] ±6.217			
$Th(OH)_4(CO_3)^{2-}$	– 2092.167 [(b)] ±6.327			
$ThSCN^{3+}$	– 623.499 [(b)] ±7.226			
$Th(SCN)_2^{2+}$	– 538.790 [(b)] ±10.626			

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Table III-1 (Continued)

Compound	$\Delta_f G^o_m$ (kJ·mol^{-1})	$\Delta_f H^o_m$ (kJ·mol^{-1})	S^o_m (J·K^{-1}·mol^{-1})	$C^o_{p,m}$ (J·K^{-1}·mol^{-1})
$ThSi_2$(cr)		– 169.500 ±9.600		
$ThSiO_4$(huttonite)		– 2110.800 ±4.700		
$ThSiO_4$(Thorite)		– 2117.500 ±4.200		
$Na_6Th(CO_3)_5\cdot 12\,H_2O$(cr)	– 8002.562 (b) ±7.301			
$ThTi_2O_6$(cr)		– 3095.000 ±4.300		

(a) Value calculated internally using $\Delta_f G^o_m = \Delta_f H^o_m - T\sum_i S^o_{m,i}$.
(b) Value calculated internally from reaction data (see Table III-2).

Table III-2: Selected thermodynamic data for reactions involving thorium compounds and complexes. All ionic species listed in this table are aqueous species. Unless noted otherwise, all data refer to the reference temperature of 298.15 K and to the standard state, *i.e.*, a pressure of 0.1 MPa and, for aqueous species, infinite dilution (I = 0). The uncertainties listed below each value represent total uncertainties and correspond in principal to the statistically defined 95% confidence interval. Values obtained from internal calculation, *cf*. footnote (a), are rounded at the third digit after the decimal point and may therefore not be exactly identical to those given in Chapters V to XII. Systematically, all the values are presented with three digits after the decimal point, regardless of the significance of these digits. The data presented in this table are available on computer media from the OECD Nuclear Energy Agency.

Species	Reaction			
	$\log_{10} K^\circ$	$\Delta_r G_m^\circ$ (kJ·mol⁻¹)	$\Delta_r H_m^\circ$ (kJ·mol⁻¹)	$\Delta_r S_m^\circ$ (J·K⁻¹·mol⁻¹)
Th(g)	Th(cr) ⇌ Th(g)			
			602.000 ±6.000	
$ThO_2(g)$	$ThO_2(cr)$ ⇌ $ThO_2(g)$			
			771.400 ±15.000	
ThO_2(am, hyd, fresh)	$4OH^- + Th^{4+}$ ⇌ $2H_2O(l)$ + ThO_2(am, hyd, fresh)			
	46.700 ±0.900	–266.566 ±5.137		
ThO_2(am, hyd, aged)	$4OH^- + Th^{4+}$ ⇌ $2H_2O(l)$ + ThO_2(am, hyd, aged)			
	47.500 ±0.900	–271.132 ±5.137		
$Th(OH)^{3+}$	$H_2O(l) + Th^{4+}$ ⇌ $H^+ + Th(OH)^{3+}$			
	–2.500 ±0.500	14.270 ±2.854	44.200 ±6.300	100.385 [a] ±23.197
$Th(OH)_2^{2+}$	$2H_2O(l) + Th^{4+}$ ⇌ $2H^+ + Th(OH)_2^{2+}$			
	–6.200 ±0.500	35.390 ±2.854	85.700 ±41.400	168.741 [a] ±139.186
$Th(OH)_4(aq)$	$4H_2O(l) + Th^{4+}$ ⇌ $4H^+ + Th(OH)_4(aq)$			
	–17.400 ±0.700	99.320 ±3.996		
$Th_2(OH)_2^{6+}$	$2H_2O(l) + 2Th^{4+}$ ⇌ $2H^+ + Th_2(OH)_2^{6+}$			
	–5.900 ±0.500	33.677 ±2.854	58.300 ±5.700	82.584 [a] ±21.380

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Table III-2 (Continued)

Species	Reaction			
	$\log_{10} K^\circ$	$\Delta_r G_m^\circ$ (kJ·mol⁻¹)	$\Delta_r H_m^\circ$ (kJ·mol⁻¹)	$\Delta_r S_m^\circ$ (J·K⁻¹·mol⁻¹)
$Th_2(OH)_3^{5+}$	$3H_2O(l) + 2Th^{4+} \rightleftharpoons 3H^+ + Th_2(OH)_3^{5+}$			
	–6.800 ±0.200	38.815 ±1.142		
$Th_4(OH)_8^{8+}$	$8H_2O(l) + 4Th^{4+} \rightleftharpoons 8H^+ + Th_4(OH)_8^{8+}$			
	–20.400 ±0.400	116.444 ±2.283	243.000 ±21.300	424.471 (a) ±71.850
$Th_4(OH)_{12}^{4+}$	$12H_2O(l) + 4Th^{4+} \rightleftharpoons 12H^+ + Th_4(OH)_{12}^{4+}$			
	–26.600 ±0.200	151.834 ±1.142		
$Th_6(OH)_{14}^{10+}$	$14H_2O(l) + 6Th^{4+} \rightleftharpoons 14H^+ + Th_6(OH)_{14}^{10+}$			
	–36.800 ±1.200	210.056 ±6.850		
$Th_6(OH)_{15}^{9+}$	$15H_2O(l) + 6Th^{4+} \rightleftharpoons 15H^+ + Th_6(OH)_{15}^{9+}$			
	–36.800 ±1.500	210.056 ±8.562	472.800 ±22.000	881.248 (a) ±79.180
ThF^{3+}	$F^- + Th^{4+} \rightleftharpoons ThF^{3+}$			
	8.870 ±0.150	–50.630 ±0.856	–0.400 ±2.000	168.473 (a) ±7.297
ThF_2^{2+}	$2F^- + Th^{4+} \rightleftharpoons ThF_2^{2+}$			
	15.630 ±0.230	–89.217 ±1.313	–3.300 ±0.400	288.166 (a) ±4.603
ThF_3^+	$3F^- + Th^{4+} \rightleftharpoons ThF_3^+$			
	20.670 ±0.160	–117.985 ±0.913		
ThF_4(cr, hyd)	$4HF(aq) + Th^{4+} \rightleftharpoons 4H^+ + ThF_4$(cr, hyd)			
	19.110 ±0.400	–109.081 ±2.283		
ThF_4(g)	$ThF_4(cr) \rightleftharpoons ThF_4(g)$			
			349.300 ±2.000	
ThF_4(aq)	$4F^- + Th^{4+} \rightleftharpoons ThF_4(aq)$			
	25.580 ±0.180	–146.012 ±1.027		

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Table III-2 (Continued)

Species	Reaction			
	$\log_{10} K^{\circ}$	$\Delta_r G_m^{\circ}$ (kJ·mol⁻¹)	$\Delta_r H_m^{\circ}$ (kJ·mol⁻¹)	$\Delta_r S_m^{\circ}$ (J·K⁻¹·mol⁻¹)
$ThCl^{3+}$	$Cl^- + Th^{4+} \rightleftharpoons ThCl^{3+}$			
	1.700 ± 0.100	–9.704 ± 0.571		
$ThCl_4(g)$	$\beta\text{-}ThCl_4 \rightleftharpoons ThCl_4(g)$			
			234.900 ± 5.000	
$ThClO_3^{3+}$	$ClO_3^- + Th^{4+} \rightleftharpoons ThClO_3^{3+}$			
	1.550 ± 0.130	–8.847 ± 0.742		
$ThBr^{3+}$	$Br^- + Th^{4+} \rightleftharpoons ThBr^{3+}$			
	1.380 ± 0.130	–7.877 ± 0.742		
$ThBr_4(g)$	$\beta\text{-}ThBr_4 \rightleftharpoons ThBr_4(g)$			
			221.500 ± 5.000	
$ThBrO_3^{3+}$	$BrO_3^- + Th^{4+} \rightleftharpoons ThBrO_3^{3+}$			
	1.900 ± 0.100	–10.845 ± 0.571		
$ThI_4(g)$	$ThI_4(cr) \rightleftharpoons ThI_4(g)$			
			209.000 ± 5.000	
$ThIO_3^{3+}$	$IO_3^- + Th^{4+} \rightleftharpoons ThIO_3^{3+}$			
	4.140 ± 0.100	–23.631 ± 0.571		
$Th(IO_3)_2^{2+}$	$2IO_3^- + Th^{4+} \rightleftharpoons Th(IO_3)_2^{2+}$			
	6.970 ± 0.120	–39.785 ± 0.685		
$Th(IO_3)_3^{+}$	$3IO_3^- + Th^{4+} \rightleftharpoons Th(IO_3)_3^{+}$			
	9.870 ± 0.110	–56.338 ± 0.628		
$ThSO_4^{2+}$	$SO_4^{2-} + Th^{4+} \rightleftharpoons ThSO_4^{2+}$			
	6.170 ± 0.320	–35.219 ± 1.827	20.920 ± 0.740	188.292 [(a)] ± 6.610

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Table III-2 (Continued)

Species	Reaction			
	$\log_{10} K^{\circ}$	$\Delta_r G_m^{\circ}$ (kJ·mol^{-1})	$\Delta_r H_m^{\circ}$ (kJ·mol^{-1})	$\Delta_r S_m^{\circ}$ (J·K^{-1}·mol^{-1})
$Th(SO_4)_2 \cdot 9H_2O(cr)$	$9H_2O(l) + 2SO_4^{2-} + Th^{4+} \rightleftharpoons Th(SO_4)_2 \cdot 9H_2O(cr)$			
	11.250 ±0.096	–64.215 ±0.548		
$Th(SO_4)_2(aq)$	$2SO_4^{2-} + Th^{4+} \rightleftharpoons Th(SO_4)_2(aq)$			
	9.690 ±0.270	–55.311 ±1.541	40.380 ±1.080	320.949 (a) ±6.312
$Th(SO_4)_3^{2-}$	$3SO_4^{2-} + Th^{4+} \rightleftharpoons Th(SO_4)_3^{2-}$			
	10.748 ±0.076	–61.352 ±0.434		
$Th(SeO_3)_2(cr)$	$Th(SeO_3)_2 \cdot H_2O(cr) \rightleftharpoons H_2O(g) + Th(SeO_3)_2(cr)$			
	–6.499 ±0.560	37.094 ±3.195	94.100 ±2.900	191.200 ±4.500
ThN_3^{3+}	$N_3^- + Th^{4+} \rightleftharpoons ThN_3^{3+}$			
	4.440 ±0.640	–25.344 ±3.653		
$Th(N_3)_2^{2+}$	$2N_3^- + Th^{4+} \rightleftharpoons Th(N_3)_2^{2+}$			
	8.590 ±0.640	–49.032 ±3.653		
$ThNO_3^{3+}$	$NO_3^- + Th^{4+} \rightleftharpoons ThNO_3^{3+}$			
	1.300 ±0.200	–7.420 ±1.142		
$Th(NO_3)_2^{2+}$	$2NO_3^- + Th^{4+} \rightleftharpoons Th(NO_3)_2^{2+}$			
	2.300 ±0.400	–13.128 ±2.283		
$ThH_2PO_4^{3+}$	$H_3PO_4(aq) + Th^{4+} \rightleftharpoons H^+ + ThH_2PO_4^{3+}$			
	3.450 ±0.320	–19.693 ±1.827		
$ThH_3PO_4^{4+}$	$H_3PO_4(aq) + Th^{4+} \rightleftharpoons ThH_3PO_4^{4+}$			
	1.890 ±0.310	–10.788 ±1.769		
$Th(H_2PO_4)_2^{2+}$	$2H_3PO_4(aq) + Th^{4+} \rightleftharpoons 2H^+ + Th(H_2PO_4)_2^{2+}$			
	6.200 ±0.320	–35.390 ±1.827		

(Continued on next page)

Table III-2 (Continued)

Species	Reaction			
	$\log_{10} K^\circ$	$\Delta_r G_m^\circ$ (kJ·mol^{-1})	$\Delta_r H_m^\circ$ (kJ·mol^{-1})	$\Delta_r S_m^\circ$ (J·K^{-1}·mol^{-1})
$Th(H_3PO_4)(H_2PO_4)^{3+}$	$2H_3PO_4(aq) + Th^{4+} \rightleftharpoons H^+ + Th(H_3PO_4)(H_2PO_4)^{3+}$			
	5.420 ±0.320	–30.938 ±1.827		
$Th(CO_3)_5^{6-}$	$5CO_3^{2-} + Th^{4+} \rightleftharpoons Th(CO_3)_5^{6-}$			
	31.000 ±0.700	–176.949 ±3.996		
$ThOH(CO_3)_4^{5-}$	$4CO_3^{2-} + OH^- + Th^{4+} \rightleftharpoons ThOH(CO_3)_4^{5-}$			
	35.600 ±0.500	–203.206 ±2.854		
$Th(OH)_2(CO_3)_2^{2-}$	$2CO_3^{2-} + 2OH^- + Th^{4+} \rightleftharpoons Th(OH)_2(CO_3)_2^{2-}$			
	36.800 ±0.500	–210.056 ±2.854		
$Th(OH)_4(CO_3)^{2-}$	$CO_3^{2-} + 4OH^- + Th^{4+} \rightleftharpoons Th(OH)_4(CO_3)^{2-}$			
	40.400 ±0.600	–230.605 ±3.425		
$ThSCN^{3+}$	$SCN^- + Th^{4+} \rightleftharpoons ThSCN^{3+}$			
	2.000 ±0.500	–11.416 ±2.854		
$Th(SCN)_2^{2+}$	$2SCN^- + Th^{4+} \rightleftharpoons Th(SCN)_2^{2+}$			
	3.400 ±0.800	–19.407 ±4.566		
$Na_6Th(CO_3)_5 \cdot 12H_2O(cr)$	$5CO_3^{2-} + 12H_2O(l) + 6Na^+ + Th^{4+} \rightleftharpoons Na_6Th(CO_3)_5 \cdot 12H_2O(cr)$			
	42.200 ±0.800	–240.879 ±4.566		

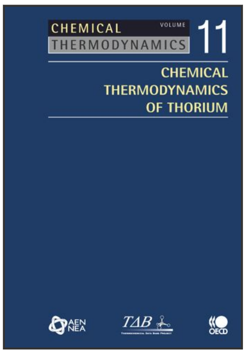
(a) Value calculated internally using $\Delta_r G_m^\circ = \Delta_r H_m^\circ - T\,\Delta_r S_m^\circ$.

(b) Value of $\log_{10} K^\circ$ calculated internally from $\Delta_r G_m^\circ$

Table III-3: Selected temperature coefficients for heat capacities in the form $C^{\circ}_{p,\mathrm{m}}(T) = a + bT + cT^2 + eT^{-2}$. The functions are valid between the temperatures T_{min} and T_{max} (in K). Units for $C^{\circ}_{p,\mathrm{m}}$ are $\mathrm{J \cdot K^{-1} \cdot mol^{-1}}$.

Compound	*a*	*b*	*c*	*e*	*T*(min)	*T*(max)
Th(cr, α) (fcc)	2.34350×10^{1}	8.94500×10^{-3}	0	1.14000×10^{4}	298.15	1633
Th(g)	2.41480×10^{1}	-1.45623×10^{-2}	1.77473×10^{-5}	-5.27700×10^{4}	298.15	700
ThO(g)	2.95010×10^{1}	1.33228×10^{-2}	-6.01025×10^{-6}	-1.48640×10^{5}	298.15	700
ThO_2(cr)	7.15780×10^{1}	6.33610×10^{-3}	7.44770×10^{-7}	-1.04834×10^{6}	298.15	2300
ThO_2(g)	4.69010×10^{1}	2.01352×10^{-2}	-1.02652×10^{-5}	-4.57730×10^{5}	298.15	800
ThH_2(cr)	8.29500	1.25602×10^{-1}	-5.05319×10^{-5}	-4.04100×10^{5}	298.15	1000
$ThH_{3.75}$(cr)	-7.42600	2.37538×10^{-1}	-9.33488×10^{-5}	-3.35550×10^{5}	298.15	1000
ThF(g) *	3.57170×10^{1}	4.00180×10^{-3}	-1.83420×10^{-6}	-1.85670×10^{5}	298.15	700
ThF_2(g) *	5.46630×10^{1}	7.46700×10^{-3}	-4.51541×10^{-6}	-3.62070×10^{5}	298.15	600
ThF_3(g) *	7.71500×10^{1}	1.26203×10^{-2}	-7.61875×10^{-6}	-6.16320×10^{5}	298.15	600
ThF_4(cr)	1.21734×10^{2}	9.06400×10^{-3}	-2.85740×10^{-7}	-1.21821×10^{6}	298.15	1383
ThF_4(g)	1.02950×10^{2}	7.43050×10^{-3}	-2.91682×10^{-6}	-1.02068×10^{6}	298.15	1300
ThOF(g)	4.89090×10^{1}	1.90003×10^{-2}	-1.12413×10^{-5}	-3.59500×10^{5}	298.15	600
$ThOF_2$(cr)	9.66560×10^{1}	7.70000×10^{-3}	-2.29500×10^{-7}	-1.13330×10^{6}	298.15	1500
ThCl(g) *	3.73210×10^{1}	1.02980×10^{-3}	-3.18700×10^{-8}	-1.04870×10^{5}	298.15	1900
$ThCl_2$(g) *	5.77010×10^{1}	8.49700×10^{-4}	-3.99960×10^{-7}	-2.34380×10^{5}	298.15	1000
$ThCl_3$(g) *	8.22270×10^{1}	1.55540×10^{-3}	-7.31790×10^{-7}	-4.10980×10^{5}	298.15	1000
$ThCl_4$(β)	1.20290×10^{2}	2.32672×10^{-2}	0	-6.15050×10^{5}	298.15	1043
$ThCl_4$(g) *	1.07721×10^{2}	2.99300×10^{-4}	-6.02300×10^{-8}	-5.73880×10^{5}	298.15	3000
$ThOCl_2$(cr)	9.59360×10^{1}	1.48040×10^{-2}	3.73900×10^{-7}	-8.31700×10^{5}	298.15	1500
ThBr(g) *	3.74030×10^{1}	1.82430×10^{-3}	-2.05000×10^{-9}	-5.05800×10^{4}	298.15	3000
$ThBr_2$(g) *	5.81670×10^{1}	2.85000×10^{-5}	-5.82000×10^{-9}	-1.28280×10^{5}	298.15	3000
$ThBr_3$(g) *	8.30940×10^{1}	4.13000×10^{-5}	-8.28000×10^{-9}	-2.05080×10^{5}	298.15	3000
$ThBr_4$(β)	1.27600×10^{2}	1.50624×10^{-2}	0	-6.15050×10^{5}	298.15	970
$ThBr_4$(g) *	1.08009×10^{2}	6.53000×10^{-5}	-1.31700×10^{-8}	-2.80920×10^{5}	298.15	3000
ThI(g) *	3.74110×10^{1}	1.54660×10^{-3}	-5.00000×10^{-10}	-3.15000×10^{4}	298.15	3000
ThI_2(g) *	5.81910×10^{1}	8.80000×10^{-6}	-1.79000×10^{-9}	-7.24600×10^{4}	298.15	3000
ThI_3(g) *	8.31280×10^{1}	1.42000×10^{-5}	-2.92000×10^{-9}	-1.18660×10^{5}	298.15	3000
ThI_4(cr)	1.40000×10^{2}	1.35000×10^{-2}	0	-6.15000×10^{5}	298.15	839
ThI_4(g) *	1.08061×10^{2}	2.27000×10^{-5}	-4.55000×10^{-9}	-1.69610×10^{5}	298.15	3000
$ThOI_2$(cr)	1.05789×10^{2}	9.91800×10^{-3}	3.72400×10^{-7}	-8.31700×10^{5}	298.15	1500
ThS(cr)	5.01240×10^{1}	5.46000×10^{-3}	0	-3.58600×10^{5}	298.15	2000
$Th(SO_4)_2$(cr)	1.04600×10^{2}	2.3096×10^{-1}	0		298.15	900
ThN(cr)	4.78360×10^{1}	1.37750×10^{-2}	0	-6.17200×10^{5}	298.15	2000
Th_3N_4(cr)	1.81517×10^{2}	2.61810×10^{-2}	0	-3.70000×10^{6}	298.15	2000
$Th_4(PO_4)_4P_2O_7$(cr)	6.96700×10^{2}	1.04550×10^{-1}	-1.86250×10^{-7}	-1.41590×10^{7}	298.15	1273

* Fitted from heat capacity values calculated from the molecular parameters given in Table E-1.



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