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A TABULATION OF THERMODYNAMIC DATA FOR CHEMICAL REACTIONS INVOLVING 58 ELEMENTS COMMON TO RADIOACTIVE WASTE PACKAGE SYSTEMS

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INTRODUCTION

The rate of release and migration of radionuclides from a nuclear waste repository to the biosphere is dependent on chemical interactions between groundwater, the geologic host rock, and the radioactive waste package. For the purpose of this report, the waste package includes the wasteform, canister, overpack, and repository backfill.

Successful isolation of nuclear waste from the biosphere requires predicting the behavior of a waste repository over a period of time of tens of thousands of years or longer. To assess the suitability of a potential repository, a complete, validated method of ascertaining the potential for movement of radionuclides from the repository through the host rock environment is needed. Mathematical models based on an understanding of the physical and chemical processes involved are the only tools available by which the repository's behavior can be predicted over the long time spans and path lengths of interest.

Chemical processes of interest include sorption (ion exchange), dissolution, complexation, and precipitation. Previous reports by Benson (1980) and White (1980) have dealt with the former two processes. Thermochemical data for complexation and precipitation calculations are presented in this report.

THERMOCHEMICAL DATA

Thermochemical data for 58 elements common to the radioactive waste package have been tabulated in two ways. In Table 1 are listed standard free energies of formation (ΔG°_{f}) of free ions, complexes, and solids.

In Table 2 are listed common logarithms of equilibrium constants (log K's) for speciation and precipitation reactions. Unless noted otherwise, all data are for 298.15°K and one atmosphere.

The data which were extracted from a variety of primary and secondary references (Alwan and Williams, 1980; Baes and Mesmer, 1976; Ball et al., 1980; Cleveland, 1970; Fuger and Oetting, 1976; Haacke and Williams, 1979; Helgeson et al., 1978; Keller, 1971; Kuck, 1978; Langmuir, 1977; Langmuir, 1978; Lemire and Tremaine, 1980; May et al., 1979; Nriagu and Dell, 1974; Rai and Serne, 1978; Robie et al., 1978; Sillen and Martell, 1964; Smith and Martell, 1976; Stoessel, R. K., 1977; Truesdell and Jones, 1974; Urusov and Khodakovsky, 1967; Wagman et al., 1968; Wolery, 1979; Helgeson, 1978; Plummer et al., 1976; Rai et al., 1980) were not critically reviewed; however, certain selection procedures were employed.

Free Energy Data

Solids. Most of the free energy data were taken from three compilations: Helgeson et al., (1978), Robie et al., (1978) and Wagman et al. (1968). In some cases, the three sources did not agree on the free energy value assigned to a particular solid phase. In these cases, a selection hierarchy was employed in which the order of preference was Helgeson et al., (1978), Robie et al. (1978), Wagman et al. (1978). Free energies for aluminosilicates were taken solely from Helgeson et al. (1978).

Free energy data for aluminum oxides were taken from May et al. (1979). Free energies for phosphate solids, not available in Robie et al. (1978), were taken from Nriagu and Dell (1974). Molybdate data were taken primarily from

Kuck (1978); molybdate free energies were also taken from Urusov and Khodakovsky (1967) if unavailable in Kuck (1978). Uranium data were obtained from Langmuir (1978) and Lemire and Tremaine (1980). Thorium data were taken from Langmuir (1977) and plutonium data were taken from Lemire and Tremaine (1980).

Dissolved Species. The majority of the free energy data for dissolved species (free ions and complexes) were taken from Truesdell and Jones (1974), Ball et al. (1980), and Smith and Martell (1976). Data not available in these sources were obtained from Robie et al. (1978) and Wagman et al. (1968). If the latter two sources disagreed on the free energy value for a particular chemical species, the value given in Robie et al. (1978) was used. Data on aluminium species were taken from May et al. (1979). Free energy data on chemical species not available in the references mentioned above were taken from a variety of literature sources.

Equilibrium Constants and Gibbs Standard Free Energies of Reaction

All chemical reactions were formulated using a fundamental basis species set (Table 3). When free energies of formation were available for all components of a chemical reaction, data of Table 1 were used to calculate the standard free energy of reaction (ΔG_r°).

Basis species free energies for ten elements (Am, Cm, Gd, La, Nd, Np, Pm, Pr, Sm, Tc) were unavailable. Therefore equilibrium constants for reactions involving these elements were obtained by addition of reactions from a single reference.

Basis species free energies of seven elements (Eu, Hf, Ru, Sn, Te, Ti, Zr) were obtained using a known free energy value for a reaction involving a particular basis species together with free energies of formation for each of the other components involved in the reaction (Table 1).

When various literature sources were not in agreement on values of the reaction free energy, a selection hierarchy was employed. The order of preference was Ball et al., (1978), Plummer et al. (1976), Truesdell and Jones (1974), Smith and Martell (1976) and Baes and Mesmer (1976). For reactions involving ion pairs, the order of selection was similar to the forementioned except that the data of Wagman et al. (1968) were given preference over the data of Baes and Mesmer (1976).

As a rule, equilibrium constants measured in media with ionic strengths greater than 0.1 were not incorporated in Table 2. However equilibrium coefficients for reactions involving Am, Ce, Cm, Np, and Zr are exceptions to this rule (see Rai and Serne; 1978).

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T A B L E S

TABLE 1. GIBBS STANDARD FREE ENERGIES OF FORMATION OF FREE IONS, COMPLEXES, AND SOLIDS

SILVER

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Ag(s)	0	16
Ag^+	18.422	16
Ag_2S (acanthite)	-9.446	24
$AgSO_4^-$	-161.3	22
$Ag_2SO_4(s)$	-147.82	22
$AgNO_3(s)$	-8.00	22
$Ag_2CO_3(s)$	-104.4	22
$Ag_3PO_4(s)$	-210.0	22
AgBr (bromargyrite)	-23.2125	16
$AgBr_2^-$	-41.2	22
$AgBr_3^{2-}$	-68.0	22
AgCl (cerargyrite)	-26.2474	16
$AgCl_2^-$	-51.5	22
AgI (iodargyrite)	-15.835	16
AgI_2^-	-20.8	22
AgI_3^{2-}	-36.8	22
AgI_4^{3-}	-50.1	22
$AgCl_3Br^{3-}$	-111.3	22
$AgClBr_3^{3-}$	-100.4	22
$Ag_2O(s)$	-2.68	22
$Ag_2O_2(s)$	6.6	22
$Ag_2O_3(s)$	29.0	22
$Ag(OH)_2^-$	-62.2	22
$Ag_2Se(s)$	-10.6	22
$Ag_2SeO_3(s)$	-72.7	22

SILVER (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$Ag_2SeO_4(s)$	-79.9	22
$Ag_2MoO_4(s)$	-178.8	22
$AgVO_3(s)$	-214.3	22
$Ag_2HVO_4(s)$	-288.6	22
$Ag_2HVO_4 \cdot AgOH(s)$	-358.6	22
$Ag_2CrO_4(s)$	-153.40	22

ALUMINUM

$Al(s)$	0	13
Al^{3+}	-117.0	13
$Al_2(SO_4)_3(s)$	-740.8824	16
$Al_2(SO_4)_3 \cdot 6H_2O(s)$	-1104.82	22
$AlPO_4$ (berlinite)	-382.7	22
$AlF_3(s)$	-342.0354	16
AlF^{2+}	-192.0	22
$AlI_3(s)$	-71.9	22
$AlOH^{2+}$	-166.9	13
$Al(OH)_2^+$	-216.5	13
$Al(OH)_4^-$	-313.5	13
$Al(OH)_3$ (gibbsite synthetic)	-276.0	13
$Al(OH)_3$ (gibbsite natural)	-275.1	13
Al_2O_3 (corundum,α)	-374.824	7
AlO(OH) (boehmite)	-217.250	7
AlO(OH) (diaspore)	-218.402	7

ALUMINUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$Al_2O_3(s,\gamma)$	-373.4947	16
AlO_2^-	-196.8	22
Al_2SiO_5 (kyanite)	-580.956	7
Al_2SiO_5 (andalusite)	-580.587	7
Al_2SiO_5 (sillimanite)	-580.091	7
$Al_2Si_2O_5(OH)_4$ (kaolinite)	-905.614	7
$Al_2Si_4O_{10}(OH)_2$ (pyrophyllite)	-1255.997	7

BARIUM

Ba(s)	0	16
Ba^{2+}	-134.020	16
BaS(s)	-109.0	22
$BaSO_4$ (barite)	-325.563	24
$Ba(HCO_3)_2(s)$	-414.54	22
$BaNO_3^+$	-159.35	22
$Ba(NO_3)_2(s)$	-190.387	16
$BaCa(CO_3)_2$ (alstonite)	-543.2	22
$BaCa(CO_3)_2$ (barytocalcite)	-543.0	22
BaO(s)	-124.377	16
$Ba(OH)_2 \cdot 8H_2O(s)$	-667.6	22
$BaF_2(s)$	-276.5	22
$BaCl_2(s)$	-193.7	22
$BaCl_2 \cdot H_2O(s)$	-252.32	22
$BaCl_2 \cdot 2H_2O(s)$	-309.86	22

BARIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$BaBr_2(s)$	-176.1	22
$BaBr_2 \cdot 2H_2O(s)$	-294.1	22
$BaO \cdot SiO_2(s)$	-368.13	22
$BaO \cdot 2SiO_2(s)$	-576.2	22
$2BaO \cdot SiO_2(s)$	-519.8	22
$2BaO \cdot 3SiO_2(s)$	-947.2	22
$BaSiF_6(s)$	-667.8	22
$BaTiO_3(s)$	-375.8	22
$BaTiO_4(s)$	-509.8	22
$BaSrTiO_4(s)$	-518.1	22
$BaCrO_4(s)$	-321.53	22
$BaMnO_4(s)$	-267.5	22
$BaZrO_3(s)$	-405.0	22
$BaSeO_3(s)$	-231.4	22
$BaSeO_4(s)$	-249.7	22
$BaMoO_4(s)$	-347.6	21

BROMINE

Br^-	-24.8540	16

CARBON

CO_3^{2-}	-126.171	11

CALCIUM

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Ca(s)	0	16
Ca^{2+}	-132.299	16
CaS (oldhamite)	-112.297	16
$CaSO_4 \cdot 1/2\ H_2O$ (macro α)	-343.41	22
$CaSO_4 \cdot 1/2\ H_2O$ (micro β)	-343.18	22
$CaCO_3$ (vaterite)	-269.0105	16
$CaCO_3 \cdot H_2O$ (monohydrocalcite)	-325.4302	16
$CaMg(CO_3)_2$ (dolomite)	-517.980	7
$CaMg_3(CO_3)_4$ (huntite)	-1004.710	24
$Ca(NO_3)_2$(s)	-177.578	16
$Ca(NO_3)_2 \cdot 2H_2O$(s)	-293.82	22
$Ca(NO_3)_2 \cdot 3H_2O$(s)	-351.8	22
$Ca(NO_3)_2 \cdot 4H_2O$(s)	-409.53	22
$Ca_3(PO_4)_2$ (whitlockite)	-931.0837	16
$Ca_3(PO_4)_2$(s,β)	-928.5	22
$Ca_3(PO_4)_2$(s,α)	-926.3	22
$Ca_{10}(PO_4)_6(OH)_2^o$	-2859.2	22
$CaHPO_4$(s)	-401.83	22
$CaHPO_4 \cdot 2H_2O$(s)	-515.00	22
$Ca(H_2PO_4)_2 \cdot H_2O$(s)	-730.98	22
$Ca_8H_2(PO_4)_6 \cdot 5H_2O$(s)	-2931.0	22
CaSe(s)	-86.8	22
$CaSeO_3 \cdot 2H_2O$(s)	-341.5	22
$CaSeO_4 \cdot 2H_2O$(s)	-355.4	22
$CaMoO_4$ (powellite)	-344.0	9

CALCIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$CaCl_2$ (hydrophilite)	-178.791	22
$CaBr_2(s)$	-158.6	22
$CaBr_2 \cdot 6H_2O(s)$	-514.6	22
$CaI_2(s)$	-126.4	22
CaF_2 (fluorite)	-280.493	24
CaO (lime)	-144.366	7
$Ca(OH)_2$ (portlandite)	-214.725	16
$CaOH^+$	-171.7	22
$Ca_3SiO_5(s)$	-665.4	22
$Ca_3Si_2O_7$ (rankinite)	-899.0	22
$Ca_3Ti_2O_7(s)$	-896.6	22
$CaZrO_3(s)$	-401.8	22
$CaFe_2O_4(s)$	-337.6353	16
$Ca_2Fe_2O_5(s)$	-478.3843	16
$CaTiO_3$ (perovskite)	-376.4952	16
Ca_2SiO_4 (larnite)	-523.7247	16
Ca_2SiO_4 (Ca-olivine)	-525.7610	16
$Ca_2Al_2SiO_7$ (gehlenite)	-903.588	7
$Ca_3Al_2Si_3O_{12}$ (grossular)	-1496.967	7
$Ca_3Fe_2Si_3O_{12}$ (andradite)	-1297.479	7
$CaAl_2Si_2O_7(OH)_2 \cdot H_2O$ (lawsonite)	-1073.628	7
$CaMgSiO_4$ (monticellite)	-512.829	7
$Ca_3Mg(SiO_4)_2$ (merwinite)	-1037.186	7
$Ca_2MgSi_2O_7$ (akermanite)	-879.802	7
$CaTiSiO_5$ (sphene)	-587.9195	16

CALCIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$Ca_2Al_3Si_3O_{12}(OH)$ (clinozoisite)	-1549.680	7
$Ca_2Al_3Si_3O_{12}(OH)$ (zoisite)	-1549.619	7
$Ca_2FeAl_2Si_3O_{12}(OH)$ (epidote)	-1451.346	7
$CaSiO_3$ (wollastonite)	-369.445	7
$CaSiO_3$ (pseudowollastonite)	-369.2531	16
$CaAl_2SiO_6$ (Ca-Al pyroxene)	-742.287	7
$CaMgSi_2O_6$ (diopside)	-724.000	7
$CaFeSi_2O_6$ (hedenbergite)	-639.218	7
$Ca_2Mg_5Si_8O_{22}(OH)_2$ (tremolite)	-2770.685	7
$CaAl_2Si_2O_8$ (anorthite)	-954.298	7
$CaAl_2Si_4O_{12}\cdot 2H_2O$ (wairakite)	-1477.652	7
$CaAl_2Si_4O_{12}\cdot 4H_2O$ (laumontite)	-1597.043	7
$Ca_2Al(AlSi_3O_{10})(OH)_2$ (prehnite)	-1390.537	7
$CaAl_2(Al_2Si_2O_{10})(OH)_2$ (margarite)	-1394.370	7
$Ca(UO_2)_2(SiO_3OH)_2$ (uranophane)	(-1189.0)	11
$Ca_2UO_2(CO_3)_3\cdot 10H_2O$ (liebigite)	-1488.0	1
$CaMgUO_2(CO_3)_3\cdot 12H_2O$ (swartzite)	-1579.0	1
$Ca(UO_2)_2(VO_4)_2$(tyuyamunite)	(-1090.0)	11

CADMIUM

Cd^{2+}	-18.5421	16
CdS (greenokite)	-34.8064	16
$CdSO_4(s)$	-196.65	22
$CdSO_4\cdot H_2O(s)$	-255.46	22
$CdSO_4\cdot 8/3\ H_2O(s)$	-350.224	22

CADMIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$Cd_3(OH)_4SO_4(s)$	-429.6	22
$Cd_3(OH)_2(SO_4)_2(s)$	-515.8	22
$CdCO_3$ (otavite)	-160.000	16
$Cd_3(PO_4)_2(s)$	-587.1	22
$CdSeO_3(s)$	-119.0	22
$CdSeO_4(s)$	-127.1	22
$CdSb(s)$	-3.11	22
$CdCl_2(s)$	-82.21	22
$CdCl_2 \cdot H_2O(s)$	-140.310	22
$CdCl_2 \cdot 5/2\ H_2O(s)$	-225.644	22
$Cd(OH)Cl(s)$	-101.8	22
$CdBr^+$	-46.35	22
$CdBr_3^-$	-97.4	22
$CdBr_2(s)$	-70.82	22
$CdBr_2 \cdot 4H_2O(s)$	-298.287	22
CdI^+	-33.8	22
CdI_3^-	-62.0	22
CdI_4^{2-}	-75.5	22
$CdI_2(s)$	-48.13	22
CdO (monteponite)	-54.6140	16
CdO_2^{2-}	-68.0	22
$HCdO_2^-$	-86.9	22
$Cd(OH)_3^-$	-143.6	22
$Cd(OH)_4^{2-}$	-181.3	22
$CdSiO_3(s)$	-264.20	22

CERIUM

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Ce^{3+}	-160.612	16
Ce^{4+}	-120.411	16
CeO_2 (cerianite)	-245.072	16
Ce_2O_3 (s, hexagonal α)	-408.2075	16

CHLORINE

Cl^-	-31.3743	16

CHROMIUM

CrO_4^{2-}	-173.96	22
Cr_2O_3(s)	-251.6864	16
$Cr_2O_7^{2-}$	-311.0	22
$HCrO_4^-$	-182.8	22
CrF_3(s)	-260.0	22
$CrCl_2$(s)	-85.1	22
$CrCl_3$(s)	-116.2	22

CESIUM

Cs^+	-67.7880	16
Cs(s)	0	16

COPPER

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Cu^+	11.9503	16
Cu^{2+}	15.6597	16
CuS (covellite)	-12.612	24
Cu_2S (chalcocite)	-20.7620	16
$CuFeS_2$ (chalcopyrite)	-44.900	7
Cu_5FeS_4 (bornite)	-86.704	7
$CuSO_4$ (chalcocyanite)	-158.296	16
$CuSO_4 \cdot H_2O(s)$	-219.46	22
$CuSO_4 \cdot 3H_2O(s)$	-334.65	22
$CuSO_4 \cdot 5H_2O$ (chalcanthite)	-449.3059	16
$Cu_3(OH)_4SO_4$ (antlerite)	-345.8	22
$Cu_4SO_4(OH)_6$ (brochantite)	-434.5005	16
$Cu_4(OH)_6SO_4 \cdot H_2O$ (langite)	-488.6	22
$Cu_2(OH)_2(CO_3)$ (malachite)	-214.204	24
$Cu_3(OH)_2(CO_3)_2$ (azunite)	-334.417	24
$CuMoO_4(s)$	-195.5	21
$CuSeO_3(s)$	-83.2	22
$Cu_2(OH)_3(NO_3)_2(s)$	-152.75	22
$Cu_3(PO_4)_2(s)$	-490.3	22
CuCl(nantokite)	-28.65	22
$CuCl^+$	-16.3	22
$CuCl_2$(melanthallite)	-42.0	22
$CuCl_2 \cdot 2H_2O(s)$	-156.8	22
CuBr(s)	-24.1	22
$CuBr_2 \cdot 3Cu(OH)_2(s)$	-306.2	22

COPPER (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
CuI(s)	-16.6	22
CuO (tenorite)	-30.568	24
Cu_2O (cuprite)	-35.384	24
CuO_2^{2-}	-43.9	22
$HCuO_2^-$	-61.8	22

EUROPIUM

Eu^{3+}	-137.20	15
EuO(s)	-132.907	16
Eu_2O_3(s, monoclinic)	-371.6917	16

FLUORINE

F^-	-67.1705	16

IRON

Fe^{2+}	-18.8504	16
Fe^{3+}	-1.09943	16
FeS (troilite)	-24.2192	16
FeS_2 (pyrite)	-38.293	24
FeS_2 (marcasite)	-37.8635	16
FeS (pyrrhotite)	-24.084	16
Fe_7S_8 (S-rich pyrrhotite)	-178.9	22

IRON (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$FeSO_4(s)$	-196.2	22
$FeSO_4^+$	-184.7	22
$Fe(SO_4)_2^-$	-364.4	22
$Fe_3(PO_4)_2 \cdot 8H_2O$ (vivianite)	-1046.2	14
$Fe_5(PO_4)_3OH(s)$	-1510.2	14
$FeMoO_4(s)$	-233.0	9
$FeCO_3$ (siderite)	-162.390	24
$Fe(NO_3)^{2+}$	-29.1	22
$FeCl_2$ (lawencite)	-72.2208	16
$FeCl^{2+}$	-34.4	22
$FeCl_2^+$	-66.7	22
$FeCl_3$ (molysite)	-79.7691	16
FeF^{2+}	-77.1	22
FeF_2^+	-150.2	22
$FeBr^{2+}$	-26.8	22
FeI^{2+}	-16.0	22
$Fe_{.947}O$ (wustite)	-58.5935	16
$FeO(s)$	-60.097	7
Fe_2O_3 (hematite)	-178.155	7
Fe_3O_4 (magnetite)	-242.574	7
$Fe(OH)_2(s)$	-118.5	14
FeO_2^{2-}	-108.8	22
$FeOH^{2+}$	-54.83	22
$HFeO_2^-$	-90.3	16
$Fe(OH)_3^-$	-147.0	22

IRON (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$FeOH_4^{2-}$	-184.0	22
$Fe_2(OH)_2^{4+}$	-111.68	22
$FeAl_2O_4$ (hercynite)	-442.3506	16
$FeTiO_3$ (ilmenite)	-277.0483	16
$FeCr_2O_4$ (chromite)	-321.2	22
FeSi(s)	-17.6	22
$FeSi_2$ (β-lebeanite)	-18.7	22
$FeSi_{2.33}$ (α-lebeanite)	-14.0	22
$Fe_3Si(s)$	-22.6	22
$FeSiO_4$ (fayalite)	-330.233	7
$FeSiO_3$ (ferrosilite)	-267.160	7

HYDROGEN

HCO_3^-	-140.261	16
$H_2CO_3^o$	-148.941	16
HF^o	-71.685	12
HF_2^-	-138.18	22
$H_2O(\ell)$	-56.678	16
HPO_4^{2-}	260.34	22
$H_2PO_4^-$	-270.17	22
$H_3PO_4^o$	-273.16	12
$H_3PO_4(s)$	-265.8437	16
$H_3PO_4 \cdot 1/2\ H_2O(s)$	-296.9	22
HS^-	2.892	16
HSO_4^-	-180.69	22

HAFNIUM

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Hf^{4+}	-133.700	18
HfO_2^o	-260.1042	16
HfF_4(s,monoclinic)	-437.5	22
$HfCl_4$(s)	-215.42	22

IODINE

I^-	-12.408	16

POTASSIUM

K(s)	0	16
K^+	-67.5167	16
K_2SO_4 (arcanite)	-315.4068	16
$KAl(SO_4)_2$(s)	-535.3227	16
K_2MoO_4(s)	-330.1	21
KNO_3 (niter)	-94.2983	16
KCl (sylvite)	-97.735	24
KBr(s)	-90.8368	16
K_2O(s)	-77.056	7
KO_2(s)	57.5014	16
KOH (s)	-90.5669	16
$KAlSi_3O_8$ (K-spar)	-895.374	7
$KAlSi_3O_8$ (max-microcline)	-895.374	7
$KAlSi_3O_8$ (high sanidine)	-893.738	7

POTASSIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$KAlSiO_4$ (kalsilite)	-481.750	7
$KFe_3(AlSi_3O_{10})(OH)_2$ (annite)	-1147.156	7
$KMg_3(AlSi_3O_{10})(OH)_2$ (phlogopite)	-1396.187	7
$KAl_2(AlSi_3O_{10})(OH)_2$ (muscovite)	-1336.301	7
$K_2(VO_2)_2(VO_4)_2$ (carnotite)	-1097.0	11

MAGNESIUM

$Mg(s)$	0	16
Mg^{2+}	-108.700	16
$MgS(s)$	-81.7	22
$MgSO_4(s)$	-279.8	22
$MgSO_4 \cdot H_2O(s)$	-341.5	22
$MgSO_4 \cdot 6H_2O(s)$	-629.1	22
$MgSO_4 \cdot 7H_2O$ (epsomite)	-686.2428	16
$Mg_3(PO_4)_2(s)$	-845.8	22
$MgMoO_4(s)$	-309.7	21
$MgCO_3$ (magnesite)	-245.658	7
$MgCO_3 \cdot 3H_2O$ (nesquehonite)	-412.035	24
$MgCO_3 \cdot 5H_2O$ (landsfordite)	-525.7	22
$Mg_5(OH)_2(CO_3)_4 \cdot 4H_2O$ (hydromagnesite)	-1401.687	24
$Mg_2(OH)_2CO_3 \cdot 3H_2O$ (artinite)	-613.8494	24
$MgHCO_3^+$ (unionized)	-250.3	22
$Mg_4(OH)_2(CO_3)_3 \cdot 3H_2O(s)$	-1100.3	22
$Mg(NO_3)_2(s)$	-140.818	16

MAGNESIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$Mg(NO_3)_2 \cdot 6H_2O(s)$	-497.3	22
$MgCl_2$(s, chloromagnesite)	-141.440	16
$MgCl_2 \cdot H_2O(s)$	-205.98	22
$MgCl_2 \cdot 2H_2O$ (s)	-267.24	22
$MgCl_2 \cdot 4H_2O$ (s)	-388.03	22
$MgCl_2 \cdot 6H_2O$ (s)	-505.49	22
MgF_2 (sellaite)	-255.9904	16
$MgBr_2(s)$	-120.4	22
$MgBr_2 \cdot 6H_2O(s)$	-491.4	22
$MgI_2(s)$	-85.6	22
MgV_2O_6 (metavanadate)	-487.43	22
$Mg_2V_2O_7$ (pyrovanadate)	-632.24	22
$MgTiO_3$ (geikilite)	-354.7732	16
$MgTiO_3$ (metatitanate)	-354.8	22
$MgTi_2O_5$ (s)	-565.7	22
Mg_2TiO_4 (orthotitanate)	-489.2	22
MgO (periclase)	-136.086	7
$Mg(OH)_2$ (brucite)	-199.646	7
$MgOH^+$	-149.8	22
$MgH_2(s)$	-8.6	22
$MgAl_2O_4$ (spinel)	-517.006	7
$MgCr_2O_4$ (picrochromite)	-398.9195	16
$MgFe_2O_4$ (magnesioferrite)	-314.7715	16
$Mg_2Si(s)$	-18.0	22
$MgCu_2(s,\beta)$	-8.1	22

MAGNESIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
MgCd(s)	-3.71	22
$MgCd_3$(s)	-4.71	22
Mg_3Cd(s)	-5.14	22
$MgNi_2$(s)	-12.9	22
Mg_2SiO_4 (forsterite)	-491.564	7
$Mg_2Al_3(AlSi_5O_{18})$ (cordierite)	-2061.279	7
$Mg_2Al_3(AlSi_5O_{18})\cdot H_2O$ (hydrous cordierite)	-2121.350	7
$MgSiO_3$ (enstatite)	-348.930	7
$Mg_7Si_8O_{22}(OH)_2$ (anthophyllite)	-2715.430	7
$Mg_3Si_2O_5(OH)_4$ (chrypotite)	-964.871	7
$Mg_{48}Si_{34}O_{85}(OH)_{62}$ (antigorite)	-15808.020	7
$Mg_3Si_4O_{10}(OH)_2$ (talc)	-1320.188	7
$Mg_5Al(AlSi_3O_{10})(OH)_8$ (7 -clinochlore)	-1957.101	7
$Mg_5Al(AlSi_3O_{10}(OH)_8$ (14 -clinochlore)	-1961.703	7
$Mg_4Si_6O_{15}(OH)_2(OH_2)_2\cdot(OH_2)_4$ (sepiolite)	-2211.192	7
$Mg_2UO_2(CO_3)_3\cdot 18H_2O$(bayleyite)	-1894.0	1

MANGANESE

Mn(s,α)	0	
Mn(s,γ)	0.34	22
Mn^{2+}	-54.4933	16
MnS (alabandite)	-52.178	24
$MnSO_4$(s)	-228.806	16
$Mn_3(PO_4)_2\cdot 8H_2O$(s)	-870.9	14
$MnHPO_4$(s)	-332.5	22

MANGANESE (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$MnMoO_4(s)$	-260.6	21
$MnCO_3$ (rhodochrosite)	-195.045	24
$MnHCO_3^+$	-196.0	22
$MnCl_2$ (scacchite)	-105.279	16
$MnCl^+$	-86.7	22
$MnCl_2 \cdot H_2O(s)$	-166.4	22
$MnCl_2 \cdot 2H_2O(s)$	-225.2	22
$MnCl_2 \cdot 4H_2O(s)$	-340.3	22
$MnCl_3^-$	-148.2	22
MnO (manganosite)	-86.740	24
MnO_2 (pyrolusite)	-111.171	16
Mn_2O_3 (bixbyite)	-210.580	16
Mn_3O_4 (haussmanite)	-306.5903	16
MnO_4^-	-106.9	22
MnO_4^{2-}	-119.7	22
$MnOH^+$	-96.8	22
$Mn(OH)_3^-$	-177.9	22
Mn_2SiO_4 (tephroite)	-389.5065	16
$MnSiO_3$ (rhodonite)	-297.1035	16

MOLYBDENUM

MoS_2 (molybdenite)	-71.0858	16
$MoO_2(s)$	-127.403	16
$MoO_3(s)$	-159.669	16

MOLYBDENUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
MoO_4^{2-}	-199.82	9
$Mo_3Si(s)$	-23.0	22
$H_2MoO_4(s)$	-216.4	9

NITROGEN

NO_3^-	-26.6491	11

AMMONIUM

NH_4^+	-18.9907	16
NH_4OH^o	-63.04	22
$NH_4VO_3(s)$	-212.3	22
$NH_4HS(s)$	-12.1	22
$NH_4Al(SO_4)_2(s)$	-487.2	22
$NH_4Al(SO_4)_2 \cdot 12H_2O(s)$	-1180.21	22
$(NH_4)_2SO_4$ (mascagnite)	-215.506	16
NH_4NO_3 (ammonia niter)	-43.9300	16
NH_4Cl (salammoniac)	-48.7036	16
$NH_4Br(s)$	-41.9	22
$NH_4Br_3(s)$	-45.1	22
$NH_4BrI_2(s)$	-45.3	22
$NH_4F(s)$	-83.36	22
$NH_4HF_2(s)$	-155.6	22
$NH_4I(s)$	-26.9	22
$NH_4I_3(s)$	-28.6	22

AMMONIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$NH_4ICl_2(s)$	-55.5	22
$NH_4ICl_4(s)$	-59.2	22
$NH_4IBr_2(s)$	-46.9	22
$NH_4IBrCl_2(s)$	-52.0	22
$(NH_4)_2SiF_6$ (s, hexagonal)	-565.38	22
$(NH_4)_2SiF_6$ (s, cubic)	-565.40	22
$H_6(NH_4)_3Al_5(PO_4)_8 \cdot 18H_2O(s)$	-3863.9	22
$NH_4H_2PO_4(s)$	-289.33	22
$NH_4HSe(s)$	-5.6	22

SODIUM

Na	0	16
Na^+	-62.5956	16
$Na_2SO_4 \cdot 10H_2O$ (mirabilite)	-871.5440	16
$Na_2MoO_4(s)$	-323.6	21
$NaAlCO_3(OH)_2$ (dawsonite)	-426.8619	16
$NaNO_3(s)$	-87.7517	16
NaCl (halite)	-91.807	24
$NaCl^o$	-92.740	24
NaF (villiaumite)	-130.573	16
Na_3AlF_6 (cryolite)	751.6527	16
$Na_2O(s)$	-89.883	7
NaOH(s)	-90.7388	16
$NaAl(SiO_3)_2$ (jadeite)	-679.445	7

SODIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$NaCa_2Mg_4Al(Al_2Si_6O_{22})(OH)_2$ (pargasite)	-2847.168	7
$NaAlSi_2O_6 \cdot H_2O$ (analcime)	-738.098	7
$NaAlSi_2O_6$ (dehydrated analcime)	-674.989	7
$NaAlSi_3O_8$ (low albite)	-886.308	7
$NaAlSi_3O_8$ (high albite)	-884.509	7
$NaAlSiO_4$ (nepheline)	-472.872	7
$NaAl_2(AlSi_3O_{10})(OH)_2$ (paragonite)	-1326.012	7
$Na_2CaUO_2(CO_3)_3 \cdot 6H_2O$ (andersonite)	-1351.0	1

NICKEL

NI	0	16
Ni^{2+}	-10.8987	16
NiS (millerite)	-20.6004	16
Ni_3S_2 (heazlewood)	-47.1009	16
$NiSO_4(s)$	-181.6	22
$NiSO_4 \cdot 6H_2O$ (retgersite)	-531.6783	16
$Ni_4(OH)_6SO_4$ (s)	-518.1	22
$Ni_7(OH)_8(SO_4)_3$ (s)	-815.0	22
$NiCO_3(s)$	-146.4	22
$Ni_3(PO_4)_2(s)$	-562.4	22
$NiCl_2(s)$	-61.9097	16
$NiCl_2 \cdot 2H_2O(s)$	-181.7	22
$NiCl_2 \cdot 4H_2O(s)$	-295.2	22
$NiCl_2 \cdot 6H_2O(s)$	-409.54	22

NICKEL (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$NiF_2(s)$	-144.4	22
$NiF_2 \cdot 4H_2O(s)$	-378.0	22
NiO (bunsenite)	-50.573	24
$NiOH^+$	-54.4	22
$NI(OH)_2(s)$	-106.9	22
$NiFe_2O_4$ (trevorite)	-232.5382	16

OXYGEN

OH^-	-37.6023	16

LEAD

Pb(s)	0	16
Pb^{2+}	-5.8317	16
PbS(galena)	-23.115	24
$PbSO_4$(anglesite)	-194.353	24
$PbSO_4 \cdot PbO(s)$	-246.7	22
$PbSO_4 \cdot 2PbO(s)$	-294.0	22
$PbSO_4 \cdot 3PbO(s)$	-341.2	22
$PbMoO_4$ (wulfenite)	-227.4	9
$PbCO_3$(cerrusite)	-150.370	24
$PbO \cdot PbCO_3(s)$	-195.2	22
$PbCl_2 \cdot PbCO_3$ (phosgenite)	-227.6	22
$PbNO_3^+$	-33.9	22
$PbCl_2$(cotunnite)	-75.0557	16

LEAD (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$PbCl_3^-$	-101.9	22
$Pb_2(OH)_3Cl(s)$	-252.55	22
$PbCl^+$	-39.39	22
$PbBr_2(s)$	-62.60	22
PbI_3^-	-47.5	22
PbI_4^{2-}	-60.9	22
PbSe (clausthalite)	-24.2775	16
$PbSeO_4(s)$	-120.7	22
$2PbCl_2 \cdot NH_4Cl(s)$	-201.49	22
$PbSiO_3(s)$	-253.86	22
$Pb_2SiO_4(s)$	-299.4	22
PbO (litharge, red)	-45.2204	16
PbO (massicot, yellow)	-45.0700	16
PbO_2 (plattnerite)	-51.4613	16
Pb_3O_4 (minium)	-143.728	16
$PbO \cdot 1/3\ H_2O(s)$	-63.7	22
$HPbO_2^-$	-80.90	22
$Pb(OH)_2(s)$	-108.1	22
$Pb(OH)_3^-$	-137.6	22
$Pb_3(OH)_4^{2+}$	-212.4	22
$Pb_4(OH)_4^{4+}$	-223.8	22
$Pb_6(OH)_8^{4+}$	-430.3	22
$Pb(MnO_4)_2 \cdot 3PbO(s)$	-393.0	22

PHOSPHORUS

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
PO_4^{3-}	-243.5469	16

PALLADIUM

Pd(s)	0	16
Pd^{2+}	42.2	22
PdS(s)	-16	22
PdS_2(s)	-17.8	22
Pd_4S(s)	-16.0	22
$PdCl_2$(s)	-29.9	22
$PdBr_3^-$	-48.8	22
$PdBr_4^{2-}$	-76.0	22
$PdBr_6^{2-}$	-80.1	22
PdI_2(s)	-15.0	22
PdI_4^{2-}	-38.0	22
PdI_6^{2-}	-40.7	22

PLUTONIUM

Pu^{3+}	-138.3	12
Pu^{4+}	-115.1	12
$Pu(SO_4)^+$	(-321.0)	11
$Pu(SO_4)^{2+}$	-300.9	11
$Pu(SO_4)_2^o$	-484.9	11
$PuO_2SO_4^o$	-363.3	11

PLUTONIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$PuO_2HPO_4(s)$	-458.4	11
$PuO_2(HPO_4)_2(s)$	-673.5	11
$PuO_2(H_2PO_4)^+$	-456.5	11
$Pu(HPO_4)^{2+}$	-393.2	11
$Pu(HPO_4)_2^o$	-668.3	11
$Pu(HPO_4)_3^{2-}$	-941.7	11
$Pu(HPO_4)_4^{4-}$	-1215.0	11
$Pu(H_2PO_4)^{2+}$	-411.8	11
$PuCO_3^{2+}$	-296.8	11
$PuO_2(CO_3)_2^{2-}$	-453.6	11
$PuF_3(s)$	-354.2	11
$PuF_4(s)$	-402.5	11
$PuCl^{3+}$	-148.0	11
PuO_2Cl^+	-212.0	11
PuF^{3+}	-193.3	11
PuO_2F^+	-256.0	11
$PuO_2F_2^o$	-330.5	11
$PuO_2F_3^-$	-404.6	11
$PuO_2F_4^{2-}$	-475.9	11
hex-$Pu_2O_3(s)$	-381.0	11
$PuO_2(s)$	-238.5	11
$Pu(OH)_3(s)$	-277.7	11
$Pu(OH)_4(s)$	-340.8	11

PLUTONIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$PuO_2(OH)$ (amorphous)	-252.4	11
$PuO_2(OH)_2(s)$	-289.4	11
$Pu(OH)^{2+}$	-184.1	11
$Pu(OH)^{3+}$	(-171.1)	11
$Pu(OH)_2^{2+}$	(-225.3)	11
$Pu(OH)_3^{+}$	(-278.0)	11
$Pu(OH)_4^{o}$	(-328.9)	11
$Pu(OH)_5^{-}$	(-378.1)	11
PuO_2^{+}	(-203.2)	11
PuO_2^{2+}	-180.9	11
$PuO_2(OH)^{+}$	-229.9	11
$(PuO_2)_2(OH)_2^{2+}$	-463.9	11
$(PuO_2)_3(OH)_5^{+}$	-796.6	11
PuO_2OH^{o}	-246.7	11

RADIUM

Ra^{2+}	-134.2	22
$Ra(s)$	0	22
$RaSO_4(s)$	-326.4	22
$Ra(NO_3)_2(s)$	-190.3	22
$RaCl_2 \cdot 2H_2O(s)$	-311.4	22

RUBIDIUM

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Rb(s)	0	16
Rb^+	-69.7216	16

SULFUR

S(s)	0	16
S^{2-}	20.5067	16
SO_4^{2-}	-177.971	16

ANTIMONY

Sb_2S_3 (stibnite)	-41.4603	16
$Sb_2S_4^{2-}$	-23.8	22
$Sb(OH)_2F^o$ (undiss)	-173.2	22
$SbCl_3$(s)	-77.37	22
$SbBr_3$(s)	-57.2	22
SbO^+	-42.33	22
SbO_2^-	-81.32	22
Sb_2O_4(s)	-190.2	22
Sb_2O_5(s)	-198.2	22
Sb_4O_6 II (s, cubic)	-303.1	22
Sb_4O_6 I (s, orthorhombic)	-299.5	22
$Sb(OH)_3$(s)	-163.8	22
Sb_2Te_3(s)	-13.2	22

RUTHENIUM

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Ru^{4+}	55.891	15
$Ru(OH)_2^{2+}$	-51.0	22

SELENIUM

Se^{2-}	30.83	16
SeO_3^{2-}	-88.4	22
SeO_4^{2-}	-105.5	22
HSe^-	10.5	22
H_2Se^o	5.3	22
$HSeO_3^-$	-98.36	22
$HSeO_4^-$	-108.1	22

SILICON

SiO_2 (α and β quartz)	-204.646	7
SiO_2 (cristobalite)	-204.895	7
SiO_2 (tridymite)	-204.066	16
SiO_2 (coesite)	-203.541	7
SiO_2 (stishovite)	-191.880	16
SiO_2 (glass)	-203.288	16
SiO_2 (chalcedony)	-204.276	7
SiO_2 (amorphous)	-202.892	7
SiO_2^o	-199.190	24
H_4SiO_4(s)	-318.6	22

SILICON (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$H_4SiO_4^o$ (undiss)	-314.7	22
$H_3SiO_4^-$	-299.18	11
$H_2SiO_4^{2-}$	-281.31	11
H_2SiO_3(s)	-261.1	22
$H_2SiO_3^o$ (undiss)	-258.0	22
$HSi(OH)_6^-$	-414.6	22
$H_2Si(OH)_6^o$ (undiss)	-428.1	22
$H_2Si_2O_5$(s)	-464.5	22
$H_6Si_2O_7$(s)	-579.8	22
SiF_6^{2-}	-525.7	22

TIN

Sn^{2+}	-7.137	18
Sn II (s, grey)	0.03	22
SnS (herzenbergite)	-25.0234	16
$SnSO_4^{2+}$	-173.1	22
SnF^+	-80.1	22
$SnOHCl \cdot H_2O$(s)	-155.0	22
SnO_2 (cassiterite)	-124.260	16
$SnO(OH)^+$	-113.3	22
$Sn(OH)_2$ (s, precipitated)	-117.5	22

STRONTIUM

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Sr(s)	0	
Sr^{2+}	-133.709	16
SrS(s)	-107.2	22
$SrSO_4$ (celestite)	-320.435	24
$SrHPO_4$(s)	-403.6	22
$SrMoO_4$(s)	-345.1	21
$SrCO_3$ (strontianite)	-275.470	24
$Sr(NO_3)_2$(s)	-186.206	16
$Sr(NO_3)_2 \cdot 4H_2O$(s)	-413.65	22
$SrBr_2$(s)	-166.326	16
$SrBr_2 \cdot H_2O$(s)	-228.1	16
$SrBr_2 \cdot 6H_2O$(s)	-519.7	16
$SrCl_2$(s,α)	-186.7	22
$SrCl_2 \cdot H_2O$(s)	-247.7	22
$SrCl_2 \cdot 2H_2O$(s)	-306.4	22
$SrCl_2 \cdot 6H_2O$(s)	-535.67	22
SrO(s)	-133.928	16
$SrOH^+$	-172.4	22
$SrSiO_3$(s)	-370.4	22
$SrSiO_4$(s)	-523.7	22
$SrTiO_3$(s)	-379.64	22
$SrTiO_4$(s)	-520.7	22
$SrZrO_3$(s)	-402.2	22

TELLURIUM

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Te^{2-}	50.655	24
TeO_2(s, tellurite)	-64.6200	16
$Te(OH)_3^+$	-118.6	22
TeSe(s)	26.0	22

THORIUM

α-Th(s)		10
Th^{4+}	-168.4	10
$ThOH^{3+}$	-220.7	10
$Th(OH)_2^{2+}$	-272.3	10
$Th(OH)_3^+$	(-322.5)	10
$Th(OH)_4^o$	-373.5	10
$Th_2(OH)_2^{6+}$	-441.8	10
$Th_4(OH)_8^{8+}$	-1098.3	10
$Th_6(OH)_{15}^{9+}$	-1810.6	10
ThO_2(s)	-273.2	10
ThO_2(s, thorianite)	-279.35	10
ThF^{3+}	-246.70	10
ThF_2^{2+}	-322.52	10
ThF_3^+	-396.2	10
ThF_4^o	-468.2	10
ThF_4(s)	-478.9	10

THORIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$ThF_4 \cdot 2.5H_2O(s)$	(-624.7)	10
$ThCl^{3+}$	-201.3	10
$ThCl_2^{2+}$	-232.3	10
$ThCl_3^{+}$	-264.8	10
$ThCl_4^{o}$	-295.6	10
$ThCl_4(s)$	-261.6	10
$ThSO_4^{2+}$	-353.8	10
$Th(SO_4)_2^{o}$	-537.6	10
$Th(SO_4)_3^{2-}$	-716.6	10
$Th(SO_4)_4^{4-}$	-891.8	10
$ThH_2PO_4^{3+}$	-444.9	10
$Th(H_2PO_4)_2^{2+}$	-720.9	10

TITANIUM

$Ti(s)$	0	16
Ti^{3+}	-73.929	17
$TiBr_3(s)$	-136.408	16
$TiBr_4(s)$	-140.9	22
$TiCl_3(s)$	-156.431	16
$TiCl_2(s)$	-111.0	22
$TiI_4(s)$	-88.8	22
$TiH_2(s)$	-19.2	22
$TiO(s)$	-122.685	16
TiO_2 (rutile)	-212.583	16

TITANIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
TiO_2 (anatase)	-211.114	16
$Ti_2O_3(s)$	-342.7110	16
$Ti_3O_5(s,\alpha)$	-553.8745	16
$Ti_4O_7(s)$	-767.9651	16

URANIUM

U^{3+}	-114.9	12
U^{4+}	-126.9	12
$U(SO_4)^{2+}$	-312.4	12
$U(SO_4)_2^o$	-496.2	12
$UO_2SO_4^o$	-409.7	12
$UO_2CO_3(s)$	-373.1	12
$UO_2CO_3^o$	-367.6	12
$UO_2(CO_3)_2^{2-}$	-503.3	12
$UO_2(CO_3)_3^{4-}$	-635.5	12
$(UO_2)_3(PO_4)_2(s)$	-1237.0	12
$(UO_2)_2(HPO_4)_2(s)$	-1008.0	12
$UO_2HPO_4^o$	-499.5	12
$UO_2(HPO_4)_2^{2-}$	-773.7	12
$UO_2(H_2PO_4)^+$	-501.9	12
$UO_2(H_2PO_4)_2^o$	-775.6	12
$UO_2(H_2PO_4)_3^-$	-1048.0	12
$U(HPO_4)_2 \cdot 4H_2O(s)$	-910.9	12
$UHPO_4^{2+}$	-403.7	12

URANIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$U(HPO_4)_2^o$	-677.6	12
$U(HPO_4)_3^{2-}$	-949.8	12
$U(HPO_4)_4^{4-}$	-1221.0	12
$UF_4(s)$	-428.3	
$UF_4 \cdot 5/2\ H_2O(s)$	-575.6	
UCl^{3+}	-162.0	
UF^{3+}	-206.0	
UF_2^{2+}	-281.3	
UF_3^+	-354.9	
UF_4^o	-428.5	
UF_5^-	-498.1	
UF_6^{2-}	-568.6	
UO_2F^+	-302.1	
$UO_2F_2^o$	-374.5	
$UO_2F_3^-$	-445.3	
$UO_2F_4^{2-}$	-514.1	
UO_2Cl^+	-261.5	
$UO_2(s)$	-246.61	12
β-$UO_2(OH)_2(s)$	-333.2	12
$UO_3 \cdot 2H_2O(s)$	-390.1	12
γ-$UO_3(s)$	-273.9	12
α-$U_3O_8(s)$	-805.4	12
$U_4O_9(s)$	-1022.0	12
$U(OH)^{3+}$	-183.0	12
$U(OH)_2^{2+}$	-237.0	12

URANIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$U(OH)_3^+$	-290.0	12
$U(OH)_4^o$	-342.0	12
$U(OH)_5^-$	-392.0	12
UO_2^+	-231.5	12
UO_2^{2+}	-227.7	12
$UO_2(OH)^+$	-276.5	12
$(UO_2)_2(OH)_2^{2+}$	-561.2	12
$(UO_2)_3(OH)_5^+$	-945.3	12
$(UO_2)_3(OH)_7^-$	-1038.0	12
$UO_2(OH)_2^o$	-324.8	12
$USiO_4$ (coffinite)	(-452.0)	11
$UO_2SiO(OH)_3^+$	(-537.0)	11

VANADIUM

V(s)	0	16
V^{3+}	-57.8	11
VO^{2+}	-106.7	22
VO_2^+	-140.3	22
VO_3^-	-187.3	22
VO_4^{3-}	-214.9	22
$V_2O_7^{4-}$	-411.0	22
VO(s)	-96.6107	16
V_2O_3 (karelianite)	-272.2400	16
V_2O_4(s)	-315.1188	16

VANADIUM (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$V_2O_5(s)$	-339.2531	16
$V_3O_5(s)$	-434.0	22
$V_4O_7(s)$	-591.0	22
HVO_4^{2-}	-233.0	22
$H_2VO_4^-$	-244.0	22
$H_4VO_4^+$	-253.67	22
VOH^{2+}	-111.41	11
$V(OH)_2^+$	(-163.2)	11
$V(OH)_3^o$	(-212.9)	11
$VOOH^+$	-155.65	11
$VO_2HO_2^o$ (undiss)	-178.1	22
$VO(OH)_2^{3+}$	-125.1	22
$VO_2H_2O_2^+$	-178.4	22
$HV_2O_7^{3-}$	-428.4	22
$H_3V_2O_7^-$	-445.5	22
$HV_{10}O_{28}^{5-}$	-1935.0	22
$H_2V_{10}O_{28}^{4-}$	-1940.0	22
$VCl_2(s)$	-96.9601	16
$VCl_3(s)$	-122.227	16
$VOSO_4(s)$	-282.6	22

YTTRIUM

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Y^{3+}	-165.8	22
Y_2O_3 (s, cubic)	-434.1800	16
$YH_2(s)$	-27.8	22
$YH_3(s)$	-33.2	22
$Y_2(OH)_2^{4+}$	-425.5	22
$YF_3(s)$	-393.1	22
YCl^{2+}	-198.7	22
$YCl_3 \cdot 6H_2O(s)$	-592.1	22
$Y(OH)_2Cl(s)$	-297.9	22
$Y(OH)_5Cl(s)$	-609.3	22
YBr^{2+}	-191.6	22
$Y_2(SO_4)_3(s)$	-866.8	22
$Y_2(SO_4)_3 \cdot 8H_2O(s)$	-1332.1	22
YNO_3^{2+}	-192.4	22
$Y_2(CO_3)_3(s)$	-752.4	22
$YZn(s)$	-18.4	22
$YZn_2(s,\alpha)$	-31.4	22
$YZn_3(s)$	-35.6	22
$YZn_4(s)$	-40.2	22
$YZn_5(s)$	-46.4	22
$YZn_{11}(s)$	-67.7	22
$Y_2Zn_{17}(s)$	-131.3	22

ZINC

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
Zn^{2+}	-35.1960	16
ZnO (zincite)	-76.5958	16
ZnO_2^{2-}	-91.85	22
$HZnO_2^-$	-109.26	22
$Zn(OH)_2(s,\gamma)$	-132.38	22
$Zn(OH)_2(s,\beta)$	-132.31	22
$Zn(OH)_2(s,\varepsilon)$	-132.68	22
$Zn(OH)_3^-$	-165.95	22
$Zn(OH)_4^{2-}$	-205.23	22
$Zn(OH)Cl^o$ (undiss)	-113.0	22
$Zn_2(OH)_3Cl(s)$	-251.0	22
$ZnBr^+$	-59.2	22
$ZnBr_2$	-74.60	22
$ZnBr_2 \cdot 2H_2O(s)$	-191.1	22
$ZnBr_3^-$	-107.3	22
ZnI^+	-43.5	22
$ZnI_2(s)$	-49.94	22
ZnI_3^-	-69.7	22
ZnI_4^{2-}	-81.3	22
ZnS (sphalerite)	-47.947	24
ZnS (wurtzite)	-44.810	24
$ZnSO_4$ (zinkosite)	-208.301	16
$ZnSO_4 \cdot H_2O(s)$	-270.58	22
$ZnSO_4 \cdot 6H_2O$ (bianchite)	-555.5382	22

ZINC (cont)

Mineral or Aqueous Species	ΔG_f^o (kcal/mole)	Ref.
$ZnSO_4 \cdot 7H_2O$ (goslarite)	-612.4885	22
$ZnO \cdot 2ZnSO_4(s)$	-492.1	22
$Zn_2(OH)_2SO_4(s)$	-351.4	22
$Zn_5(OH)_8(NO_3)_2(s)$	-624.4	22
$ZnCO_3$ (smithsonite)	-174.850	7
$ZnMoO_4(s)$	-243.3	21
ZnSe(s)	-39.0	22
$ZnSeO_3 \cdot H_2O(s)$	-189.5	22
Zn_2TiO_4 (Zn-Ti spinel)	-366.6432	16
Zn_2SiO_4 (willemite)	-363.9904	16
$ZnFe_2O_4(s)$	-254.2	22

ZIRCONIUM

Zr^{4+}	-138.39	18
$ZrH_2(s)$	-30.8	22
ZrF_4 (β, monoclinic)	-432.6	22
$ZrCl_4(s)$	-212.7	22
$ZrSiO_4$ (zircon)	-458.6257	16

TABLE 2. EQUILIBRIUM CONSTANTS FOR SPECIATION AND PRECIPITATION REACTIONS AT 298.15°K AND 1 BAR

SILVER

Reaction	Log K	Ref.
$Ag(s) = Ag^+ + e^-$	-13.51	
$Ag_2S(acanthite) + 4H_2O = 2Ag^+ + SO_4^{2-} + 8H^+ + 8e^-$	-69.67	
$AgHS^o + 4H_2O = Ag^+ + SO_4^{2-} + 9H^+ + 8e^-$	-47.66	3
$Ag(HS)_2^- + 8H_2O = Ag^+ + 2SO_4^{2-} + 18H^+ + 16e^-$	-85.68	3
$AgS^- + 4H_2O = Ag^+ + SO_4^{2-} + 8H^+ + 8e^-$	-39.36	18(20°,0.1)
$AgHS_2^{2-} + 8H_2O = Ag^+ + 2SO_4^{2-} + 17H^+ + 16e^-$	-76.18	18(20°,0.1)
$AgSO_4^- = Ag^+ + SO_4^{2-}$	-1.28	
$Ag_2SO_4(s) = 2Ag^+ + SO_4^{2-}$	-4.91	
$AgNO_3(s) = Ag^+ + NO_3^-$	0.167	
$AgNO_3^o = Ag^+ + NO_3^-$	0.29	19
$Ag_2CO_3(s) + 2Ag^+ + CO_3^{2-}$	-11.05	
$Ag_3PO_4(s) = 3Ag^+ + PO_4^{3-}$	-15.92	
$AgBr(bromargyrite) = Ag^+ + Br^-$	-12.30	
$AgBr^o = Ag^+ + Br^-$	-4.24	
$AgBr_2^- = Ag^+ + 2Br^-$	-7.27	
$AgBr_3^{2-} = Ag^+ + 3Br^-$	-8.70	
$AgBr_4^{3-} = Ag^+ + 4Br^-$	-9.0	3
$AgI(iodargyrite) = Ag^+ + I^-$	-16.02	
$AgI^o = Ag^+ + I^-$	-6.6	3
$AgI_2^- = Ag^+ + 2I^-$	-10.56	
$AgI_3^{2-} = Ag^+ + 3I^-$	-13.20	
$AgI_4^{3-} = Ag^+ + 4I^-$	-13.85	
$AgF \cdot 4H_2O(s) = Ag^+ + F^- + 4H_2O$	0.55	3
$AgF^o = Ag^+ + F^-$	-0.36	3
$AgCl(cerargyrite) = Ag^+ + Cl^-$	-9.75	
$AgCl^o = Ag^+ + Cl^-$	-3.27	3
$AgCl_2^- = Ag^+ + 2Cl^-$	-5.26	
$AgCl_3^{2-} = Ag^+ 3Cl^-$	-5.29	3
$AgCl_4^{3-} = Ag^+ + 4Cl^-$	-5.51	3
$AgCl_3Br^{3-} = Ag^+ + 3Cl^- + Br^-$	-7.88	
$AgClBr_3^{3-} = Ag^+ + Cl^- + 3Br^-$	-9.45	
$Ag_2O(s) + 2H^+ = 2Ag^+ + H_2O$	12.58	
$Ag_2O_2(s) + 4H^+ + 2e^- = 2Ag^+ + 2H_2O$	60.93	

SILVER (cont)

Reaction	Log K	Ref.
$Ag_2O_3(s) + 6H^+ + 4e^- = 2Ag^+ + 3H_2O$	118.9	
$AgOH^o + H^+ = Ag^+ + H_2O$	12.0	3
$Ag(OH)_2^- + 2H^+ = Ag^+ + 2H_2O$	24.00	
$Ag_2Se(s) + 3H_2O = 2Ag^+ + SeO_3^{2-} + 6H^+ + 6e^-$	-94.63	
$Ag_2SeO_3(s) = 2Ag^+ + SeO_3^{2-}$	-15.50	
$Ag_2SeO_4(s) + 2H^+ + 2e^- = 2Ag^+ + SeO_3^{2-} + H_2O$	20.77	
$Ag_2MoO_4(s) = 2Ag^+ + MoO_4^{2-}$	-11.6	
$AgVO_3(s) + H_2O = Ag^+ + VO_4^{3-} + 2H^+$	-54.62	
$Ag_2HVO_4(s) = 2Ag^+ + VO_4^{3-} + H^+$	-81.04	
$Ag_2HVO_4 \cdot AgOH(s) = 3Ag^+ + VO_4^{3-} + H_2O$	-104.32	
$Ag_2CrO_4(s) = 2Ag^+ + CrO_4^{2-}$	-11.94	
$Ag_2Te(s) = 2Ag^+ + Te^{2-}$	(-71.7)	18

ALUMINUM

$Al(s) = Al^{3+} + 3e^-$	85.78	
$Al_2(SO_4)_3(s) = 2Al^{3+} + 3SO_4^{2-}$	19.817	
$Al_2(SO_4)_3 \cdot 6H_2O(s) = 2Al^{3+} + 3SO_4^{2-} + 6H_2O$	2.317	
$AlSO_4^+ = Al^{3+} + SO_4^{2-}$	-3.02	3
$Al(SO_4)_2^- = Al^{3+} + 2SO_4^{2-}$	-4.92	3
$AlOHSO_4(s) + H^+ = Al^{3+} + SO_4^{2-} + H_2O$	-3.23	3
$Al_4(OH)_{10}SO_4(s) + 10H^+ = 4Al^{3+} + SO_4^{2-} + 10H_2O$	22.7	3
$AlPO_4$(berlinite) $= Al^{3+} + PO_4^{3-}$	-22.84	
$AlI_3(s) = Al^{3+} + 3I^-$	60.35	
$AlF_3(s) = Al^{3+} + 3F^-$	-17.25	
$AlF_3^o = Al^{3+} + 3F^-$	-17.02	20
$AlF^{2+} = Al^{3+} + F^-$	-5.740	
$AlF_2^+ = Al^{3+} + 2F^-$	-12.750	20
$AlF_4^- = Al^{3+} + 4F^-$	-19.720	20
$AlO_2^- + 4H^+ = Al^{3+} + 2H_2O$	24.601	
$AlOH^{2+} + H^+ = Al^{3+} + H_2O$	4.969	
$Al(OH)_2^+ + 2H^+ = Al^{3+} + 2H_2O$	10.158	
$Al(OH)_4^- + 4H^+ = Al^{3+} + 4H_2O$	22.150	
Al_2O_3(α corundum) $+ 6H^+ = 2Al^{3+} + 3H_2O$	21.415	

ALUMINUM (cont)

Reaction	Log K	Ref.
$Al_2O_3(s,\gamma) + 6H^+ = 2Al^{3+} + 3H_2O$	22.390	
$Al(OH)_3$(synthetic gibbsite) $+ 3H^+ = Al^{3+} + 3H_2O$	8.089	
$Al(OH)_3$(natural gibbsite) $+ 3H^+ = Al^{3+} + 3H_2O$	8.749	
$Al(OH)_3$(amorphous) $+ 3H^+ = Al^{3+} + 3H_2O$	10.359	20
$AlO(OH)$(boehmite) $+ 3H^+ = Al^{3+} + 2H_2O$	9.609	
$AlO(OH)$(diaspore) $+ 3H^+ = Al^{3+} + 2H_2O$	8.764	
Al_2SiO_5(andalusite) $+ 6H^+ = 2Al^{3+} + SiO_2^{\circ} + 3H_2O$	16.596	
Al_2SiO_5(sillimanite) $+ 6H^+ = 2Al^{3+} + SiO_2^{\circ} + 3H_2O$	16.960	
Al_2SiO_5(kyanite) $+ 6H^+ = 2Al^{3+} + SiO_2^{\circ} + 3H_2O$	16.326	
$Al_2Si_2O_5(OH)_4$(kaolinite) $+ 6H^+ = 2Al^{3+} + 2SiO_2^{\circ} + 5H_2O$	7.446	
$Al_2Si_4O_{10}(OH)_2$(pyrophyllite) $+ 6H^+ = 2Al^{3+} + 4SIO_2^{\circ} + 4H_2O$	1.081	

AMERICIUM

$Am^{2+} = Am^{4+} + 2e^-$	-11.29	15
$Am^{3+} = Am^{4+} + e^-$	-41.0	15
$Am(s) = Am^{4+} + 4e^-$	80.0	15
$AmO_2^+ + 4H^+ + e^- = Am^{4+} + 2H_2O$	21.0	15
$AmO_2^{2+} + 4H^+ + 2e^- = Am^{4+} + 2H_2O$	48.0	15
$AmOH^{2+} + H^+ = Am^{4+} + H_2O + e^-$	-35.1	15
$Am(OH)_3(s) + 3H^+ = Am^{4+} + 3H_2O + e^-$	-18.6	15
$Am(OH)_4(s) + 4H^+ = Am^{4+} + 4H_2O$	3.84	15
$AmO_2OH(s) + 5H^+ + e^- = Am^{4+} + 3H_2O$	1.7	15
$AmO_2(OH)_2(s) + 6H^+ + 2e^- = Am^{4+} + 4H_2O$	34.29	15
$AmO_2(s) + 4H^+ = Am^{4+} + 2H_2O$	-6.23	15
$AmCl^{2+} = Am^{4+} + Cl^- + e^-$	-42.2	15
$AmF^{2+} = Am^{4+} + F^- + e^-$	-44.4	15
$AmF_2^+ = Am^{4+} + 2F^- + e^-$	-47.1	15
$AmF_3^{\circ} = Am^{4+} + 3F^- + e^-$	-51.24	15
$AmF_3(s) = Am^{4+} + 3F^- + e^-$	-56.11	15
$AmNO_3^{2+} = Am^{4+} + NO_3^- + e^-$	-41.26	15
$AmSO_4^+ = Am^{4+} + SO_4^{2-} + e^-$	[illegible].68	15
$Am(SO_4)_2^- = Am^{4+} + 2SO_4^{2-} + e^-$	-45.03	15
$AmH_2PO_4^{2+} = Am^{4+} + PO_4^{3-} + 2H^+ + e^-$	-63.03	15

BARIUM

Reaction	Log K	Ref.
$Ba(s) = Ba^{2+} + 2e^-$	98.26	
$BaS(s) + 4H_2O = Ba^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-17.39	
$BaSO_4$(barite) $= Ba^{2+} + SO_4^{2-}$	-9.95	
$BaSO_4^o = Ba^{2+} + SO_4^{2-}$	-2.7	18
$BaCO_3$(witherite) $= Ba^{2+} + CO_3^{2-}$	-8.30	18
$BaCO_3^o = Ba^{2+} + CO_3^-$	-2.78	18
$Ba(HCO_3)_2(s) = Ba^{2+} + 2CO_3^{2-} + 2H^+$	-20.66	
$BaNO_3^+ = Ba^{2+} + NO_3^-$	0.97	
$Ba(NO_3)_2(s) = Ba^{2+} + 2NO_3^-$	-2.25	
$Ba(NO_3)_2^o = Ba^{2+} + 2NO_3^-$	-1.0	18
$BaCa(CO_3)_2$(alstonite) $= Ba^{2+} + Ca^{2+} + 2CO_3^{2-}$	-17.99	
$BaCa(CO_3)_2$(barytocalcite) $= Ba^{2+} + Ca^{2+} + 2CO_3^{2-}$	-17.84	
$BaO(s) + 2H^+ = Ba^{2+} + H_2O$	48.62	
$BaOH^+ + H^+ = Ba^{2+} + H_2O$	13.39	18
$Ba(OH)_2 \cdot 8H_2O(s) + 2H^+ = Ba^{2+} + 10H_2O$	24.34	
$BaF_2(s) = Ba^{2+} + 2F^-$	-5.97	
$BaCl_2(s) = Ba^{2+} + 2Cl^-$	2.25	
$BaCl^+ = Ba^{2+} + Cl^-$	(0.13)	18
$BaCl_2 \cdot H_2O(s) = Ba^{2+} + 2Cl^- + H_2O$	0.82	
$BaCl_2 \cdot 2H_2O(s) = Ba^{2+} + 2Cl^- + 2H_2O$	0.19	
$BaBr_2(s) = Ba^{2+} + 2Br^-$	5.59	
$BaBr_2 \cdot 2H_2O(s) = Ba^{2+} + 2Br^- + 2H_2O$	2.19	
$BaO \cdot SiO_2(s) + 2H^+ = Ba^{2+} + SiO_2^o + H_2O$	15.95	
$BaO \cdot 2SiO_2(s) + 2H^+ = Ba^{2+} + 2SiO_2^o + H_2O$	9.44	
$2BaO \cdot SiO_2(s) + 4H^+ = 2Ba^{2+} + SiO_2^o + 2H_2O$	44.56	
$2BaO \cdot 3SiO_2(s) + 4H^+ = 2Ba^{2+} + 3SiO_2^o + 2H_2O$	23.29	
$BaSiF_6(s) + 2H_2O = Ba^{2+} + 6F^- + SiO_2^o + 4H^+$	-32.93	
$BaTiO_3(s) + 6H^+ + e^- = Ba^{2+} + Ti^{3+} + 3H_2O$	1.600	
$BaTiO_4(s) + 8H^+ + 3e^- = Ba^{2+} + Ti^{3+} + 4H_2O$	-55.087	
$BaSrTiO_4(s) + 8H^+ + e^- = Ba^{2+} + Sr^{2+} + Ti^{3+} + 4H_2O$	36.855	
$BaCrO_4(s) = Ba^{2+} + CrO_4^{2-}$	-9.93	
$BaMnO_4(s) + 4H^+ = Ba^{2+} + Mn^{2+} + 4H_2O$	108.30	
$BaZrO_3(s) + 6H^+ = Ba^{2+} + Zr^{4+} + 3H_2O$	27.45	
$BaSeO_3(s) = Ba^{2+} + SeO_3^{2-}$	-6.58	

BARIUM (cont)

Reaction	Log K	Ref.
$BaSeO_4(s) + 2H^+ + 2e^- = Ba^{2+} + SeO_3^{2-} + H_2O$	21.55	
$BaMoO_4(s) = Ba^{2+} + MoO_4^{2-}$	-10.09	
$BaHPO_4(s) = Ba^{2+} + H^+ + PO_4^{3-}$	-19.71	18(20°,0)

CALCIUM

$Ca(s) = Ca^{2+} + 2e^-$	96.99	
$CaS(oldhamite) + 4H_2O = Ca^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-21.07	
$CaSO_4(anhydrite) = Ca^{2+} + SO_4^{2-}$	4.62	18
$CaSO_4 \cdot 1/2\ H_2O(macro\ \alpha) = Ca^{2+} + SO_4^{2-} + 1/2\ H_2O$	-3.52	
$CaSO_4 \cdot 1/2\ H_2O(micro\ \beta) = Ca^{2+} + SO_4^{2-} + 1/2\ H_2O$	-3.35	
$CaSO_4 \cdot 2H_2O(gypsum) = Ca^{2+} + SO_4^{2-} + 2H_2O$	-4.85	20
$CaCO_3(aragonite) = Ca^{2+} + CO_3^{2-}$	-8.22	18
$CaCO_3(calcite) = Ca^{2+} + CO_3^{2-}$	-8.35	18
$CaCO_3(vaterite) = Ca^{2+} + CO_3^{2-}$	-7.73	
$CaCO_3^o = Ca^{2+} + CO_3^-$	-3.15	3
$CaCO_3 \cdot H_2O(monohydrocalcite) = Ca^{2+} + CO_3^{2-} + H_2O$	-7.54	
$CaMg_3(CO_3)_2(dolomite) = Ca^{2+} + Mg^{2+} + 2CO_3^{2-}$	-18.06	
$CaMg_3(CO_3)_4(huntite) = Ca^{2+} + 3Mg^{2+} + 4CO_3^{2-}$	-30.52	
$CaHCO_3^+ = Ca^{2+} + H^+ + CO_3^{2-}$	-11.33	18
$Ca(NO_3)_2(s) = Ca^{2+} + 2NO_3^-$	5.88	
$Ca(NO_3)_2^o = Ca^{2+} + 2NO_3^-$	-0.6	18
$CaNO_3^+ = Ca^{2+} + NO_3^-$	-0.7	18
$Ca(NO_3)_2 \cdot 2H_2O(s) = Ca^{2+} + 2NO_3^- + 2H_2O$	3.76	
$Ca(NO_3)_2 \cdot 3H_2O(s) = Ca^{2+} + 2NO_3^- + 3H_2O$	2.81	
$Ca(NO_3)_2 \cdot 4H_2O(s) = Ca^{2+} + 2NO_3^- + 4H_2O$	2.04	
$CaPO_4^- = Ca^{2+} + PO_4^{3-}$	-6.46	20
$Ca_3(PO_4)_2(whitlockite) = 3Ca^{2+} + 2PO_4^{3-}$	-34.53	
$Ca_3(PO_4)_2(s,\beta) = 3Ca^{2+} + 2PO_4^{3-}$	-32.63	
$Ca3(PO_4)_2(s,\alpha) = 3Ca^{2+} + 2PO_4^{3-}$	-31.02	
$CaHPO_4(s) = Ca^{2+} + H^+ + PO_4^{3-}$	-19.05	
$CaHPO_4^o = Ca^{2+} + H^+ + PO_4^{3-}$	-15.05	20
$CaH_2PO_4^+ = Ca^{2+} + 2H^+ + PO_4^{3-}$	-20.93	20
$CaHPO_4 \cdot 2H_2O(s) = Ca^{2+} + H^+ + PO_4^{3-} + 2H_2O$	-18.91	

CALCIUM (cont)

Reaction	Log K	Ref.
$Ca(H_2PO_4)_2 \cdot H_2O(s) = Ca^{2+} + 4H^+ + 2PO_4^{3-} + H_2O$	-40.26	
$Ca_8H_2(PO_4)_6 \cdot 5H_2O(s) = 8Ca^{2+} + 2H^+ + 6PO_4^{3-} + 5H_2O$	-93.80	
$Ca_{10}(PO_4)_6(OH)_2^{\circ} + 2H^+ = 10Ca^{2+} + 6PO_4^{3-} + 2H_2O$	28.17	
$Ca_5(PO_4)_3OH$(hydroxyapatite) $+ H^+ = 5Ca^{2+} + 3PO_4^{3-} + 2H_2O$	-40.35	3
$Ca_5(PO_4)_3F$(fluoroapatite) $= 5Ca^{2+} + 3PO_4^{3-} + F^-$	-54.53	3
$Ca_{9.496}Na_{0.36}Mg_{0.144}(PO_4)_{4.8}(CO_3)_{1.2}F_{2.48}$($FCO_3$ apatite) $= 9.496Ca^{2+}$ $+ 0.36Na^+ + 0.144Mg + 4.8PO_4^{3-} + 1.2CO_3^{2-} + 2.48F^-$	-114.4	3
$Ca_2Fe(PO_4)_2 \cdot 4H_2O$(anapaite) $= 2Ca^{2+} + Fe^{2+} + 2PO_4^{3-} + 4H_2O$	-34.14	14
$CaFe(PO_4)_2(OH)_2 \cdot 8H_2O$(mitridatite) $+ 2H^+ + 2e^- = Ca^{2+} + 2Fe^{2+} + 2PO_4^{3-} + 10H_2O$	-27.24	14
$CaFe_4(OH)_8(PO_4)_2 \cdot 7H_2O$(foucherite) $+ 8H^+ + 4e^- = Ca^{2+} + 4Fe^{2+} + 2PO_4^{3-} + 15H_2O$	-25.14	14
$CaSe(s) + 3H_2O = Ca^{2+} + SeO_3^{2-} + 6H^+ + 6e^-$	-26.49	
$CaSeO_3 \cdot 2H_2O(s) = Ca^{2+} + SeO_3^{2-} + 2H_2O$	-5.46	
$CaSeO_4 \cdot 2H_2O(s) + 2H^+ + 2e^- = Ca^{2+} + SeO_3^{2-} + 3H_2O$	25.90	
$CaMoO_4$(powellite) $= Ca^{2+} + MoO_4^{2-}$	-8.71	
$CaCl_2$(hydrophilite) $= Ca^{2+} + 2Cl^-$	11.92	
$CaBr_2(s) = Ca^{2+} + 2Br^-$	17.16	
$CaBr_2 \cdot 6H_2O(s) = Ca^{2+} + 2Br^- + 6H_2O$	5.48	
$CaI_2(s) = Ca^{2+} + 2I^-$	22.52	
CaF_2(fluorite) $= Ca^{2+} + 2F^-$	-10.16	
$CaF^+ = Ca^{2+} + F^-$	-0.94	3
CaO(lime) $+ 2H^+ = Ca^{2+} + H_2O$	32.71	
$Ca(OH)_2$(portlandite) $+ 2H^+ = Ca^{2+} + 2H_2O$	22.68	
$CaOH^+ + H^+ = Ca^{2+} + H_2O$	12.67	
$CaFe_2O_4(s) + 8H^+ + 2e^- = Ca^{2+} + 2Fe^{2+} + 4H_2O$	43.31	
$Ca_2Fe_2O_5(s) + 10H^+ + 2e^- = 2Ca^{2+} + 2Fe^{2+} + 5H_2O$	78.67	
$CaZrO_3(s) + 6H^+ = Ca^{2+} + Zr^{4+} + 3H_2O$	28.54	
$CaTiO_3$(perovskite) $+ 6H^+ + e^- = Ca^{2+} + Ti^{3+}\ 3H_2O$	-0.171	
$Ca_3Ti_2O_7(s) + 14H^+ + 2e^- = 3Ca^{2+} + 2Ti^{3+} + 7H_2O$	32.919	
$Ca_2Al_2SiO_7$(gehlinite) $+ 10H^+ = 2Ca^{2+} + 2Al^{3+} + SiO_2^{\circ} + 5H_2O$	56.88	
$Ca_3Al_2Si_3O_{12}$(grossular) $+ 12H^+ = 3Ca^{2+} + 2Al^{3+} + 3SiO_2^{\circ} + 6H_2O$	52.47	
$CaAl_2SiO_6$(Ca-Al pyx.) $+ 8H^+ = Ca^{2+} + 2Al^{3+} + SiO_2 + 4H_2O$	36.59	
$CaAl_2Si_2O_8$(anorthite) $+ 8H^+ = Ca^{2+} + 2Al^{3+} + 2SiO_2^{\circ} + 4H_2O$	27.19	
$Ca_3Fe_2Si_3O_{12}$(andradite) $+ 12H^+ + 2e^- = 3Ca^{2+} + 2Fe^{2+} + 3SiO_2^{\circ} + 6H_2O$	54.81	
$CaFeSi_2O_6$(hedenbergite) $+ 4H^+ = Ca^{2+} + Fe^{2+} + 2SiO_2^{\circ} + 2H_2O$	17.35	

CALCIUM (cont)

Reaction	Log K	Ref.
$CaMgSiO_4$(monticellite) + $4H^+ = Ca^{2+} + Mg^{2+} + SiO_2^o + 2H_2O$	29.85	
$Ca_3Mg(SiO_4)_2$(merwinite) + $8H^+ = 3Ca^{2+} + Mg^{2+} + 2SiO_2^o + 4H_2O$	68.55	
$Ca_2MgSi_2O_7$(akermanite) + $6H^+ = 2Ca^{2+} + Mg^{2+} + 2SiO_2^o + 3H_2O$	45.39	
$CaMgSi_2O_6$(diopside) + $4H^+ = Ca^{2+} + Mg^{2+} + 2SiO_2^o + 2H_2O$	21.07	
Ca_2SiO_4(larnite) + $4H^+ = 2Ca^{2+} + SiO_2^o + 2H_2O$	39.16	
Ca_2SiO_4(Ca-olivine) + $4H^+ = 2Ca^{2+} + SiO_2^o + 2H_2O$	37.67	
$Ca_3SiO_5 + 6H^+ = 3Ca^{2+} + SiO_2^o + 3H_2O$	73.84	
$Ca_3Si_2O_7$(rankinite) + $6H^+ = 3Ca^{2+} + SiO_2^o + 3H_2O$	48.62	
$CaSiO_3$(wollastonite) + $2H^+ = Ca^{2+} + SiO_2^o + H_2O$	13.73	
$CaSiO_3$(pseudowollastonite) + $2H^+ = Ca^{2+} + SiO_2^o + H_2O$	13.87	
$CaTiSiO_5$(sphene) + $6H^+ + e^- = Ca^{2+} + Ti^{3+} + SiO_2^o + 3H_2O$	-9.140	
$CaAl_2Si_2O_7(OH)_2 \cdot H_2O$(lawsonite) + $8H^+ = Ca^{2+} + 2Al^{3+} + 2SiO_2^o + 6H_2O$	22.81	
$CaAl_2Si_4O_{12} \cdot 2H_2O$(wairakite) + $8H^+ = Ca^{2+} + 2Al^{3+} + 4SiO_2^o + 6H_2O$	18.68	
$CaAl_2Si_4O_{12} \cdot 4H_2O$(laumontite) + $8H^+ = Ca^{2+} + 2Al^{3+} + 4SiO_2^o + 8H_2O$	14.25	
$CaAl_2(Al_2Si_2O_{10})(OH)_2$(margarite) + $14H^+ = Ca^{2+} + 4Al^{3+} + 2SiO_2^o + 8H_2O$	42.33	
$Ca_2Al_3Si_3O_{12}(OH)$(clinozoisite) + $13H^+ = 2Ca^{2+} + 3Al^{3+} + 3SiO_2^o + 7H_2O$	44.16	
$Ca_2Al_2Si_3O_{12}(OH)$(zoisite) + $13H^+ = 2Ca^{2+} + 3Al^{3+} + 3SiO_2^o + 7H_2O$	44.20	
$Ca_2Al_2FeSi_3O_{12}(OH)$(epidote) + $13H^+ + e^- = 2Ca^{2+} + 2Al^{3+} + Fe^{2+} + 3SiO_2^o + 7H_2O$	44.29	
$Ca_2Al(AlSi_3O_{10})(OH)_2$(prehnite) + $10H^+ = 2Ca^{2+} + 2Al^{3+} + 3SiO_2^o + 6H_2O$	33.51	
$Ca_2Mg_5Si_8O_{22}(OH)_2$(tremolite) + $14H^+ = 2Ca^{2+} + 5Mg^{2+} + 8SiO_2^o + 8H_2O$	61.85	
$Ca(UO_2)_2(VO_4)_2$(tjuyamunite) + $8H^+ + 4e^- = Ca^{2+} + 2U^{4+} + 2VO_4^{3-} + 4H_2O$	(-34.74)	
$Ca_2UO_2(CO_3)_3 \cdot 10H_2O$(liebigite) + $4H^+ + 2e^- = 2Ca^{2+} + U^{4+} + 3CO_3^{2-} + 12H_2O$	-27.75	
$CaMgUO_2(CO_3)_3 \cdot 12H_2O$(swartzite) + $4H^+ + 2e^- = Ca^{2+} + Mg^{2+} + U^{4+} + 3CO_3^{2-} + 14H_2O$	-28.66	
$Ca(UO_2)_2(SiO_3OH)_2$(uranophane) + $14H^+ + 4e^- = Ca^{2+} + 2U^{4+} + 2SiO_2^o + 8H_2O$	35.85	

CADMIUM

$Cd(\alpha) = Cd^{2+} + 2e^-$	13.59	3
CdS(greenokite) + $4H_2O = Cd^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-47.66	
$CdHS^+ + 4H_2O = Cd^{2+} + SO_4^{2-} + 9H^+ + 8e^-$	-43.78	3
$Cd(HS)_2^o + 8H_2O = Cd^{2+}\ 2SO_4^{2-} + 18H^+ + 16e^-$	-77.39	3
$Cd(HS)_3^- + 12H_2O = Cd^{2+} + 3SO_4^{2-} + 27H^+ + 24e^-$	-119.54	3
$Cd(HS)_4^{2-} + 16H_2O = Cd^{2+} + 4SO_4^{2-} + 36H^+ + 32e^-$	-155.34	3
$CdSO_4(s) = Cd^{2+} + SO_4^{2-}$	-0.10	

CADMIUM (cont)

Reaction	Log K	Ref.
$CdSO_4^{o} = Cd^{2+} + SO_4^{2-}$	-2.46	3
$CdSO_4 \cdot H_2O(s) = Cd^{2+} + SO_4^{2-} + H_2O$	-1.66	
$CdSO_4 \cdot 8/3\ H_2O(s) = Cd^{2+} + SO_4^{2-} + 8/3\ H_2O$	-1.88	
$Cd_3(OH)_4SO_4(s) + 4H^+ = 3Cd^{2+} + 4H_2O + SO_4^{2-}$	22.51	
$Cd_3(OH)_2(SO_4)_2(s) + 2H^+ = 3Cd^{2+} + 2H_2O + 2SO_4^{2-}$	6.69	
$Cd_4(OH)_6SO_4(s) + 6H^+ = 4Cd^{2+} + 6H_2O + SO_4^{2-}$	28.4	3
$Cd(SO_4)_2^{2-} = Cd^{2+} + 2SO_4^{2-}$	-3.5	3
$CdCO_3(otavite) = Cd^{2+} + CO_3^{2-}$	-11.21	
$CdCO_3^{o} = Cd^{2+} + CO_3^{2-}$	-5.4	3
$Cd(CO_3)_3^{4-} = Cd^{2+} + 3CO_3^{2-}$	-6.22	3
$CdHCO_3^{+} = Cd^{2+} + HCO_3^{-}$	-2.1	3
$CdNO_3^{+} = Cd^{2+} + NO_3^{-}$	-0.4	3
$Cd(NO_3)_2^{o} = Cd^{2+} + 2NO_3^{-}$	-0.2	18
$Cd_3(PO_4)_2(s) = 3Cd^{2+} + 2PO_4^{3-}$	-32.54	
$CdSeO_3(s) = Cd^{2+} + SeO_3^{2-}$	-8.84	
$CdSeO_4(s) + 2H^+ + 2e^- = Cd^{2+} + SeO_3^{2-} + H_2O$	26.77	
$CdTe(s) = Cd^{2+} + Te^{2-}$	(-41.5)	18
$CdSb(s) + H_2O = Cd^{2+} + SbO^{+} + 2H^{+}\ 5e^-$	0.79	
$CdF^{+} = Cd^{2+} + F^-$	-1.1	3
$CdF_2(s) = Cd^{2+} + 2F^-$	-2.98	3
$CdF_2^{o} = Cd^{2+} + 2F^-$	-1.5	3
$CdCl^{+} = Cd^{2+} + Cl^-$	-1.98	3
$CdCl_2(s) = Cd^{2+} + 2Cl^-$	-0.67	
$CdCl_2^{o} = Cd^{2+} + 2Cl^-$	-2.6	3
$CdCl_3^{-} = Cd^{2+} + 3Cl^-$	-2.4	3
$CdCl_4^{2-} = Cd^{2+} + 4Cl^-$	-1.7	18
$CdCl_2 \cdot H_2O(s) = Cd^{2+} + 2Cl^- + H_2O$	-1.72	
$CdCl_2 \cdot 5/2\ H_2O(s) = Cd^{2+} + 2Cl^- + 5/2\ H_2O$	-1.95	
$Cd(OH)Cl(s) + H^+ = Cd^{2+} + Cl^- + H_2O$	3.51	
$Cd(OH)Cl^{o} + H^+ = Cd^{2+} + Cl^- + H_2O$	7.40	3
$CdBr^{+} = Cd^{2+} + Br^-$	-2.17	
$CdBr_2(s) = Cd^{2+} + 2Br^-$	-1.88	
$CdBr_2^{o} = Cd^{2+} + 2Br^-$	-2.9	3
$CdBr_3^{-} = Cd^{2+} + 3Br^-$	-3.15	

CADMIUM (cont)

Reaction	Log K	Ref.
$CdBr_4^{2-} = Cd^{2+} + 4Br^-$	-2.9	
$CdBr_2 \cdot 4H_2O(s) = Cd^{2+} + 2Br^- + 4H_2O$	-2.44	
$CdI^+ = Cd^{2+} + I^-$	-2.1	
$CdI_2(s) = Cd^{2+} + 2I^-$	-3.5	
$CdI_2^o = Cd^{2+} + 2I^-$	-3.6	3
$CdI_3^- = Cd^{2+} + 3I^-$	-4.6	
$CdI_4^{2-} = Cd^{2+} + 4I^-$	-5.4	
$CdO(\text{monteponite}) + 2H^+ = Cd^{2+} + H_2O$	15.11	
$CdO_2^{2-} + 4H^+ = Cd^{2+} + 2H_2O$	46.85	
$HCdO_2^- + 3H^+ = Cd^{2+} + 2H_2O$	32.99	
$Cd(OH^+ + H^+ = Cd^{2+} + H_2O$	10.08	3
$Cd(OH)_2(\text{amorphous}) + 2H^+ = Cd^{2+} + 2H_2O$	13.73	3
$Cd(OH)_2(\text{crystalline}) + 2H^+ = Cd^{2+} + 2H_2O$	13.65	3
$Cd(OH)_2^o + 2H^+ = Cd^{2+} + 2H_2O$	20.35	3
$Cd(OH)_3^- + 3H^+ = Cd^{2+} + 3H_2O$	32.97	
$Cd(OH)_4^{2-} + 4H^+ = Cd^{2+} + 4H_2O$	46.88	
$Cd_2OH^{3+} + H^+ = 2Cd^{2+} + H_2O$	9.39	3
$Cd_4(OH)_4^{4+} + 4H^+ = 4Cd^{2+} + 4H_2O$	32.76	18
$CdSiO_3(s) + 2H^+ = Cd^{2+} + SiO_2^o + H_2O$	7.49	

CERIUM

$Ce(s) = Ce^{3+} + 3e^-$	117.75	
$Ce^{4+} + e^- = Ce^{3+}$	29.47	
$Ce_2S_3(s) + 12H_2O = 2Ce^{3+} + 3SO_4^{2-} + 24H^+ + 24e^-$	-72.32	15
$CeSO_4^+ = Ce^{3+} + SO_4^{2-}$	-3.59	18
$Ce(SO_4)_2^{3-} = Ce^{3+} + 2SO_4^{2-}$	-5.2	18
$CePO_4(s) = Ce^{3+} + PO_4^{3-}$	-21.3	15
$CePO_4^o = Ce^{3+} + PO_4^{3-}$	(-18.5)	18
$CeH_2PO_4^{2+} = Ce^{3+} + PO_4^{3-} + 2H^+$	-2.33	18
$CeNO_3^{2+} = Ce^{3+} + NO_3^-$	-1.09	15
$CeF^{2+} = Ce^{3+} + F^-$	-4.0	18
$CeCl^{2+} = Ce^{3+} + Cl^-$	0.78	
$CeO_2(\text{cerianite}) + 4H^+ + e^- = Ce^{3+} + 2H_2O$	21.18	

CERIUM (cont)

Reaction	Log K	Ref.
$Ce_2O_3(s) + 6H^+ = 2Ce^{3+} + 3H_2O$	60.89	
$CeOH^{2+} + H^+ = Ce^{3+} + H_2O$	8.3	2
$CeOH^{3+} + H^+ + e^- = Ce^{3+} + H_2O$	28.37	15
$Ce(OH)_2^{2+} + 2H^+ + e^- = Ce^{3+} + 2H_2O$	29.17	15
$Ce(OH)_3(s) + 3H^+ = Ce^{3+} + 3H_2O$	20.77	
$Ce_2(OH)_2^{6+} + 2H^+ + 2e^- = 2Ce^{3+} + 2H_2O$	55.34	15
$Ce_2(OH)_3^{5+} + 2H^+ + 2e^- = 2Ce^{3+} + 3H_2O$	54.84	15
$Ce_2(OH)_4^{4+} + 4H^+ + 2e^- = Ce^{3+} + 4H_2O$	55.44	15
$Ce_2(OH)_2^{4+} + 2H^+ = 2Ce^{3+} + 2H_2O$	15.5	15
$Ce_3(OH)_5^{4+} + 5H^+ = 3Ce^{3+} + 5H_2O$	33.45	18

CURIUM

$Cm^{3+} = Cm^{4+} + e^-$	-52.40	15
$Cm(s) = Cm^{4+} + 4e^-$	64.75	15
$CmO_2^+ + 4H^+ + e^- = Cm^{4+} + 2H_2O$	45.65	15
$CmO_2^{2+} + 4H^+ + 2e^- = Cm^{4+} + 2H_2O$	79.46	15
$CmOH^{2+} + H^+ = Cm^{4+} + H_2O + e^-$	-49.00	15
$Cm(OH)_2^+ + H^+ = Cm^{4+} + 2H_2O + e^-$	-43.3	15
$CmCl^{2+} = Cm^{4+} + Cl^- + e^-$	-52.58	15
$CmF^{2+} = Cm^{4+} + F^- + e^-$	-55.74	15
$CmF_2^+ = Cm^{4+} + 2F^- + e^-$	-55.74	15
$CmF_3^o = Cm^{4+} + 3F^- + e^-$	-61.48	15
$CmNO_3^{2+} = Cm^{4+} + NO_3^- + e^-$	-52.97	15
$CmSO_4^+ = Cm^{4+} + SO_4^{2-} + e^-$	-54.26	15
$CmH_2PO_4^{2+} = Cm^{4+} + 2H^+ + PO_4^{3-} + e^-$	-74.32	15
$CmPO_4^o = Cm^{4+} + PO_4^{3-} + e^-$	-72.6	15

CHROMIUM

$Cr^{3+} + 4H_2O = CrO_4^{2-} + 8H^+ + 3e^-$	-67.08	17
$Cr_2O_3(s) + 5H_2O = 2CrO_4^{2-} + 10H^+ + 6e^-$	-137.21	
$Cr_2O_7^{2-} + H_2O = 2CrO_4^{2-} + 2H^+$	-14.49	

CHROMIUM (cont)

Reaction	Log K	Ref.
$HCrO_4^- = H^+ + CrO_4^{2-}$	-6.48	
$H_2CrO_4^o = 2H^+ + CrO_4^{2-}$	-6.28	2
$CrOH^{2+} + 3H_2O = CrO_4^{2-} + 7H^+ + 3e^-$	-63.16	18
$Cr(OH)_2^+ + 2H_2O = CrO_4^{2-} + 6H^+ + 3e^-$	-56.40	18(25°,0.1)
$Cr(OH)_3(s) + H_2O = CrO_4^{2-} + 5H^+ + 3e^-$	-54.91	18(25°,0.1)
$Cr(OH)_3^o + H_2O = CrO_4^{2-} + 5H^+ + 3e^-$	-49.08	2
$Cr(OH)_4^- = CrO_4^{2-} + 4H^+ + 3e^-$	-39.68	2
$Cr_2(OH)_2^{4+} + 6H_2O = 2CrO_4^{2-} + 14H^+ + 6e^-$	-129.10	2
$Cr_3(OH)_4^{5+} + 8H_2O = 3CrO_4^{2-} + 20H^+ + 9e^-$	-193.09	2
$CrF^{2-} + 4H_2O = CrO_4^{2-} + F^- + 8H^+ + 3e^-$	-72.28	18
$CrF_3(s) + 4H_2O = CrO_4^{2-} + 3F^- + 8H^+ + 3e^-$	-81.55	
$CrCl_2(s) + 4H_2O = CrO_4^{2-} + 2Cl^- + 8H^+ + 4e^-$	-55.06	
$CrCl_3(s) + 4H_2O = CrO_4^{2-} + 3Cl^- + 8H^+ + 3e^-$	-54.86	

CESIUM

$Cs(s) = Cs^+ + e^-$	49.70	
$CsNo_3^o = Cs^+ + NO_3^-$	0.10	23
$CsCl^o = Cs^+ + Cl^-$	-0.50	23
$CsBr^o = Cs^+ + Br^-$	(-0.03)	23
$CsI^o = Cs^+ + I^-$	(0.03)	23
$Cs_2O(s) + 2H^+ = 2Cs^+ + H_2O$	124.41	23
$CsOH(s) + H^+ = Cs^+ + H_2O$	149.54	23

COPPER

$Cu(s) = Cu^{2+} + 2e^-$	-11.48	
$Cu^+ = Cu^{2+} + e^-$	-2.72	
$CuS(covellite) + 4H_2O = Cu^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-56.46	
$Cu_2S(chalcocite) + 4H_2O = 2Cu^{2+} + SO_4^{2-} + 8H^+ + 10e^-$	-73.92	
$Cu(HS)_3^- + 12H_2O = Cu^{2+} + 3SO_4^{2-} + 27H^+ + 24e^-$	-126.74	3
$Cu_{0.9}^{2+}Cu_{0.2}^{+}S(blaublei\ I) + 4H_2O = 1.1Cu^{2+} + SO_4^{2-} + 8H^+ + 8.2e^-$	-58.31	3
$Cu_{0.6}^{2+}Cu_{0.8}^{+}S(blaublei\ II) + 4H_2O = 1.4Cu^{2+} + SO_4^{2-} + 8H^+ + 8.8e^-$	-63.06	3
$Cu_{0.25}^{2+}Cu_{1.5}^{+}S(anilite) + 4H_2O = 1.75Cu^{2+} + SO_4^{2-} + 8H^+ + 9.5e^-$	-69.57	3

COPPER (cont)

Reaction	Log K	Ref.
$Cu_{0.066}^{2+}Cu_{1.868}^{+}S$(djurleite) + $4H_2O$ = $1.934Cu^{2+}$ + SO_4^{2-} + $8H^+$ + $9.868e^-$	-72.61	3
$CuFeS_2$(chalcopyrite) + $8H_2O$ = Cu^{2+} + Fe^{2+} + $2SO_4^{2-}$ + $16H^+$ + $16e^-$	-102.05	
Cu_5FeS_4(bornite) + $16H_2O$ = $5Cu^{2+}$ + Fe^{2+} + $4SO_4^{2-}$ + $32H^+$ + $36e^-$	-250.09	
$CuSO_4^o$ = Cu^{2+} + SO_4^{2-}	-2.31	3
$CuSO_4$(chalcocyanite) = Cu^{2+} + SO_4^{2-}	2.94	
$CuSO_4 \cdot H_2O$(s) = Cu^{2+} + SO_4^{2-} + H_2O	-2.54	
$CuSO_4 \cdot 3H_2O$(s) = Cu^{2+} + SO_4^{2-} + $3H_2O$	-3.89	
$CuSO_4 \cdot 5H_2O$(chalcanthite) = Cu^{2+} + SO_4^{2-} + $5H_2O$	-2.64	
Cu_2SO_4(s) = $2Cu^{2+}$ + SO_4^{2-} + $2e^-$	-7.39	3
Cu_2OSO_4(s) + $2H^+$ = Cu^{2+} + SO_4^{2-} + H_2O	11.53	3
$Cu_3(OH)_4SO_4$(antlerite) + $4H^+$ = $3Cu^{2+}$ + SO_4^{2-} + $4H_2O$	8.73	
$Cu_4(OH)_6SO_4$(brochantite) + $6H^+$ = $4Cu^{2+}$ + SO_4^{2-} + $6H_2O$	15.32	
$Cu_4(OH)_6SO_4 \cdot H_2O$(langite) + $6H^+$ = $4Cu^{2+}$ + SO_4^{2-} + $7H_2O$	17.21	
$Cu(OH)_{1.5}(SO_4)_{0.25}$(s) + $1.5H^+$ = Cu^{2+} + $0.25SO_4^{2-}$ + $1.5H_2O$	3.82	
$Cu_3(PO_4)_2$(s) = $3Cu^{2+}$ + $2PO_4^{3-}$	-36.79	
$Cu_3(PO_4)_2 \cdot 3H_2O$(s) = $3Cu^{2+}$ + $2PO_4^{3-}$ + $3H_2O$	-35.12	3
$CuHPO_4^o$ = Cu^{2+} + H^+ + PO_4^{3-}	-15.55	18(25°,0.1)
$CuNO_3^+$ = Cu^{2+} + NO_3^-	-0.5	18
$Cu(NO_3)_2^o$ = Cu^{2+} + $2NO_3^-$	0.4	18
$Cu_2(OH)_3(NO_3)$(s) + $3H^+$ = $2Cu^{2+}$ + $3H_2O$ + NO_3^-	9.25	
$CuCO_3^o$ = Cu^{2+} + CO_3^{2-}	-6.73	3
$CuCO_3$(s) = Cu^{2+} + CO_3^{2-}	-9.63	
$Cu(CO_3)_2^{2-}$ = Cu^{2+} + $2CO_3^{2-}$	-9.83	
$CuHCO_3^+$ = Cu^{2+} + H^+ + CO_3^{2-}	-13.03	
$Cu_2(OH)_2(CO_3)$(malachite) + $2H^+$ = $2Cu^{2+}$ + CO_3^{2-} + $2H_2O$	-4.40	
$Cu_3(OH)_2(CO_3)_2$(azurite) + $2H^+$ = $3Cu^{2+}$ + $2CO_3^{2-}$ + $2H_2O$	-11.51	
$CuMoO_4$(s) = Cu^{2+} + MoO_4^{2-}	-8.31	
$CuCrO_4$(s) = Cu^{2+} + CrO_4^{2-}	-5.44	18
$CuSeO_3$(s) = Cu^{2+} + SeO_3^{2-}	-7.67	
$CuFeO_2$(s) + $4H^+$ = Cu^{2+} + Fe^{2+} + $2H_2O$	1.35	
$CuFe_2O_4$(s) + $8H^+$ + $2e^-$ = Cu^{2+} + $2Fe^{2+}$ + $4H_2O$	31.89	
$CuBr^+$ = Cu^{2+} + Br^-	-0.03	18
CuBr(s) = Cu^{2+} + Br^- + e^-	-10.93	
$CuBr_2 \cdot 3Cu(OH)_2$(s) + $6H^+$ = $4Cu^{2+}$ + $2Br^-$ + $6H_2O$	15.35	

COPPER (cont)

Reaction	Log K	Ref.
$CuCl^+ = Cu^{2+} + Cl^-$	-0.43	
$CuCl$(nantokite) $= Cu^{2+} + Cl^- + e^-$	-9.48	
$CuCl_2^o = Cu^{2+} + 2Cl^-$	-0.16	
$CuCl_2$(melanothallite) $= Cu^{2+} + 2Cl^-$	3.73	
$CuCl_2^- = Cu^{2+} + 2Cl^- + e^-$	-8.22	3
$CuCl_2 \cdot 2H_2O(s) = Cu^{2+} + 2Cl^- + 2H_2O$	2.67	
$CuCl_3^- = Cu^{2+} + 3Cl^-$	2.29	3
$CuCl_3^{2-} = Cu^{2+} + 3Cl^- + e^-$	-8.46	
$CuCl_4^{2-} = Cu^{2+} + 4Cl^-$	4.59	
$Cu_2(OH)_3Cl$(atacamite) $+ 3H^+ = 2Cu^{2+} + 3H_2O + Cl^-$	7.34	3
$CuF^+ = Cu^{2+} + F^-$	-1.26	3
$CuF(s) = Cu^{2+} + F^- + e^-$	4.36	3
$CuF_2(s) = Cu^{2+} + 2F^-$	-0.62	3
$CuF_2 \cdot 2H_2O(s) = Cu^{2+} + 2F^- + 2H_2O$	-4.55	3
$CuI(s) = Cu^{2+} + I^- + e^-$	-14.55	
CuO(tenorite) $+ 2H^+ = Cu^{2+} + H_2O$	7.66	
Cu_2O(cuprite) $+ 2H^+ = 2Cu^{2+} + H_2O + 2e^-$	-7.35	
$CuO_2^{2-} + 4H^+ = Cu^{2+} + 2H_2O$	39.44	
$HCuO_2^- + 3H^+ = Cu^{2+} + 2H_2O$	26.32	
$CuOH^+ + H^+ = Cu^{2+} + H_2O$	8.0	3
$Cu(OH)_2^o + 2H^+ = Cu^{2+} + 2H_2O$	13.68	3
$Cu(OH)_2(s) + 2H^+ = Cu^{2+} + 2H_2O$	8.64	3
$Cu(OH)_3^- + 3H^+ = Cu^{2+} + 3H_2O$	26.9	3
$Cu(OH)_4^{2-} + 4H^+ = Cu^{2+} + 4H_2O$	39.6	3
$Cu_2(OH)_2^{2+} + 2H^+ = 2Cu^{2+} + 2H_2O$	10.36	3
$CuFeO_2$(cuprous ferrite) $+ 4H^+ = Cu^{2+} + Fe^{2+} + 2H_2O$	-29.39	3
$CuFe_2O_4$(cupric ferrite) $+ 8H^+ + 2e^- = Cu^{2+} + 2Fe^{2+} + 4H_2O$	-29.62	3
$CuSiO_3 \cdot H_2O$(dioptase) $+ 2H^+ = Cu^{2+} + SiO_2^o + 2H_2O$	4.92	3
$Cu_2Te(s) = 2Cu^{2+} + Te^{2-} + 2e^-$	(-67.74)	18

EUROPIUM

Reaction	Log K	Ref.
$Eu^{2+} = Eu^{3+} + e^-$	5.94	15
$Eu(s) = Eu^{3+} + 3e^-$	100.59	15
$EuSO_4^+ = Eu^{3+} + SO_4^{2-}$	-3.67	18
$Eu(SO_4)_2^- = Eu^{3+} + 2SO_4^{2-}$	-5.41	18
$Eu_2(SO_4)_3 \cdot 8H_2O(s) = Eu^{3+} + 3SO_4^{2-} + 8H_2O$	-9.80	15
$EuNO_3^{2+} = Eu^{3+} + NO_3^-$	-1.23	18
$EuO(s) + 2H^+ = Eu^{3+} + H_2O + e^-$	44.70	
$Eu_2O_3(s) + 6H^+ = 2Eu^{3+} + 3H_2O$	53.33	
$Eu_3O_4(s) + 8H^+ = 3Eu^{3+} + 4H_2O + e^-$	92.42	15
$Eu(OH)_3(s) + 3H^+ = Eu^{3+} + 3H_2O$	16.37	18
$EuOH^{2+} + H^+ = Eu^{3+} + H_2O$	7.8	15
$EuCl^{2+} = Eu^{3+} + Cl^-$	-0.90	15
$EuCl_2^+ = Eu^{3+} + 2Cl^-$	-0.19	15
$EuF^{2+} = Eu^{3+} + F^-$	-3.19	15
$Eu_2P_2O_7^{2+} + H_2O = 2Eu^{3+} + 2H^+ + 2PO_4^{3-}$	-41.05	15

IRON

$Fe^{3+} + e^- = Fe^{2+}$	13.01	
$Fe(s) = Fe^{2+} + 2e^-$	13.82	
$FeS(troilite) + 4H_2O = Fe^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-39.67	
$FeS(mackinawite) + 4H_2O = Fe^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-38.26	3
$FeS_2(pyrite) + 8H_2O = Fe^{2+} + 2SO_4^{2-} + 16H^+ + 14e^-$	-85.72	
$FeS_2(marcasite) + 8H_2O = Fe^{2+} + 2SO_4^{2-} + 16H^+ + 14e^-$	-85.41	
$FeS(pyrrhotite) + 4H_2O = Fe^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-39.57	
$Fe_7S_8(S\text{-rich pyrrhotite}) + 32H_2O = 7Fe^{2+} + 8SO_4^{2-} + 64H^+ + 62e^-$	-320.29	
$Fe_3S_4(greigite) + 16H_2O = 3Fe^{2+} + 4SO_4^{2-} + 32H^+ + 30e^-$	-153.46	3
$Fe(HS)_2^o + 8H_2O = Fe^{2+} + 2SO_4^{2-} + 18H^+ + 16e^-$	-76.17	3
$Fe(HS)_3^- + 12H_2O = Fe^{2+} + 3SO_4^{2-} + 27H^+ + 24e^-$	-111.82	3
$FeSO_4(s) = Fe^{2+} + SO_4^{2-}$	0.46	
$FeSO_4^o = Fe^{2+} + SO_4^{2-}$	-2.25	3
$FeSO_4^+ + e^- = Fe^{2+} + SO_4^{2-}$	8.89	
$Fe(SO_4)_2^- = Fe^{2+} + 2SO_4^{2-}$	7.62	
$FeSO_4 \cdot 7H_2O(melanterite) = Fe^{2+} + SO_4^{2-} + 7H_2O$	-2.47	3

IRON (cont)

Reaction	Log K	Ref.
$Fe_2(SO_4)_3(s) + 2e^- = 2Fe^{2+} + 3SO_4^{2-}$	29.6	3
$NaFe_3(SO_4)_2(OH)_6$(Na-jarosite) $+ 6H^+ + 3e^- = Na^+ + 3Fe^{2+} + 2SO_4^{2-} + 6H_2O$	27.83	3
$KFe_3(SO_4)_2(OH)_6$(K-jarosite) $+ 6H^+ + 3e^- = K^+ + 3Fe^{2+} + 2SO_4^{2-} + 6H_2O$	24.23	3
$(H_3O)Fe_3(SO_4)_2(OH)_6$(H-jarosite) $+ 5H^+ + 3e^- = 3Fe^{2+} + 2SO_4^{2-} + 7H_2O$	26.93	3
$FeHPO_4^o = Fe^{2+} + H^+ + PO_4^{3-}$	-15.91	20
$FeHPO_4^+ + e^- = Fe^{2+} + H^+ + PO_4^{3-}$	-4.73	20
$FeH_2PO_4^+ = Fe^{2+} + 2H^+ + PO_4^{3-}$	-22.22	3
$FeH_2PO_4^{2+} + e^- = Fe^{2+} + PO_4^{3-}$	-11.94	3
$FePO_4 \cdot 2H_2O$(strengite) $+ e^- = Fe^{2+} + PO_4^{3-} + 2H_2O$	-13.39	20
$Fe_3(PO_4)_2 \cdot 8H_2O$(vivianite) $= 3Fe^{2+} + 2PO_4^{3-} + 8H_2O$	-36.02	
$Fe_5(PO_4)_3OH(s) + H^+ = 5Fe^{2+} + 3PO_4^{3-} + H_2O$	-460.87	
$Fe_3(PO_4)_2(OH)_2$(limpacombite) $+ 2H^+ + 2e^- = 3Fe^{2+} + 2PO_4^{3-} + 2H_2O$	-32.24	14
$Fe_3(PO_4)_2(OH)_3 \cdot 3H_2O$(tinticite) $+ 3H^+ + 3e^- = 3Fe^{2+} + 2PO_4^{3-} + 6H_2O$	-30.04	14
$Fe_4(PO_4)_3(OH)_3 \cdot 12H_2O$(cacoxenite) $+ 3H^+ + 3e^- = 4Fe^{2+} + 3PO_4^{3-} + 15H_2O$	-50.36	14
$Fe_5(PO_4)_3(OH)_5$(rock bridgite) $+ 5H^+ + 4e^- = 5Fe^{2+} + 3PO_4^{3-} + 5H_2O$	-48.26	14
$Fe_6(PO_4)_4(OH)_5 \cdot 6H_2O$(beraunite) $+ 5H^+ + 5e^- = 6Fe^{2+} + 4PO_4^{3-} + 11H_2O$	-68.78	14
$FeMoO_4(s) = Fe^{2+} + MoO_4^{2-}$	-10.51	
$FeCO_3$(siderite) $= Fe^{2+} + CO_3^{2-}$	-12.73	
$FeNO_3^{2+} + e^- = Fe^{2+} + NO_3^-$	12.02	
$FeAl_2O_4$(hercynite) $+ 8H^+ = Fe^{2+} + 2Al^{3+} + 4H_2O$	27.28	
$FeTiO_3$(ilmenite) $+ 6H^+ + e^- = Fe^{2+} + Ti^{3+} + 3H_2O$	-10.436	
$FeCr_2O_4$(chromite) $+ 4H_2O = Fe^{2+} + 2CrO_4^{2-} + 8H^+ + 6e^-$	-132.80	
$FeCl^{2+} + e^- = Fe^{2+} + Cl^-$	11.60	
$FeCl_2$(lawercite) $= Fe^{2+} + 2Cl^-$	6.88	
$FeCl_2^+ + e^- = Fe^{2+} + 2Cl^-$	10.92	
$FeCl_3$(molysite) $+ e^- = Fe^{2+} + 3Cl^-$	24.34	
$FeCl_3^o + e^- = Fe^{2+} + 3Cl^-$	11.88	3
$FeCl_4^- + e^- = Fe^{2+} + 4Cl^-$	13.80	23
$Fe(OH)_{2.7}Cl_{0.3}(s) + 2.7H^+ + e^- = Fe^{2+} + 2.7H_2O + 0.3Cl^-$	9.97	3
$FeF^{2+} + e^- = Fe^{2+} + F^-$	6.54	
$FeF_2^+ + e^- = Fe^{2+} + 2F^-$	2.19	
$FeF_3^o + e^- = Fe^{2+} + 3F^-$	-0.99	3
$FeBr^{2+} + e^- = Fe^{2+} + Br^-$	12.39	
$FeI^{2+} + e^- = Fe^{2+} + I^-$	11.19	

IRON (cont)

Reaction	Log K	Ref.
$Fe_{0.947}O$(wustite) + $2H^+$ + $0.106e^-$ = $0.947Fe^{2+}$ + H_2O	11.68	
$FeO(s)$ + $2H^+$ = Fe^{2+} + H_2O	11.31	
Fe_2O_3(hematite) + $6H^+$ + $2e^-$ = $2Fe^{2+}$ + $3H_2O$	21.69	
Fe_2O_3(maghemite) + $6H^+$ + $2e^-$ = $2Fe^{2+}$ + $3H_2O$	32.41	20
Fe_3O_4(magnetite) + $8H^+$ + $2e^-$ = $3Fe^{2+}$ + $4H_2O$	29.83	
FeO_2^{2-} + $4H^+$ = Fe^{2+} + $2H_2O$	17.16	
$HFeO_2^-$ + $3H^+$ = Fe^{2+} + $2H_2O$	30.72	
$FeOH^+$ + H^+ = Fe^{2+} + H_2O	9.5	3
$FeOH^{2+}$ + H^+ + e^- = Fe^{2+} + H_2O	15.17	
$Fe(OH)_2(s)$ + $2H^+$ = Fe^{2+} + $2H_2O$	10.05	
$Fe(OH)_2^+$ + $2H^+$ + e^- = Fe^{2+} + $2H_2O$	18.68	3
$Fe(OH)_2^o$ + $2H^+$ = Fe^{2+} + $2H_2O$	20.57	20
$Fe(OH)_3(s)$ + $3H^+$ + e^- = Fe^{2+} + $3H_2O$	17.90	3
$Fe(OH)_3^o$ + $3H^+$ + e^- = Fe^{2+} + $3H_2O$	26.61	3
$Fe(OH)_3^-$ + $3H^+$ = Fe^{2+} + $3H_2O$	30.71	
$Fe(OH)_4^{2-}$ + $4H^+$ = Fe^{2+} + $4H_2O$	45.13	
$Fe(OH)_4^-$ + $4H^+$ + e^- = Fe^{2+} + $4H_2O$	34.61	3
$Fe_2(OH)_2^{4+}$ + $2H^+$ + $2e^-$ = $2Fe^{2+}$ + $2H_2O$	28.87	
$Fe_3(OH)_4^{5+}$ + $4H^+$ + $3e^-$ = $3Fe^{2+}$ + $4H_2O$	45.33	3
$Fe_3(OH)_8(s)$ + $8H^+$ + $2e^-$ = $3Fe^{2+}$ + $8H_2O$	46.24	3
FeOOH(geothite) + $3H^+$ + e^- = Fe^{2+} + $2H_2O$	13.51	3
$Fe_3Si_2O_5(OH)_4$(greenalite) + $6H^+$ = $3Fe^{2+}$ + $2SiO_2^o$ + $5H_2O$	17.65	3
$Fe_3Si_4O_{10}(OH)_2$(minnesotaite) + $6H^+$ = $3Fe^{2+}$ + $4SiO_2^o$ + $4H_2O$	7.34	23
$FeSi(s)$ + $2H_2O$ = Fe^{2+} + SiO_2^o + $4H^+$ + $6e^-$	63.84	
$FeSi_2$(β-lebeamite) + $4H_2O$ = Fe^{2+} + $2SiO_2^o$ + $8H^+$ + $10e^-$	125.97	
$FeSi_{2.33}$(α-lebeamite) + $4.66H_2O$ = Fe^{2+} + $2.33SiO_2^o$ + $9.32H^+$ + $11.32e^-$	150.18	
$Fe_3Si(s)$ + $2H_2O$ = $3Fe^{2+}$ + SiO_2^o + $4H^+$ + $10e^-$	87.82	
$FeSiO_3$(ferrosilite) + $2H^+$ = Fe^{2+} + SiO_2^o + H_2O	5.54	
Fe_2SiO_4(fayalite) + $4H^+$ = $2Fe^{2+}$ + SiO_2^o + $2H_2O$	14.67	
$FeTe(s)$ = Fe^{2+} + Te^{2-}	(-30.0)	18

GADOLINIUM

Reaction	Log K	Ref.
$GdOH^{2+} + H^+ = Gd^{3+} + H_2O$	8.0	2
$Gd(OH)_3(s) + 3H^+ = Gd^{3+} + 3H_2O$	16.27	18
$Gd_2(CO_3)_3(s) = 2Gd^{3+} + 3CO_3^{2-}$	-32.2	18
$GdSO_4^+ = Gd^{3+} + SO_4^{2-}$	-3.66	18
$Gd(SO_4)_2^- = Gd^{3+} + 2SO_4^{2-}$	-5.21	18
$GdF^{2+} = Gd^{3+} + F^-$	-4.3	18

HYDROGEN

$HCO_3^- = H^+ + CO_3^{2-}$	-10.33	
$H_2CO_3^o = 2H^+ + CO_3^{2-}$	-16.69	
$HCl^o = H^+ + Cl^-$	6.10	23
$HF^o = H^+ + F^-$	-3.31	
$HF_2^- = H^+ + 2F^-$	-2.81	
$H_2F_2^o = 2H^+ + 2F^-$	-6.77	3
$HPO_4^{2-} = H^+ + PO_4^{3-}$	-12.31	
$H_2PO_4^- = 2H^+ + PO_4^{3-}$	-19.52	
$H_3PO_4^o = 3H^+ + PO_4^{3-}$	-21.67	
$H_3PO_4(s) = 3H^+ + PO_4^{3-}$	-16.35	
$H_3PO_4 \cdot 1/2\ H_2O(s) = 3H^+ + PO_4^{3-} + 1/2\ H_2O$	-18.34	

HAFNIUM

$HfOH^{3+} + H^+ = Hf^{4+} + H_2O$	0.29	18
$Hf(OH)_4^o + 4H^+ = Hf^{4+} + 4H_2O$	10.7	2
$Hf(OH)_5^- + 5H^+ = Hf^{4+} + 5H_2O$	17.15	18
$HfO_2(s) + 4H^+ = Hf^{4+} + 2H_2O$	1.16	18
$HfO_2^o + 4H^+ = Hf^{4+} + 2H_2O$	-9.566	
$HfF_4(s,monoclinic) = Hf^{4+} + 4F^-$	-25.746	
$HfCl_4(s) = Hf^{4+} + 4Cl^-$	32.095	

POTASSIUM

Reaction	Log K	Ref.
$K(s) = K^+ + e^-$	49.50	
$KSO_4^- = K^+ + SO_4^{2-}$	-0.85	3
K_2SO_4(arcanite) $= 2K^+ + SO_4^{2-}$	-1.76	
$KAl(SO_4)_2(s) = K^+ + Al^{3+} + 2SO_4^{2-}$	3.77	
$KAl_3(OH)_6(SO_4)_2$(alunite) $+ 6H^+ = K^+ + 3Al^{3+} + 2SO_4^{2-} + 6H_2O$	0.78	23
$KAl(SO_4)_2 \cdot 12H_2O$(alum K) $= K^+ + Al^{3+} + 2SO_4^{2-} + 12H_2O$	-5.17	3
$K_2MoO_4(s) = 2K^+ + MoO_4^{2-}$	3.48	
$KCrO_4^- = K^+ + CrO_4^{2-}$	(-0.57)	18(18°,0)
$KHPO_4^- = K^+ + H^+ + PO_4^{3-}$	-12.60	3
KNO_3(niter) $= K^+ + NO_3^-$	-0.10	
$KNO_3^o = K^+ + NO_3^-$	(0.15)	18
KCl(sylvite) $= K^+ + Cl^-$	0.85	
$KCl^o = K^+ + Cl^-$	(0.7)	18
$KI^o = K^+ + I^-$	(0.19)	18
$KBr(s) = K^+ + Br^-$	1.12	
$KOH^o + H^+ = K^+ + H_2O$	14.49	18
$KOH(s) + H^+ = K^+ + H_2O$	24.65	
$KO_2(s) + 4H^+ + 3e^- = K^+ + 2H_2O$	90.45	
$K_2O(s) + 2H^+ = 2K^+ + H_2O$	84.06	
$KAlSi_3O_8$(Kspar) $+ 4H^+ = K^+ + Al^{3+} + 3SiO_2^o + 2H_2O$	0.05	
$KAlSi_3O_8$(max-muradine) $+ 4H^+ = K^+ + Al^{3+} + 3SiO_2^o + 2H_2O$	0.05	
$KAlSi_3O_8$(high sanidine) $+ 4H^+ = K^+ + Al^{3+} + 3SiO_2^o + 2H_2O$	1.25	
$KAlSiO_4$(kalsilite) $+ 4H^+ = K^+ + Al^{3+} + SiO_2^o + 2H_2O$	11.23	
$KFe_3(AlSi_3O_{10})(OH)_2$(annite) $+ 10H^+ = K^+ + 3Fe^{2+} + Al^{3+} + 3SiO_2^o + 6H_2O$	23.13	
$KMg_3(AlSi_3O_{10})(OH)_2$(phlogopite) $+ 10H^+ = K^+ + 3Mg^{2+} + Al^{3+} + 3SiO_2^o + 6H_2O$	38.17	
$KAl_2(AlSi_3O_{10})(OH)_2$(muscovite) $+ 10H^+ = K^+ + 3Al^{3+} + 3SiO_2^o + 6H_2O$	14.56	
$K_2(UO_2)_2(VO_4)_2$(carnotite) $+ 8H^+ + 4e^- = 2K^+ + 2U^{4+} + 2VO_4^{3-} + 4H_2O$	-37.87	
$K_4Pu(SO_4)_4 \cdot 2H_2O(s) = 4K^+ + Pu^{4+} + 4SO_4^{2-} + 2H_2O$	-18.0	8

LANTHIUM

Reaction	Log K	Ref.
$LaOH^{2+} + H^+ = La^{3+} + H_2O$	8.49	18
$La(OH)_3(s) + 3H^+ = La^{3+} + 3H_2O$	21.27	18
$La_5(OH)_9^{6+} + 9H_2O = 5La^{3+} + 9H^+$	71.11	18
$La_2(CO_3)_3(s) = 2La^{3+} + 3CO_3^{2-}$	-33.4	18
$LaSO_4^+ = La^{3+} + SO_4^{2-}$	-3.64	18
$La(SO_4)_2^- = La^{3+} + 2SO_4^{2-}$	-5.29	18
$LaF^{2+} = La^{3+} + F^-$	-3.6	18

MAGNESIUM

$Mg(s) = Mg^{2+} + 2e^-$	79.69	
$MgS(s) + 4H_2O = Mg^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-15.94	
$MgSO_4(s) = Mg^{2+} + SO_4^{2-}$	5.04	
$MgSO_4^o = Mg^{2+} + SO_4^{2-}$	-2.23	18
$MgSO_4 \cdot H_2O(s) = Mg^{2+} + SO_4^{2-} + H_2O$	1.36	
$MgSO_4 \cdot 6H_2O(s) = Mg^{2+} + SO_4^{2-} + 6H_2O$	-1.73	
$MgSO_4 \cdot 7H_2O$(epsomite) $= Mg^{2+} + SO_4^{2-} + 7H_2O$	-2.07	
$MgPO_4^- = Mg^{2+} + PO_4^{3-}$	-6.59	20
$Mg_3(PO_4)_2(s) = 3Mg^{2+} + 2PO_4^{3-}$	-23.90	
$MgHPO_4^o = Mg^{2+} + H^+ + PO_4^{3-}$	-15.18	20
$MgH_2PO_4^+ = Mg^{2+} + 2H^+ + PO_4^{3-}$	-21.03	20
$MgMoO_4(s) = Mg^{2+} + MoO_4^{2-}$	-0.87	
$MgCO_3^o = Mg^{2+} + CO_3^{2-}$	-2.98	3
$MgHCO_3^+ = Mg^{2+} + H^+ + CO_3^{2-}$	-11.31	
$MgCO_3$(magnesite) $= Mg^{2+} + CO_3^{2-}$	-7.91	
$MgCO_3 \cdot 3H_2O$(nesquehonite) $= Mg^{2+} + CO_3^{2-} + 3H_2O$	-5.23	
$MgCO_3 \cdot 5H_2O$(lansfordite) $= Mg^{2+} + CO_3^{2-} + 5H_2O$	-5.45	
$Mg_5(OH)_2(CO_3)_4 \cdot 4H_2O$(hydromagnesite) $+ 2H^+ = 5Mg^{2+} + 4CO_3^{2-} + 6H_2O$	-9.85	
$Mg_2(OH)_2CO_3 \cdot 3H_2O$(artinite) $+ 2H^+ = 2Mg^{2+} + CO_3^{2-} + 5H_2O$	9.62	
$Mg_4(OH)_2(CO_3)_3 \cdot 3H_2O(s) + 2H^+ = 4Mg^{2+} + 3CO_3^{2-} + 5H_2O$	-2.64	
$Mg(NO_3)_2(s) = Mg^{2+} + 2NO_3^-$	15.53	
$Mg(NO_3)_2 \cdot 6H_2O(s) = Mg^{2+} + 2NO_3^- + 6H_2O$	3.49	
$MgCl_2$(chloromagnesite) $= Mg^{2+} + 2Cl^-$	22.00	
$MgCl_2 \cdot H_2O(s) = Mg^{2+} + 2Cl^- + H_2O$	16.24	

MAGNESIUM (cont)

Reaction	Log K	Ref.
$MgCl_2 \cdot 2H_2O(s) = Mg^{2+} + 2Cl^- + 2H_2O$	12.88	
$MgCl_2 \cdot 4H_2O(s) = Mg^{2+} + 2Cl^- + 4H_2O$	7.43	
$MgCl_2 \cdot 6H_2O(s) = Mg^{2+} + 2Cl^- + 6H_2O$	4.42	
MgF_2(sellaite) + $Mg^{2+} + 2F^-$	-9.49	
$MgF^+ = Mg^{2+} + F^-$	-1.82	20
$MgBr_2(s) = Mg^{2+} + 2Br^-$	27.87	
$MgBr_2 \cdot 6H_2O(s) = Mg^{2+} + 2Br^- + 6H_2O$	5.19	
$MgI_2(s) = Mg^{2+} + 2I^-$	35.13	
MgV_2O_6(metavanadate) + $2H_2O = Mg^{2+} + 2VO_4^{3-} + 4H^+$	-45.66	
$Mg_2V_2O_7$(pyrovanadate) + $H_2O = 2Mg^{2+} + 2VO_4^{3-} + 2H^+$	-30.59	
$MgTiO_3$(geikilite) + $6H^+ + e^- = Mg^{2+} + Ti^{3+} + 3H_2O$	-1.547	
$MgTiO_3$(metatitanate) + $6H^+ + e^- = Mg^{2+} + Ti^{3+} + 3H_2O$	-1.567	
$MgTi_2O_5(s) + 10H^+ + 2e^- = Mg^{2+} + 2Ti^{3+} + 5H_2O$	-18.880	
Mg_2TiO_4(orthotitanate) + $8H^+ + e^- = 2Mg^{2+} + Ti^{3+} + 4H_2O$	21.144	
MgO(periclase) + $2H^+ = Mg^{2+} + H_2O$	21.48	
$Mg(OH)_2$(brucite) + $2H^+ = Mg^{2+} + 2H_2O$	16.43	
$MgOH^+ + H^+ = Mg^{2+} + H_2O$	11.42	
$MgH_2(s) = Mg^{2+} + 2H^+ + 4e^-$	73.39	
$Mg_4(OH)_4^{4+} + 4H^+ = 4Mg^{2+} + 4H_2O$	39.66	18
$MgAl_2O_4$(spinel) + $8H^+ = Mg^{2+} + 2Al^{3+} + 4H_2O$	38.42	
$MgCr_2O_4$(picrochromite) + $4H_2O = Mg^{2+} + 2CrO_4^{2-} + 8H^+ + 6e^-$	-123.91	
$MgFe_2O_4$(magnesioferrite) + $8H^+ + 2e^- = Mg^{2+} + 2Fe^{2+} + 4H_2O$	42.77	
$Mg_2Si(s) + 2H_2O = 2Mg^{2+} + SiO_2^o + 4H^+ + 8e^-$	209.12	
$MgCu_2(s,\beta) = Mg^{2+} + 2Cu^{2+} + 6e^-$	96.72	
$MgCd(s) = Mg^{2+} + Cd^{2+} + 4e^-$	90.57	
$MgCd_3(s) = Mg^{2+} + 3Cd^{2+} + 8e^-$	117.02	
$Mg_3Cd(s) = 3Mg^{2+} + Cd^{2+} + 8e^-$	248.90	
$MgNi_2(s) = Mg^{2+} + 2Ni^{2+} + 6e^-$	86.22	
Mg_2SiO_4(forsterite) + $4H^+ = 2Mg^{2+} + SiO_2^o + 2H_2O$	28.14	
$MgSiO_3$(enstatite) + $2H^+ = Mg^{2+} + SiO_2^o + H_2O$	11.46	
$Mg_2Al_3(AlSi_5O_{18})$(cordierite) + $16H^+ = 2Mg^{2+} + 4Al^{3+} + 5SiO_2^o + 8H_2O$	53.88	
$Mg_2Al_3(AlSi_5O_{18}) \cdot H_2O$(hydrous cordierite) + $16H^+ = 2Mg^{2+} + 4Al^{3+} + 5SiO_2^o + 9H_2O$	51.39	
$Mg_7Si_8O_{22}(OH)_2$(anthophyllite) + $14H^+ = 7Mg^{2+} + 8SiO_2^o + 8H_2O$	67.75	
$Mg_3Si_2O_5(OH)_4$(chrysotile) + $6H^+ = 3Mg^{2+} + 2SiO_2^o + 5H_2O$	31.52	

MAGNESIUM (cont)

Reaction	Log K	Ref.
$Mg_{48}Si_{34}O_{85}(OH)_{62}$(antigorite) + $96H^+ = 48Mg^{2+} + 34SiO_2^o + 79H_2O$	483.58	
$Mg_3Si_4O_{10}(OH)_2$(talc) + $6H^+ = 3Mg^{2+} + 4SiO_2^o + 4H_2O$	21.54	
$Mg_5Al(AlSi_3O_{10})(OH)_8$(7 clinochlore) + $16H^+ = 5Mg^{2+} + 2Al^{3+} + 3SiO_2^o + 12H_2O$	71.92	
$Mg_5Al(AlSi_3O_{10})(OH)_8$(14 clinochlore) + $16H^+ = 5Mg^{2+} + 2Al^{3+} + 3SiO_2^o + 12H_2O$	68.55	
$Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$(sepiolite) + $8H^+ = 4Mg^{2+} + 6SiO_2^o + 11H_2O$	30.94	
$Mg_3Si_4O_{10}(OH)_2 \cdot 3H_2O$(kerolite) + $6H^+ = 3Mg^{2+} + 4SiO_2^o + 7H_2O$	23.54	19
$Mg_2UO_2(CO_3)_3 \cdot 18H_2O$(bayleyite) + $4H^+ = 2Mg^{2+} + U^{4+} + 3CO_3^{2-} + 20H_2O$	-27.59	
$Mg_2(UO_2)_6(SO_4)_3(OH)_{10} \cdot 8H_2O$(Mg-zippeite) + $34H^+ + 12e^-$ $= 2Mg^{2+} + 6U^{4+} + 3SO_4^{2-} + 30H_2O$	49.03	6

MANGANESE

$Mn(s,\alpha) = Mn^{2+} + 2e^-$	39.95	
$Mn(s,\gamma) = Mn^{2+} + 2e^-$	40.20	
$Mn^{3+} + e^- = Mn^{2+}$	25.51	3
MnS(alabandite) + $4H_2O = Mn^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-34.04	
$MnSO_4(s) = Mn^{2+} + SO_4^{2-}$	2.68	
$MnSO_4^o = Mn^{2+} + SO_4^{2-}$	-2.26	3
$Mn_2(SO_4)_3(s) + 2e^- = 2Mn^{2+} + 3SO_4^{2-}$	45.31	23
$MnHPO_4(s) = Mn^{2+} + H^+ + PO_4^{3-}$	-25.27	
$Mn_3(PO_4)_2(s) = 3Mn^{2+} + 2PO_4^{3-}$	-23.83	3
$Mn_3(PO_4)_2 \cdot 3H_2O$(reddingite) = $3Mn^{2+} + 2PO_4^{3-} + 3H_2O$	-36.84	14
$MnFe_2(OH)_2(PO_4)_2 \cdot 8H_2O$(laveite/stronzite) + $2H^+ + 2e^-$ $= Mn^{2+} + 2Fe^{2+} + 2PO_4^{3-} + 10H_2O$	-27.34	14
$MnMoO_4(s) = Mn^{2+} + MoO_4^{2-}$	-4.61	
$MnCO_3$(rhodochrosite) = $Mn^{2+} + CO_3^{2-}$	-10.54	
$MnCO_3^o = Mn^{2+} + CO_3^{2-}$	-6.5	23
$MnHCO_3^+ = Mn^{2+} + H^+ + CO_3^{2-}$	-11.25	
$Mn(NO_3)_2^o = Mn^{2+} + 2NO_3^-$	0.40	3
$MnCl^+ = Mn^{2+} + Cl^-$	-0.61	
$MnCl_2$(scacchite) = $Mn^{2+} + 2Cl^-$	8.77	
$MnCl_2^o = Mn^{2+} + 2Cl^-$	-0.04	3
$MnCl_2 \cdot H_2O(s) = Mn^{2+} + 2Cl^- + H_2O$	5.51	
$MnCl_2 \cdot 2H_2O(s) = Mn^{2+} + 2Cl^- + 2H_2O$	3.96	

MANGANESE (cont)

Reaction	Log K	Ref.
$MnCl_2 \cdot 4H_2O(s) = Mn^{2+} + 2Cl^- + 4H_2O$	2.68	
$MnCl_3^- = Mn^{2+} + 3Cl^-$	0.31	
$MnF^+ = Mn^{2+} + F^-$	-0.85	3
$MnO(manganosite) + 2H^+ = Mn^{2+} + H_2O$	17.91	
$MnO_2(pyrolucite) + 4H^+ + 2e^- = Mn^{2+} + 2H_2O$	41.55	
$MnO_2(birnessite) + 4H^+ + 2e^- = Mn^{2+} + 2H_2O$	43.60	3
$MnO_2(nsutite) + 4H^+ + 2e^- = Mn^{2+} + 2H_2O$	43.01	3
$MnO_4^- + 8H^+ + 5e^- = Mn^{2+} + 4H_2O$	127.79	
$MnO_4^{2-} + 8H^+ + 4e^- = Mn^{2+} + 4H_2O$	118.40	
$Mn_2O_3(bixbyite) + 6H^+ + 2e^- = 2Mn^{2+} + 3H_2O$	50.17	
$Mn_3O_4(haussmanite) + 8H^+ + 2e^- = 3Mn^{2+} + 4H_2O$	61.28	
$MnOH^+ + H^+ = Mn^{2+} + H_2O$	10.54	
$Mn(OH)_2(pyrochroite) + 2H^+ = Mn^{2+} + 2H_2O$	15.09	3
$Mn(OH)_3^- + 3H^+ = Mn^{2+} + 3H_2O$	34.18	
$Mn(OH)_3(s) + 3H^+ + e^- = Mn^{2+} + 3H_2O$	31.84	25
$Mn(OH)_4^{2-} + 4H^+ = Mn^{2+} + 4H_2O$	48.26	3
$MnOOH(s) + 3H^+ + e^- = Mn^{2+} + 2H_2O$	25.27	3
$Mn_2(OH)^{3+} + H^+ = 2Mn^{2+} + H_2O$	10.59	18
$Mn_2(OH)_3^+ + 3H^+ = 2Mn^{2+} + 3H_2O$	23.87	18
$MnSiO_3(rhodonite) + 2H^+ = Mn^{2+} + SiO_2^o + H_2O$	9.72	
$Mn_2SiO_4(tephroite) + 4H^+ = 2Mn^{2+} + SiO_2^o + 2H_2O$	23.47	
$MnTe(s) = Mn^{2+} + Te^{2-}$	(-15.9)	18

MOLYBDENUM

$MoS_2(molybdenite) + 12H_2O = MoO_4^{2-} + 2SO_4^{2-} + 24H^+ + 18e^-$	-143.30	
$MoO_2(s) + 2H_2O = MoO_4^{2-} + 4H^+ + 2e^-$	-30.01	
$MoO_3(s) + H_2O = MoO_4^{2-} + 2H^+$	-12.12	
$HMoO_4^- = H^+ + MoO_4^{2-}$	-4.24	18(20°,0)
$H_2MoO_4(s) = 2H^+ + MoO_4^{2-}$	-12.16	
$H_2MoO_4^o = 2H^+ + MoO_4^{2-}$	-8.24	18(20°,0)
$Mo_3Si(s) + 14H_2O = 3MoO_4^{2-} + SiO_2^o + 28H^+ + 22e^-$	-13.08	

AMMONIUM

Reaction	Log K	Ref.
$NH_4OH^o + H^+ = NH_4^+ + H_2O$	9.26	
$NH_4HS(s) + 4H_2O = NH_4^+ + SO_4^{2-} + 9H^+ + 8e^-$	-30.68	
$NH_4SO_4^- = NH_4^+ + SO_4^{2-}$	-1.11	20
$(NH_4)_2SO_4$(mascagnite) $= 2NH_4^+ + SO_4^{2-}$	0.33	
$NH_4Al(SO_4)_2(s) = NH_4^+ + Al^{3+} + 2SO_4^{2-}$	3.47	
$NH_4Al(SO_4)_2 \cdot 12H_2O(s) = NH_4^+ + Al^{3+} + 2SO_4^{2-} + 12H_2O$	-5.97	
NH_4NO_3(ammonium niter) $= NH_4^+ + NO_3^-$	1.25	
$NH_4H_2PO_4(s) = NH_4^+ + 2H^+ + PO_4^{3-}$	-19.64	
$H_6(NH_4)_3Al_5(PO_4)_8 \cdot 18H_2O(s) = 6H^+ + 3NH_4^+ + 5Al^{3+} + 8PO_4^{3-} + 18H_2O$	-185.74	
$NH_4VO_3(s) + H_2O = NH_4^+ + VO_4^{3-} + 2H^+$	-25.72	
$NH_4HSe(s) + 3H_2O = NH_4^+ + 7H^+ + SeO_3^{2-} + 6e^-$	-50.03	
$NH_4Br(s) = NH_4^+ + Br^-$	1.43	
$NH_4Br_3(s) + 2e^- = NH_4^+ + 3Br^-$	35.52	
NH_4Cl(salammoniac) $= NH_4^+ + Cl^-$	1.22	
$NH_4F(s) = NH_4^+ + F^-$	2.05	
$NH_4HF_2(s) = NH_4^+ + H^+ + 2F^-$	-1.66	
$NH_4I(s) = NH_4^+ + I^-$	3.30	
$NH_4I_3(s) + 2e^- = NH_4^+ + 3I^-$	20.24	
$NH_4ICl_2(s) + 2e^- = NH_4^+ + I^- + 2Cl^-$	28.33	
$NH_4ICl_4(s) + 4e^- = NH_4^+ + I^- + 4Cl^-$	71.62	
$NH_4IBr_2(s) + 2e^- = NH_4^+ + I^- + 2Br^-$	25.08	
$NH_4BrI_2(s) + 2e^- = NH_4^+ + Br^- + 2I^-$	17.13	
$NH_4IBrCl(s) + 2e^- = NH_4^+ + I^- + Br^- + Cl^-$	26.12	
$(NH_4)_2SiF_6$(s,hexagonal) $+ 2H_2O = 2NH_4^+ + SiO_2^o + 6F^- + 4H^+$	-28.26	
$(NH_4)_2SiF_6$(s,cubic) $+ 2H_2O = 2NH_4^+ + SiO_2^o + 6F^- + 4H^+$	-28.27	
$NO_3^- + 10H^+ + 8e^- = NH_4^+ + 3H_2O$	119.04	

SODIUM

$Na(s) = Na^+ + e^-$	45.89	
$NaSO_4^- = Na^+ + SO_4^{2-}$	-0.70	3
Na_2SO_4(thenardite) $= 2Na^+ + SO_4^{2-}$	-0.18	20
$Na_2SO_4 \cdot 10H_2O$(mirabilite) $= 2Na^+ + SO_4^{2-} + 10H_2O$	-1.17	
$NaHPO_4^- = Na^+ + H^+ + PO_4^{3-}$	-12.60	3

SODIUM (cont)

Reaction	Log K	Ref.
$Na_2MoO_4(s) = 2Na^+ + MoO_4^{2-}$	1.03	
$NaCO_3^- = Na^+ + CO_3^-$	-0.96	23
$Na_2CO_3 \cdot H_2O$(thermonatrite) $= 2Na^+ + CO_3^{2-} + H_2O$	0.125	20
$Na_2CO_3 \cdot 10H_2O$(natron) $= 2Na^+ + CO_3^{2-} + 10H_2O$	-1.31	20
$NaHCO_3$(nahcolite) $= Na^+ + H^+ + CO_3^{2-}$	-10.88	20
$NaHCO_3^o = Na^+ + H^+ + CO_3^{2-}$	-10.08	20
$Na_3H(CO_3)_2 \cdot 2H_2O$(trona) $= 3Na^+ + H^+ + 2CO_3^{2-} + 2H_2O$	-11.12	20
$NaAlCO_3(OH)_2$(dawsonite) $+ 2H^+ = Na^+ + Al^{3+} + CO_3^{2-} + 2H_2O$	-5.67	
$NaNO_3(s) = Na^+ + NO_3^-$	1.09	
NaCl(halite) $= Na^+ + Cl^-$	1.59	
$NaCl^o = Na^+ + Cl^-$	0.90	
NaF(villiaumite) $= Na^+ + F^-$	-0.59	
Na_3AlF_6(cryolite) $= 3Na^+ + Al^{3+} + 6F^-$	-32.14	
$Na_2O(s) + 2H^+ = 2Na^+ + H_2O$	67.44	
$NaOH(s) + H^+ = Na^+ + H_2O$	20.92	
$NaOH^o + H^+ = Na^+ + H_2O$	14.19	18
$NaAlSi_2O_6$(jadeite) $+ 4H^+ = Na^+ + Al^{3+} + 2SiO_2^o + 2H_2O$	8.71	
$NaCa_2Mg_4(Al_2Si_6O_{22})(OH)_2$(pargasite) $+ 22H^+ = Na^+ + 2Ca^{2+} + 4Mg^{2+} + 3Al^{3+} + 6SiO_2^o + 12H_2O$	103.45	
$NaAlSi_2O_6 \cdot H_2O$(analcime) $+ 4H^+ = Na^+ + Al^{3+} + 2SiO_2^o + 3H_2O$	7.27	
$NaAlSi_2O_6$(dehydrated analcime) $+ 4H^+ = Na^+ + Al^{3+} + 2SiO_2^o + 2H_2O$	11.98	
$NaAlSi_3O_8$(low albite) $+ 4H^+ = Na^+ + Al^{3+} + 3SiO_2^o + 2H_2O$	3.09	
$NaAlSi_3O_8$(high albite) $+ 4H^+ = Na^+ + Al^{3+} + 3SiO_2^o + 2H_2O$	4.41	
$NaAlSiO_4$(nepheline) $+ 4H^+ = Na^+ + Al^{3+} + SiO_2^o + 2H_2O$	14.13	
$NaAl_2(AlSi_3O_{10})(OH)_2$(paragonite) $+ 10H^+ = Na^+ + 3Al^{3+} + 3SiO_2^o + 6H_2O$	18.49	
$Na_2CaUO_2(CO_3)_3 \cdot 6H_2O$(andersonite) $+ 4H^+ + 2e^- = 2Na^+ + Ca^{2+} + U^{4+} + 3CO_3^{2-} + 8H_2O$	-98.73	
$NaSi_7O_{13}(OH)_3 \cdot 3H_2O$(magadiite) $+ H^+ = Na^+ + 7SiO_2^o + 5H_2O$	-25.36	

NEODYMIUM

Reaction	Log K	Ref.
$NdOH^{2+} + H^+ = Nd^{3+} + H_2O$	7.99	18
$Nd(OH)_3(s) + 3H^+ = Nd^{3+} + 3H_2O$	18.87	18
$Nd(OH)_4^- + 4H^+ = Nd^{3+} + 4H_2O$	37.36	18
$Nd_2(OH)_2^{4+} + 2H^+ = 2Nd^{3+} + 2H_2O$	13.88	18
$Nd_2(CO_3)_3(s) = 2Nd^{3+} + 3CO_3^{2-}$	-33.0	18
$NdSO_4^+ = Nd^{3+} + SO_4^{2-}$	3.64	18
$Nd_2SO_4^{4+} = Nd^{3+} + 2SO_4^{2-}$	5.1	18

NICKEL

$Ni(s) = Ni^{2+} + 2e^-$	7.99	
$NiS(millerite) + 4H_2O = Ni^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-42.85	
$NiS(s,\alpha) + 4H_2O = Ni^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-40.1	18
$NiS(s,\beta) + 4H_2O = Ni^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-45.6	18
$NiS(s,\gamma) + 4H_2O = Ni^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-47.3	18
$Ni_3S_2(heazlewoodite) + 8H_2O = 3Ni^{2+} + 2SO_4^{2-} + 16H^+$	-82.03	
$NiSO_4(s) = Ni^{2+} + SO_4^{2-}$	5.33	
$NiSO_4^o = Ni^{2+} + SO_4^{2-}$	-2.29	3
$Ni(SO_4)_2^{2-} = Ni^{2+} + 2SO_4^{2-}$	-1.02	3
$NiSO_4 \cdot 6H_2O(\alpha, green\ retgersite) = Ni^{2+} + SO_4^{2-} + 6H_2O$	-2.01	
$NiSO_4 \cdot 7H_2O(morenosite) = Ni^{2+} + SO_4^{2-} + 7H_2O$	-2.36	3
$Ni_4(OH)_6SO_4(s) + 6H^+ = 4Ni^{2+} + SO_4^{2-} + 6H_2O$	31.92	
$Ni_7(OH)_8(SO_4)_3(s) + 8H^+ = 7Ni^{2+} + 3SO_4^{2-} + 8H_2O$	132.28	
$NiPO_4^{2-} = Ni^{2+} + PO_4^{3-}$	-2.08	18(25°,0.1)
$Ni_3(PO_4)_2(s) = 3Ni^{2+} + 2PO_4^{3-}$	-31.24	
$NiCO_3(s) = Ni^{2+} + CO_3^{2-}$	-6.84	
$NiCO_3^o = Ni^{2+} + CO_3^{2-}$	-6.87	3
$Ni(CO_3)_2^{2-} = Ni^{2+} + 2CO_3^{2-}$	-10.11	3
$NiHCO_3^+ = Ni^{2+} + H^+ + CO_3^{2-}$	-12.47	3
$NiNO_3^+ = Ni^{2+} + NO_3^-$	-0.4	18
$NiCl^+ = Ni^{2+} + Cl^-$	-0.4	3
$NiCl_2(s) = Ni^{2+} + 2Cl^-$	8.61	

NICKEL (cont)

Reaction	Log K	Ref.
$NiCl_2 \cdot 2H_2O(s) = Ni^{2+} + 2Cl^- + 2H_2O$	3.89	
$NiCl_2 \cdot 4H_2O(s) = Ni^{2+} + 2Cl^- + 4H_2O$	3.78	
$NiCl_2 \cdot 6H_2O(s) = Ni^{2+} + 2Cl^- + 6H_2O$	3.06	
$NiF^+ = Ni^{2+} + F^-$	-1.3	3
$NiF_2(s) = Ni^{2+} + 2F^-$	0.616	
$NiF_2 \cdot 4H_2O(s) = Ni^{2+} + 2F^- + 4H_2O$	-4.434	
$NiBr^+ = Ni^{2+} + Br^-$	-0.5	3
$NiO(bunsenite) + 2H^+ = Ni^{2+} + H_2O$	12.466	
$NiOH^+ + H^+ = Ni^{2+} + H_2O$	9.660	
$Ni(OH)_2(s) + 2H^+ = Ni^{2+} + 2H_2O$	12.723	
$Ni(OH)_2^{\circ} + 2H^+ = Ni^{2+} + 2H_2O$	19.0	3
$Ni(OH)_3^- + 3H^+ = Ni^{2+} + 3H_2O$	30.0	3
$NiFe_2O_4(trevorite) + 8H^+ + 2e^- = Ni^{2+} + 2Fe^{2+} + 4H_2O$	31.358	
$Ni_2(UO_2)_6(SO_4)_3(OH)_{10} \cdot 8H_2O(Ni\text{-}zippeite) + 34H^+ + 12e^-$ $= 2Ni^{2+} + 6U^{4+} + 3SO_4^{2-} + 30H_2O$	49.53	6
$Ni_2(OH)^{3-} + H^+ = 2Ni^{2+} + H_2O$	(10.69)	18
$Ni_4(OH)_4^{4+} + 4H^+ = 4Ni^{2+} + 4H_2O$	27.66	18
$NiTe(s) = Ni^{2+} + Te^{2-}$	(-38.1)	18

NEPTUNIUM

$Np^{3+} = Np^{4+} + e^-$	-2.57	15
$Np(s) = Np^{4+} + 4e^-$	91.56	15
$NpO_2^+ + 4H^+ + e^- = Np^{4+} + 2H_2O$	10.91	15
$NpO_2^{2+} + 4H^+ + 2e^- = Np^{4+} + 2H_2O$	30.33	15
$NpO_2^{3+} + 4H^+ + 3e^- = Np^{4+} + 2H_2O$	40.64	15
$NpOH^{3+} + H^+ = Np^{4+} + H_2O$	2.05	15
$NpO_2OH^{\circ} + 5H^+ + e^- = Np^{4+} + 3H_2O$	20.91	15
$NpO_2OH^+ + 5H^+ + 2e^- = Np^{4+} + 3H_2O$	33.70	15
$Np(OH)_3(s) + 3H^+ = Np^{4+} + 3H_2O + e^-$	19.42	15
$Np(OH)_4(s) + 4H^+ = Np^{4+} + 4H_2O$	0.74	15
$NpO_2(OH)(s) + 5H^+ + e^- = Np^{4+} + 3H_2O$	15.81	15
$NpO_2(OH)_2(s) + 6H^+ + 2e^- = Np^{4+} + 4H_2O$	35.61	15

NEPTUNIUM (cont)

Reaction	Log K	Ref.
$NpO_2(s) + 4H^+ = Np^{4+} + 2H_2O$	-2.68	8
$NpCl^{3+} = Np^{4+} + Cl^-$	0.04	15
$NpCl_2^{2+} = Np^{4+} + 2Cl^-$	0.24	15
$NpO_2Cl^o + 4H^+ + e^- = Np^{4+} + Cl^- + 2H_2O$	11.21	15
$NpO_2Cl^- + 4H^+ + e^- = Np^{4+} + Cl^- + 2H_2O$	30.68	15
$NpF^{3+} = Np^{4+} + F^-$	-4.82	15
$NpO_2F^+ + 4H^+ + 2e^- = Np^{4+} + F^- + 2H_2O$	26.47	15
$NpO_2F_2^o + 4H^+ + 2e^- = Np^{4+} + 2F^- + 2H_2O$	23.36	15
$NpNO_3^{3+} = Np^{4+} + NO_3^-$	-0.38	15
$Np(NO_3)_2^{2+} = Np^{4+} + 2NO_3^-$	-0.08	15
$NpO_2NO_3^o + 4H^+ + e^- = Np^{4+} + NO_3^- + 2H_2O$	11.16	15
$NpO_2NO_3^+ + 4H^+ + 2e^- = Np^{4+} + NO_3^- + 2H_2O$	31.31	15
$NpSO_4^{2+} = Np^{4+} + SO_4^{2-}$	-2.43	15
$Np(SO_4)_2^o = Np^{4+} + 2SO_4^{2-}$	-3.47	15
$NpO_2SO_4^o + 4H^+ + 2e^- = Np^{4+} + SO_4^{2-} + 2H_2O$	28.43	15
$NpO_2(SO_4)_2^{2-} + 4H^+ + 2e^- = Np^{4+} + 2SO_4^{2-} + 2H_2O$	27.56	15
$NpO_2HPO_4^- + 3H^+ + e^- = Np^{4+} + PO_4^{3-} + 2H_2O$	-4.78	15
$NpO_2HCO_3^o + 3H^+ + e^- = Np^{4+} + CO_3^{2-} + 2H_2O$	-1.85	15

OXYGEN

$OH^- + H^+ = H_2O(\ell)$	13.99	

LEAD

$Pb(s) = Pb^{2+} + 2e^-$	4.28	
$PbS(galena) + 4H_2O = Pb^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-48.40	
$Pb(HS)_2^o + 8H_2O = Pb^{2+} + 2SO_4^{2-} + 18H^+ + 16e^-$	-82.49	3
$Pb(HS)_3^- + 12H_2O = Pb^{2+} + 3SO_4^{2-} + 27H^+ + 24e^-$	-117.40	3
$PbSO_4(anglesite) = Pb^{2+} + SO_4^{2-}$	-7.74	
$PbSO_4^o = Pb^{2+} + SO_4^{2-}$	-2.75	3
$Pb(SO_4)_2^{2-} = Pb^{2+} + 2SO_4^{2-}$	-3.47	3

LEAD (cont)

Reaction	Log K	Ref.
$PbSO_4 \cdot PbO(s) + 2H^+ = 2Pb^{2+} + SO_4^{2-} + H_2O$	-0.28	
$PbSO_4 \cdot 2PbO(s) + 4H^+ = 3Pb^{2+} + SO_4^{2-} + 2H_2O$	10.87	
$PbSO_4 \cdot 3PbO(s) + 6H^+ = 4Pb^{2+} + SO_4^{2-} + 3H_2O$	22.09	
$Pb_4(OH)_6SO_4(s) + 6H^+ = 4Pb^{2+} + SO_4^{2-} + 6H_2O$	21.10	3
$PbHPO_4^{\circ} = Pb^{2+} + H^+ + PO_4^{3-}$	-15.41	18
$PbHPO_4(s) = Pb^{2+} + H^+ + PO_4^{3-}$	-27.77	3
$PbH_2PO_4^+ = Pb^{2+} + 2H^+ + PO_4^{3-}$	-21.02	18
$Pb_3(PO_4)_2(s) = 3Pb^{2+} + 2PO_4^{3-}$	-44.29	3
$Pb_5(PO_4)_3Cl$(Cl-pyromorphite) $= 5Pb^{2+} + 3PO_4^{3-} + Cl^-$	-84.43	3
$Pb_5(PO_4)_3OH$(hydrous pyromorphite) $+ H^+ = 5Pb^{2+} + 3PO_4^{3-} + H_2O$	-62.79	3
$PbAl_3(PO_4)_2(OH)_5 \cdot H_2O$(plumbogummite) $+ 5H^+ = Pb^{2+} + 3Al^{3+} + 2PO_4^{3-} + 6H_2O$	-32.79	3
$PbAl_3PO_4SO_4(OH)_6$(hinsdalite) $+ 6H^+ = Pb^{2+} + 3Al^{3+} + PO_4^{3-} + SO_4^{2-} + 6H_2O$	-2.5	3
$Pb_2CuPO_4(OH)_3 \cdot 3H_2O$(tsumebite) $+ 3H^+ = 2Pb^{2+} + Cu^{2+} + PO_4^{3-} + 6H_2O$	-9.79	3
$PbMoO_4$(wulfenite) $= Pb^{2+} + MoO_4^{2-}$	-15.94	
$PbCO_3$(cerrusite) $= Pb^{2+} + CO_3^{2-}$	-13.47	
$PbCO_3^{\circ} = Pb^{2+} + CO_3^{2-}$	-7.24	3
$Pb(CO_3)_2^{2-} = Pb^{2+} + 2CO_3^{2-}$	-10.64	3
$PbHCO_3^+ = Pb^{2+} + H^+ + CO_3^{2-}$	-13.23	3
$PbCl_2 \cdot PbCO_3$(phosgenite) $= 2Pb^{2+} + 2Cl^- + CO_3^{2-}$	-19.81	
$PbO \cdot PbCO_3(s) + 2H^+ = 2Pb^{2+} + CO_3^{2-} + H_2O$	-0.50	
$2PbO \cdot PbCO_3(s) + 4H^+ = 3Pb^{2+} + CO_3^{2-} + 2H_2O$	11.02	3
$2PbCO_3 \cdot Pb(OH)_2$(hydrocerrusite) $+ 2H^+ = 3Pb^{2+} + 2CO_3^{2-} + 2H_2O$	-17.46	3
$PbNO_3^+ = Pb^{2+} + NO_3^-$	-1.04	
$PbCl^+ = Pb^{2+} + Cl^-$	-1.602	
$PbCl_2$(cotunnite) $= Pb^{2+} + 2Cl^-$	-4.75	
$PbCl_2^{\circ} = Pb^{2+} + 2Cl^-$	-1.80	3
$PbCl_3^- = Pb^{2+} + 3Cl^-$	-1.43	
$PbCl_4^{2-} = Pb^{2+} + 4Cl^-$	-1.38	3
PbClF(matlockite) $= Pb^{2+} + Cl^- + F^-$	-9.43	3
$Pb_2(OH)_3Cl(s) + 3H^+ = 2Pb^{2+} + 3H_2O + Cl^-$	8.79	3
PbOHCl(laurionite) $+ H^+ = Pb^{2+} + Cl^- + H_2O$	0.62	
$2PbCl_2 \cdot NH_4Cl(s) = 2Pb^{2+} + 5Cl^- + NH_4^+$	-10.24	
$PbF^+ = Pb^{2+} + F^-$	-1.25	3
$PbF_2(s) = Pb^{2+} + 2F^-$	-7.44	3

LEAD (cont)

Reaction	Log K	Ref.
$PbF_2^o = Pb^{2+} + 2F^-$	-3.42	3
$PbF_4^{2-} = Pb^{2+} + 4F^-$	-3.10	3
$PbBr^+ = Pb^{2+} + Br^-$	-1.77	3
$PbBr_2^o = Pb^{2+} + 2Br^-$	-1.44	3
$PbBr_2(s) = Pb^{2+} + 2Br^-$	-5.18	
$PbBr_3^- = Pb^{2+} + 3Br^-$	-3.0	18
$PbBr_4^{2-} = Pb^{2+} + 4Br^-$	-2.3	18
$PbBrF(s) = Pb^{2+} + Br^- + F^-$	-8.49	3
$PbI^- = Pb^{2+} + I^-$	-1.94	3
$PbI_2(s) = Pb^{2+} + 2I^-$	-8.07	3
$PbI_2^o = Pb^{2+} + 2I^-$	-3.2	3
$PbI_3^- = Pb^{2+} + 3I^-$	-3.26	
$PbI_4^{2-} = Pb^{2+} + 4I^-$	-3.99	
$PbSe(clausthalite) + 3H_2O = Pb^{2+} + SeO_3^{2-} + 6H^+ + 6e^-$	-73.37	
$PbSeO_4(s) + 2H^+ + 2e^- = Pb^{2+} + SeO_3^{2-} + H_2O$	22.15	
$PbTe(s) = Pb^{2+} + Te^{2-}$	(-46.3)	18
$PbSiO_3(s) + 2H^+ = Pb^{2+} + SiO_2^o + H_2O$	5.75	
$Pb_2SiO_4(s) + 4H^+ = 2Pb^{2+} + SiO_2^o + 2H_2O$	18.19	
$Pb(MnO_4)_2 \cdot 3PbO(s) + 6H^+ + 2e^- = 4Pb^{2+} + 2MnO_4^{2-} + 3H_2O$	146.63	
$PbO(litharge, red) + 2H^+ = Pb^{2+} + H_2O$	12.67	
$PbO(massicot, yellow) + 2H^+ = Pb^{2+} + H_2O$	12.78	
$PbO_2(plattnerite) + 4H^+ + 2e^- = Pb^{2+} + 2H_2O$	-49.65	
$Pb_2O_3(s) + 6H^+ + 2e^- = 2Pb^{2+} + 3H_2O$	61.04	3
$Pb_3O_4(minium) + 8H^+ + 2e^- = 3Pb^{2+} + 4H_2O$	73.66	
$PbOH^+ + H^+ = Pb^{2+} + H_2O$	7.71	3
$Pb(OH)_2(s) + 2H^+ = Pb^{2+} + 2H_2O$	8.13	
$Pb(OH)_2^o + 2H^+ = Pb^{2+} + 2H_2O$	17.12	3
$Pb(OH)_3^- + 3H^+ = Pb^{2+} + 3H_2O$	28.05	
$Pb(OH)_4^{2-} + 4H^+ = Pb^{2+} + 4H_2O$	39.7	3
$Pb_2OH^{3+} + H^+ = 2Pb^{2+} + H_2O$	6.36	3
$Pb_3(OH)_4^{2+} + 4H^+ = 3Pb^{2+} + 4H_2O$	23.32	
$Pb_4(OH)_4^{4+} + 4H^+ = 4Pb^{2+} + 4H_2O$	19.23	
$Pb_6(OH)_8^{4+} + 8H^+ = 6Pb^{2+} + 8H_2O$	42.60	
$HPbO_2^- + 3H^+ = Pb^{2+} + 2H_2O$	28.07	

LEAD (cont)

Reaction	Log K	Ref.
$PbO \cdot 1/3\ H_2O(s) + 2H^+ = Pb^{2+} + 4/3\ H_2O$	12.97	
$PbO \cdot Pb(OH)_2(s) + 4H^+ = 2Pb^{2+} + 3H_2O$	26.20	3

PALLADIUM

$Pd(s) = Pd^{2+} + 2e^-$	-30.94	
$PdS(s) + 4H_2O = Pd^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-78.40	
$PdS_2(s) + 8H_2O = Pd^{2+} + 2SO_4^{2-} + 16H^+ + 14e^-$	-115.46	
$Pd_4S(s) + 4H_2O = 4Pd^{2+} + SO_4^{2-} + 8H^+$	-171.22	
$PdCl^+ = Pd^{2+} + Cl^-$	-6.10	18
$PdCl_2(s) = Pd^{2+} + 2Cl^-$	-6.86	
$PdCl_2^{\ o} = Pd^{2+} + 2Cl^-$	-10.70	18
$PdCl_3^- = Pd^{2+} + 3Cl^-$	-13.10	18
$PdCl_4^{2-} = Pd^{2+} + 4Cl^-$	-15.40	18
$PdBr_3^- = Pd^{2+} + 3Br^-$	-12.05	
$PdBr_4^{2-} = Pd^{2+} + 4Br^-$	-13.77	
$PdBr_6^{2-} + 2e^- = Pd^{2+} + 6Br^-$	19.67	
$PdI_2(s) = Pd^{2+} + 2I^-$	-23.74	
$PdI_4^{2-} = Pd^{2+} + 4I^-$	-22.41	
$PdI_6^{2-} + 2e^- = Pd^{2+} + 6I^-$	-6.20	
$PdOH^+ + H^+ = Pd^{2+} + H_2O$	0.99	18
$Pd(OH)_2^{\ o} + 2H^+ = Pd^{2+} + 2H_2O$	-11.81	18
$Pd(OH)_2(s) + 2H^+ = Pd^{2+} + 2H_2O$	-14.51	18

PROMETHIUM

$Pm(OH)_3(s) + 3H^+ = Pm^{3+} + 3H_2O$	7.97	15
$Pm_2O_3(s) + 6H^+ = 2Pm^{3+} + 3H_2O$	42.04	15
$PmH_2PO_4^{2+} = Pm^{3+} + 2H^+ + PO_4^{3-}$	-22.03	18

PRASEODYNIUM

Reaction	Log K	Ref.
$PrOH^{2+} + H^+ = Pr^{3+} + H_2O$	8.10	2
$Pr(OH)_3(s) + 3H^+ = Pr^{3+} + 3H_2O$	20.47	18
$PrSO_4^+ = Pr^{3+} + SO_4^{2-}$	-3.62	18

PLUTONIUM

$Pu(s) = Pu^{4+} + 4e^-$	84.38	
$Pu^{3+} = Pu^{4+} + e^-$	-17.01	
$PuSO_4^+ = Pu^{4+} + SO_4^{2-} + e^-$	-20.48	
$PuSO_4^{2+} = Pu^{4+} + SO_4^{2-}$	-5.74	
$Pu(SO_4)_2^o = Pu^{4+} + 2SO_4^{2-}$	-10.16	
$PuO_2SO_4^o + 4H^+ + 2e^- = Pu^{4+} + SO_4^{2-} + 2H_2O$	31.62	
$Pu(HSO_4)_2^+ = Pu^{4+} + 2H^+ + 2SO_4^{2-} + e^-$	-22.00	4
$Pu(HPO_4)^{2+} = Pu^{4+} + H^+ + PO_4^{3-}$	-25.33	
$Pu(HPO_4)_2^o = Pu^{4+} + 2H^+ + 2PO_4^{3-}$	-48.46	
$Pu(HPO_4)_2(s) = Pu^{4+} + 2H^+ + 2PO_4^{3-}$	-52.62	12
$Pu(HPO_4)_3^{2-} = Pu^{4+} + 3H^+ + 3PO_4^{3-}$	-70.35	
$Pu(HPO_4)_4^{4-} = Pu^{4+} + 4H^+ + 4PO_4^{3-}$	-92.16	
$PuH_2PO_4^{2+} = Pu^{4+} + 2H^+ + PO_4^{3-} + e^-$	-38.97	
$PuO_2HPO_4(s) + 3H^+ + 2e^- = Pu^{4+} + PO_4^{3-} + 2H_2O$	9.97	
$PuO_2(HPO_4)_2(s) + 2H^+ + 4e^- = Pu^{4+} + 2PO_4^{3-} + 2H_2O$	30.83	
$PuO_2H_2PO_4^+ + 2H^+ + 2e^- = Pu^{4+} + PO_4^{3-} + 2H_2O$	11.37	
$PuNO_3^{3+} = Pu^{4+} + NO_3^-$	-0.72	8
$PuCO_3^{2+} = Pu^{4+} + CO_3^{2-}$	-40.71	
$PuO_2CO_3^o + 4H^+ + 2e^- = Pu^{4+} + CO_3^{2-} + 2H_2O$	22.86	17
$PuO_2(CO_3)_2^{2-} + 4H^+ + 2e^- = Pu^{4+} + 2CO_3^{2-} + 2H_2O$	19.94	
$PuO_2CO_3OH^- + 5H^+ + 2e^- = Pu^{4+} + CO_3^{2-} + 3H_2O$	25.03	4
$PuO_2CO_3(OH)_2^{2-} + 6H^+ + 2e^- = Pu^{4+} + CO_3^{2-} + 4H_2O$	39.84	4
$PuCl^{2+} = Pu^{4+} + Cl^- + e^-$	-8.51	4
$PuCl^{3+} = Pu^{4+} + Cl^-$	-1.12	
$PuO_2Cl^+ + 4H^+ + 2e^- = Pu^{4+} + Cl^- + 2H_2O$	35.07	
$PuO_2Cl^o + 4H^+ + e^- = Pu^{4+} + Cl^- + 2H_2O$	18.69	17
$PuO_2Cl_2^o + 4H^+ + 2e^- = Pu^{4+} + 2Cl^- + 2H_2O$	35.52	4

PLUTONIUM (cont)

Reaction	Log K	Ref.
$PuF^{3+} = Pu^{4+} + F^-$	-8.09	
$PuF_3(s) = Pu^{4+} + 3F^- + e^-$	-27.56	
$PuF_4(s) = Pu^{4+} + 4F^-$	-13.72	
$PuO_2F^+ + 4H^+ + 2e^- = Pu^{4+} + F^- + 2H_2O$	29.05	
$PuO_2F_2^o + 4H^+ + 2e^- = Pu^{4+} + 2F^- + 2H_2O$	23.68	
$PuO_2F_3^- + 4H^+ + 2e^- = Pu^{4+} + 3F^- + 2H_2O$	18.60	
$PuO_2F_4^{2-} + 4H^+ + 2e^- = Pu^{4+} + 4F^- + 2H_2O$	15.57	
$PuO_2(s) + 4H^+ = Pu^{4+} + 2H_2O$	-7.36	
$PuO_2^+ + 4H^+ + e^- = Pu^{4+} + 2H_2O$	18.52	
$PuO_2^{2+} + 4H^+ + 2e^- = Pu^{4+} + 2H_2O$	34.86	
$hex\text{-}Pu_2O_3(s) + 6H^+ = 2Pu^{4+} + 3H_2O + 2e^-$	14.10	
$PuOH^{3+} + H^+ = Pu^{4+} + H_2O$	1.0	12
$PuOH^{2+} + H^+ = Pu^{4+} + H_2O + e^-$	-9.03	
$Pu(OH)_2^{2+} + 2H^+ = Pu^{4+} + 2H_2O$	2.31	
$Pu(OH)_3^+ + 3H^+ = Pu^{4+} + 3H_2O$	5.23	
$Pu(OH)_3(s) + 3H^+ = Pu^{4+} + 3H_2O + e^-$	5.45	
$Pu(OH)_4^o + 4H^+ = Pu^{4+} + 4H_2O$	9.47	
$Pu(OH)_4(s) + 4H^+ = Pu^{4+} + 4H_2O$	0.74	
$Pu(OH)_4(amorphous) + 4H^+ = Pu^{4+} + 4H_2O$	5.72	26
$Pu(OH)_5^- + 5H^+ = Pu^{4+} + 5H_2O$	14.95	
$PuO_2(OH)(amorphous) + 5H^+ + e^- = Pu^{4+} + 3H_2O$	24.00	
$PuO_2(OH)^o + 5H^+ + e^- = Pu^{4+} + 3H_2O$	28.18	
$PuO_2(OH)^+ + 5H^+ + 2e^- = Pu^{4+} + 3H_2O$	40.49	
$PuO_2(OH)_2(s) + 6H^+ + 2e^- = Pu^{4+} + 4H_2O$	38.42	
$PuO_2(OH)_2^o + 6H^+ + 2e^- = Pu^{4+} + 4H_2O$	46.20	4
$PuO_2(OH)_3^- + 7H^+ + 2e^- = Pu^{4+} + 5H_2O$	55.07	4
$(PuO_2)_2(OH)_2^{2+} + 10H^+ + 4e^- = 2Pu^{4+} + 6H_2O$	77.98	
$(PuO_2)_3(OH)_5^+ + 17H^+ + 6e^- = 3Pu^{4+} + 11H_2O$	126.22	

RADIUM

Reaction	Log K	Ref.
$Ra(s) = Ra^{2+} + 2e^-$	98.39	
$RaSO_4(s) = Ra^{2+} + SO_4^{2-}$	-10.43	
$Ra(NO_3)_2(s) = Ra^{2+} + 2NO_3^-$	-2.05	
$RaCl_2 \cdot 2H_2O(s) = Ra^{2+} + 2Cl^- + 2H_2O$	-0.80	

RUBIDIUM

$Rb(s) = Rb^+ + e^-$	51.12	
$RbCl^o = Rb^+ + Cl^-$	0.55	18
$RbI^o = Rb^+ + I^-$	-0.04	18

RUTHENIUM

$Ru^{3+} = Ru^{4+} + e^-$	-11.35	15
$RuCl_3(s) = Ru^{4+} + 3Cl^- + e^-$	-6.39	15
RuO_2(amorphous, hydrated) $+ 4H^+ = Ru^{4+} + 2H_2O$	4.51	15
$Ru(OH)_3(s) + 3H^+ = Ru^{4+} + 3H_2O + e^-$	-3.55	15
$Ru(OH)_4(s) + 4H^+ = Ru^{4+} + 4H_2O$	12.30	15
$Ru(OH)_2^{2+} + 2H^+ = Ru^{4+} + 2H_2O$	4.73	15
$RuCl_5(OH)^{2-} + H^+ = Ru^{4+} + 5Cl^- + H_2O$	-8.13	15
$RuS_2(s) + 8H_2O = Ru^{4+} + 16H^+ + 2SO_4^{2-} + 16e^-$	-144.86	15
$RuO_4(s) + 8H^+ + 4e^- = Ru^{4+} + 4H_2O$	100.55	15
$RuO_4^- + 8H^+ + 3e^- = Ru^{4+} + 4H_2O$	82.20	15
$RuO_4^o + 8H^+ + 4e^- = Ru^{4+} + 4H_2O$	99.43	15
$RuO_4^{2-} + 8H^+ + 2e^- = Ru^{4+} + 4H_2O$	72.01	15

SULFUR

Reaction	Log K	Ref.
$S(s) + 4H_2O = SO_4^{2-} + 8H^+ + 6e^-$	-35.73	
$S^{2-} + 4H_2O = SO_4^{2-} + 8H^+ + 8e^-$	-20.70	
$HS^- + 4H_2O = SO_4^{2-} + 9H^+ + 8e^-$	-33.61	
$H_2S^o + 4H_2O = SO_4 + 10H^+ + 8e^-$	-40.62	23
$HSO_4^- = H^+ + SO_4^{2-}$	-1.99	

ANTIMONY

$Sb(s) + H_2O = SbO^+ + 2H^+ + 3e^-$	-10.51	
Sb_2S_3(stibnite) $+ 14H_2O = 2SbO^+ + 3SO_4^{2-} + 28H^+ + 24e^-$	-158.64	
$Sb_2S_4^{2-} + 18H_2O = 2SbO^+ + 4SO_4^{2-} + 36H^+ + 30e^-$	-181.42	
$SbCl_3(s) + H_2O = SbO^+ + 2H^+ + 3Cl^-$	1.763	
$SbBr_3(s) + H_2O = SbO^+ + 2H^+ + 3Br^-$	2.21	
$SbF_3(s) + H_2O = SbO^+ + 2H^+ + 3F^-$	-10.44	15
$SbOF^o = SbO^+ + F^-$	-5.51	15
$Sb(OH)_2F^o = SbO^+ + F^- + H_2O$	-5.15	
$SbO_2^- + 2H^+ = SbO^+ + H_2O$	12.97	
$HSbO_2^o + H^+ = SbO^+ + H_2O$	1.19	15
Sb_2O_3(orthorhombic valentinite) $+ 2H^+ = 2SbO^+ + H_2O$	-2.32	15
Sb_2O_3(s,cubic) $+ 2H^+ = 2SbO^+ + H_2O$	-3.05	15
Sb_2O_3(s,rhombic) $+ 2H^+ = 2SbO^+ + H_2O$	-6.20	18
$Sb_2O_4(s) + 4H^+ + 2e^- = 2SbO^+ + 2H_2O$	5.73	
$Sb_2O_5(s) + 6H^+ + 4e^- = 2SbO^+ + 3H_2O$	41.42	
Sb_4O_6(s,cubic) $+ 4H^+ = 4SbO^+ + 2H_2O$	-14.97	
Sb_4O_6(s,orthorhombic) $+ 4H^+ = 4SbO^+ + 2H_2O$	-12.33	
$Sb(OH)_2^+ = SbO^+ + H_2O$	-0.20	15
$Sb(OH)_3^o + H^+ = SbO^+ + 2H_2O$	1.18	15
$Sb(OH)_3(s) + H^+ = SbO^+ + 2H_2O$	-5.95	
$Sb(OH)_4^- + 2H^+ = SbO^+ + 3H_2O$	12.97	18
$Sb_2Te_3(s) + 2H_2O = 2SbO^+ + 3Te^{2-} + 4H^+$	-142.13	

SELENIUM

Reaction	Log K	Ref.
$Se(s) + 3H_2O = SeO_3^{2-} + 6H^+ + 4e^-$	-59.85	
$Se^{2-} + 3H_2O = SeO_3^{2-} + 6H^+ + 6e^-$	-37.25	
$HSe^- + 3H_2O = SeO_3^{2-} + 7H^+ + 6e^-$	-52.15	
$H_2Se(s) + 3H_2O = SeO_3^{2-} + 8H^+ + 6e^-$	-55.96	
$HSeO_3^- = H^+ + SeO_3^{2-}$	-7.30	
$HSeO_4^- + H^+ = SeO_3^{2-} + H_2O + 2e^-$	27.11	
$SeO_4^{2-} + 2H^+ + 2e^- = SeO_3^{2-} + H_2O$	29.02	
$H_2SeO_3^o = SeO_3^{2-} + 2H^+$	-11.25	2

SILICON

$SiF_6^{2-} + 2H_2O = SiO_2^o + 4H^+ + 6F^-$	-27.01
SiO_2(α and β quartz) $= SiO_2^o$	-4.00
SiO_2(cristobalite) $= SiO_2^o$	-4.18
SiO_2(tridymite) $= SiO_2^o$	-3.58
SiO_2(coesite) $= SiO_2^o$	-3.19
SiO_2(stishovite) $= SiO_2^o$	5.36
SiO_2(glass) $= SiO_2^o$	-3.00
SiO_2(chalcedony) $= SiO_2^o$	-3.73
SiO_2(amorphous) $= SiO_2^o$	-2.71
$H_2SiO_3(s) = SiO_2^o + H_2O$	-3.84
$H_2SiO_3^o = SiO_2^o + H_2O$	-1.56
$H_2SiO_4^{2-} + 2H^+ + 2e^- = SiO_2^o + 2H_2O$	22.90
$H_3SiO_4^- + H^+ + e^- = SiO_2^o + 2H_2O$	9.80
$H_4SiO_4^o = SiO_2^o + 2H_2O$	-1.58
$H_4SiO_4(s) = SiO_2^o + 2H_2O$	-4.44
$H_2Si_2O_5(s) = 2SiO_2^o + H_2O$	-6.92
$H_6Si_2O_7(s) = 2SiO_2 + 3H_2O$	-8.35
$HSi(OH)_6^- + H^+ = SiO_2^o + 4H_2O$	8.29
$H_2Si(OH)_6^o = SiO_2^o + 4H_2O$	-1.61

SAMARIUM

Reaction	Log K	Ref.
$SmOH^{2+} + H^+ = Sm^{3+} + H_2O$	7.90	2
$Sm(OH)_3(s) + 3H^+ = Sm^{3+} + 3H_2O$	16.50	2
$Sm_2(CO_3)_3(s) = 2Sm^{3+} + 3CO_3^{2-}$	-32.50	18
$SmSO_4^+ = Sm^{3+} + SO_4^{2-}$	-3.67	18
$Sm(SO_4)_2^- = Sm^{3+} + 2SO_4^{2-}$	-5.20	18

TIN

$Sn(s) = Sn^{2+} + 2e^-$	5.23	
$Sn(s, II\ grey) = Sn^{2+} + 2e^-$	5.25	
$SnS(herzenbergite) + 4H_2O = Sn^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-48.85	
$SnSO_4^{2+} + 2e^- = Sn^{2+} + SO_4^{2-}$	8.80	
$SnCl^+ = Sn^{2+} + Cl^-$	-1.51	18
$SnCl_2^o = Sn^{2+} + 2Cl^-$	-2.25	18
$SnCl_3^- = Sn^{2+} + 3Cl^-$	-2.0	18
$SnCl_4^{2-} = Sn^{2+} + 4Cl^-$	-1.5	18
$SnOHCl \cdot H_2O(s) + H^+ = Sn^{2+} + Cl^- + 2H_2O$	-2.30	
$SnBr^+ = Sn^{2+} + Br^-$	-1.16	18
$SnBr_2^o = Sn^{2+} + 2Br^-$	-1.70	18
$SnF^+ = Sn^{2+} + F^-$	-4.25	
$SnO(s) + 2H^+ = Sn^{2+} + H_2O$	1.78	18
$SnO_2(cassiterite) + 4H^+ + 2e^- = Sn^{2+} + 2H_2O$	-2.76	
$SnOH^+ + H^+ = Sn^{2+} + H_2O$	3.40	2
$Sn(OH)_2^o + 2H^+ = Sn^{2+} + 2H_2O$	7.06	2
$Sn(OH)_2(s,precipitated) + 2H^+ = Sn^{2+} + 2H_2O$	2.19	
$Sn(OH)_3^- + 3H^+ = Sn^{2+} + 3H_2O$	16.61	2
$Sn_2(OH)_2^{2+} + 2H^+ = 2Sn^{2+} + 2H_2O$	4.77	2
$Sn_3(OH)_4^{2+} + 4H^+ = 3Sn^{2+} + 4H_2O$	6.88	2
$SnO(OH)^+ + 3H^+ + 2e^- = Sn^{2+} + 2H_2O$	5.27	
$SnTe(s) = Sn^{2+} + Te^{2-}$	(-44.7)	18

STRONTIUM

Reaction	Log K	Ref.
$Sr(s) = Sr^{2+} + 2e^-$	98.03	
$SrS(s) + 4H_2O = Sr^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-16.30	
$SrSO_4(celestite) = Sr^{2+} + SO_4^{2-}$	-6.42	
$SrSO_4^o = Sr^{2+} + SO_4^{2-}$	-2.55	18
$SrPO_4^- = Sr^{2+} + PO_4^{3-}$	-4.18	15
$Sr_3(PO_4)_2(s) = 3Sr^{2+} + 2PO_4^{3-}$	-27.8	15
$SrHPO_4(s) = Sr^{2+} + H^+ + PO_4^{3-}$	-19.31	
$SrMoO_4(s) = Sr^{2+} + MoO_4^{2-}$	-8.46	
$SrCO_3(strontianite) = Sr^{2+} + CO_3^{2-}$	-9.25	3
$SrNO_3^+ = Sr^{2+} + NO_3^-$	-0.82	15
$Sr(NO_3)_2(s) = Sr^{2+} + 2NO_3^-$	0.59	
$Sr(NO_3)_2^o = Sr^{2+} + 2NO_3^-$	-0.8	18
$Sr(NO_3)_2 \cdot 4H_2O(s) = Sr^{2+} + 2NO_3^- + 4H_2O$	0.05	
$SrF_2(s) = Sr^{2+} + 2F^-$	-8.54	3
$SrF_2^o = Sr^{2+} + 2F^-$	-2.02	15
$SrBr_2(s) = Sr^{2+} + 2Br^-$	12.53	
$SrBr_2 \cdot H_2O(s) = Sr^{2+} + 2Br^- + H_2O$	8.79	
$SrBr_2 \cdot 6H_2O(s) = Sr^{2+} + 2Br^- + 6H_2O$	2.78	
$SrCl_2(s,\alpha) = Sr^{2+} + 2Cl^-$	7.15	
$SrCl_2^o = Sr^{2+} + 2Cl^-$	0.00	15
$SrCl_2 \cdot H_2O(s) = Sr^{2+} + 2Cl^- + H_2O$	3.98	
$SrCl_2 \cdot 2H_2O(s) = Sr^{2+} + 2Cl^- + 2H_2O$	2.50	
$SrCl_2 \cdot 6H_2O(s) = Sr^{2+} + 2Cl^- + 6H_2O$	0.63	
$SrO(s) + 2H^+ = Sr^{2+} + H_2O$	41.39	
$SrOH^+ + H^+ = Sr^{2+} + H_2O$	13.19	
$Sr(OH)_2^o + 2H^+ = Sr^{2+} + 2H_2O$	28.51	15
$SrSiO_3(s) + 2H^+ = Sr^{2+} + SiO_2^o + H_2O$	14.06	
$SrSiO_4(s) + 4H^+ + 2e^- = Sr^{2+} + SiO_2^o + 2H_2O$	-56.78	
$SrZrO_3(s) + 6H^+ = Sr^{2+} + Zr^{4+} + 3H_2O$	29.28	
$SrTiO_3(s) + 6H^+ + 2e^- = Sr^{2+} + Ti^{3+} + 3H_2O$	-1.44	
$SrTiO_4(s) + 8H^+ + 3e^- = Sr^{2+} + Ti^{3+} + 4H_2O$	-63.31	

TECHNITIUM

Reaction	Log K	Ref.
$TcO(OH)^+ + H^+ = TcO^{2+} + H_2O$	1.39	18(20°,0.1)
$TcO(OH)_2^o + 2H^+ = TcO^{2+} + 2H_2O$	3.78	18(20°,0.1)

TELLURIUM

$Te(s) + 2e^- = Te^{2-}$	-37.14
$TeO_2(tellurite) + 4H^+ + 6e^- = Te^{2-} + 2H_2O$	-1.41
$Te(OH)_3^+ + 3H^+ + 6e^- = Te^{2-} + 3H_2O$	0.57
$TeSe(s) + 4e^- = Te^{2-} + Se^{2-}$	-40.68

THORIUM

$Th(s,\alpha) = Th^{4+} + 4e^-$	123.46
$Th^{3+} = Th^{4+} + e^-$	59.17
$ThSO_4^{2+} = Th^{4+} + SO_4^{2-}$	-5.45
$Th(SO_4)_2^o = Th^{4+} + 2SO_4^{2-}$	-9.72
$Th(SO_4)_3^{2-} = Th^{4+} + 3SO_4^{2-}$	-10.47
$Th(SO_4)_4^{4-} = Th^{4+} + 4SO_4^{2-}$	-8.44
$ThH_2PO_4^{3+} = Th^{4+} + 2H^+ + PO_4^{3-}$	-24.16
$Th(H_2PO_4)_2^{2+} = Th^{4+} + 4H^+ + 2PO_4^{3-}$	-47.95
$ThF^{3+} = Th^{4+} + F^-$	-8.16
$ThF_2^{2+} = Th^{4+} + 2F^-$	-14.50
$ThF_3^+ = Th^{4+} + 3F^-$	-19.27
$ThF_4^o = Th^{4+} + 4F^-$	-22.81
$ThF_4(s) = Th^{4+} + 4F^-$	-30.66
$ThF_4 \cdot 2.5\ H_2O(s) = Th^{4+} + 4F^- + 2.5\ H_2O$	(-33.67)
$ThCl^{3+} = Th^{4+} + Cl^-$	-1.12
$ThCl_2^{2+} = Th^{4+} + 2Cl^-$	-0.84
$ThCl_3^+ = Th^{4+} + 3Cl^-$	-1.67
$ThCl_4^o = Th^{4+} + 4Cl^-$	-1.25
$ThCl_4(s) = Th^{4+} + 4Cl^-$	23.68
$ThO_2(s) + 4H^+ = Th^{4+} + 2H_2O$	6.27
$ThO_2(thorianite) + 4H^+ = Th^{4+} + 2H_2O$	1.76
$ThOH^{3+} + H^+ = Th^{4+} + H_2O$	3.21

THORIUM (cont)

Reaction	Log K	Ref.
$Th(OH)_2^{2+} + 2H^+ = Th^{4+} + 2H_2O$	6.93	
$Th(OH)_3^{+} + 3H^+ = Th^{4+} + 3H_2O$	(11.68)	
$Th(OH)_4^{o} + 4H^+ = Th^{4+} + 4H_2O$	15.84	
$Th(OH)_4(s) + 4H^+ = Th^{4+} + 4H_2O$	-9.45	10
$Th(OH)_6^{2-} + 6H^+ = Th^{4+} + 6H_2O$	49.62	15
$Th_2(OH)_2^{6+} + 2H^+ = 2Th^{4+} + 2H_2O$	6.13	
$Th_4(OH)_8^{8+} + 8H^+ = 4Th^{4+} + 8H_2O$	21.06	
$Th_6(OH)_{15}^{9+} + 15H^+ = 6Th^{4+} + 15H_2O$	36.64	

TITANIUM

$Ti(s) = Ti^{3+} + 3e^-$	54.20	17
$TiBr_3(s) = Ti^{3+} + 3Br^-$	8.86	
$TiBr_4(s) + e^- = Ti^{3+} + 4Br^-$	23.79	
$TiCl_3(s) = Ti^{3+} + 2Cl^- + e^-$	18.82	
$TiCl_3(s) = Ti^{3+} + 3Cl^-$	8.52	
$TiI_4(s) + e^- = Ti^{3+} + 4I^-$	25.48	
$TiH_2(s) = Ti^{3+} + 2H^+ + 5e^-$	40.12	
$TiO(s) + 2H^+ = Ti^{3+} + H_2O + e^-$	5.81	
$TiO_2(rutile) + 4H^+ + e^- = Ti^{3+} + 2H_2O$	-18.55	
$TiO_2(anatase) + 4H^+ + e^- = Ti^{3+} + 2H_2O$	-17.47	
$Ti_2O_3(s) + 6H^+ = 2Ti^{3+} + 3H_2O$	-18 20	
$Ti_3O_5(s,\alpha) + 10H^+ + e^- = 3Ti^{3+} + 5H_2O$	-35.70	
$Ti_4O_7(s) + 14H^+ + 2e^- = 4Ti^{3+} + 7H_2O$	-55.35	
$TiOH^{2+} + H^+ = Ti^{3+} + H_2O$	1.29	18
$Ti_2(OH)_2^{4+} + 2H^+ = 2Ti^{3+} + 2H_2O$	3.6	2

URANIUM

$U(s) = U^{4+} + 4e^-$	93.04
$U^{3+} = U^{4+} + e^-$	8.80
$USO_4^{2+} = U^{4+} + SO_4^{2-}$	-5.52
$U(SO_4)_2^{o} = U^{4+} + 2SO_4^{2-}$	-9.79
$UO_2SO_4^{o} + 4H^+ + 2e^- = U^{4+} + SO_4^{2-} + 2H_2O$	6.25

URANIUM (cont)

Reaction	Log K	Ref.
$UO_2CO_3(s) + 4H^+ + 2e^- = U^{4+} + CO_3^{2-} + 2H_2O$	-4.89	
$UO_2CO_3^o + 4H^+ + 2e^- = U^{4+} + CO_3^{2-} + 2H_2O$	-0.86	
$UO_2(CO_3)_2^{2-} + 4H^+ + 2e^- = U^{4+} + 2CO_3^{2-} + 2H_2O$	-7.85	
$UO_2(CO_3)_3^{4-} + 4H^+ + 2e^- = U^{4+} + 3CO_3^{2-} + 2H_2O$	-12.27	
$(UO_2)_3(PO_4)_2(s) + 12H^+ + 6e^- = 3U^{4+} + 2PO_4^{3-} + 6H_2O$	-21.36	
$(UO_2)_2(HPO_4)_2(s) + 6H^+ + 4e^- = 2U^{4+} + 2PO_4^{3-} + 4H_2O$	-29.62	
$U(HPO_4)_2 \cdot 4H_2O(s) = U^{4+} + 2PO_4^{3-} + 2H^+ + 4H_2O$	-51.40	
$UO_2HPO_4^o + 3H^+ + 2e^- = U^{4+} + PO_4^{3-} + 2H_2O$	-11.51	
$UO_2(HPO_4)_2^{2-} + 2H^+ + 2e^- = U^{4+} + 2PO_4^{3-} + 2H_2O$	-33.98	
$UO_2(H_2PO_4)^+ + 2H^+ + 2e^- = U^{4+} + PO_4^{3-} + 2H_2O$	-13.27	
$UO_2(H_2PO_4)_2^o + 2e^- = U^{4+} + 2PO_4^{3-} + 2H_2O$	-35.37	
$UO_2(H_2PO_4)_3^- + 2e^- = U^{4+} + 3PO_4^{3-} + 2H^+ + 2H_2O$	-56.53	
$UHPO_4^{2+} = U^{4+} + H^+ + PO_4^{3-}$	-24.38	
$U(HPO_4)_2^o = U^{4+} + 2H^+ + 2PO_4^{3-}$	-46.63	
$U(HPO_4)_3^{2-} = U^{4+} + 3H^+ + 3PO_4^{3-}$	-67.64	
$U(HPO_4)_4^{4-} = U^{4+} + 4H^+ + 4PO_4^{3-}$	-87.91	
$UCl^{3+} = U^{4+} + Cl^-$	-2.73	
$UO_2Cl^+ + 4H^+ + 2e^- = U^{4+} + Cl^- + 2H_2O$	7.43	
$UF^{3+} = U^{4+} + F^-$	-8.77	
$UF_2^{2+} = U^{4+} + 2F^-$	-14.71	
$UF_3^+ = U^{4+} + 3F^-$	-19.42	
$UF_4^o = U^{4+} + 4F^-$	-24.13	
$UF_4(s) = U^{4+} + 4F^-$	-23.99	
$UF_5^- = U^{4+} + 5F^-$	-25.92	
$UF_6^{2-} = U^{4+} + 6F^-$	-28.39	
$UF_4 \cdot 2.5\ H_2O(s) = U^{4+} + 4F^- + 2.5\ H_2O$	-28.10	
$UO_2F^+ + 4H^+ + 2e^- = U^{4+} + F^- + 2H_2O$	3.91	
$UO_2F_2^o + 4H^+ + 2e^- = U^{4+} + 2F^- + 2H_2O$	0.20	12
$UO_2F_3^- + 4H^+ + 2e^- = U^{4+} + 3F^- + 2H_2O$	-2.59	
$UO_2F_4^{2-} + 4H^+ + 2e^- = U^{4+} + 4F^- + 2H_2O$	-3.78	
$UO_2(s) + 4H^+ = U^{4+} + 2H_2O$	-4.66	
$UO_2^+ + 4H^+ + e^- = U^{4+} + 2H_2O$	6.42	
$UO_2^{2+} + 4H^+ + 2e^- = U^{4+} + 2H_2O$	9.20	
$UO_3(s,\gamma) + 6H^+ + 2e^- = U^{4+} + 3H_2O$	16.89	

URANIUM (cont)

Reaction	Log K	Ref.
$UO_3 \cdot 2H_2O(s) + 6H^+ + 2e^- = U^{4+} + 5H_2O$	14.80	
$U_3O_8(s,\alpha) + 16H^+ + 4e^- = 3U^{4+} + 8H_2O$	21.06	
$U_4O_9(s) + 18H^+ + 2e^- = 4U^{4+} + 9H_2O$	-3.15	
$U(OH)^{3+} + H^+ = U^{4+} + H_2O$	0.42	
$U(OH)_2^{2+} + 2H^+ = U^{4+} + 2H_2O$	2.39	
$U(OH)_3^+ + 3H^+ = U^{4+} + 3H_2O$	5.08	
$U(OH)_4^o + 4H^+ = U^{4+} + 4H_2O$	8.51	
$U(OH)_5^- + 5H^+ = U^{4+} + 5H_2O$	13.41	
$UO_2(OH)^+ + 5H^+ + 2e^- = U^{4+} + 3H_2O$	14.98	
$UO_2(OH)_2^o + 6H^+ + 2e^- = U^{4+} + 4H_2O$	21.12	
$UO_2(OH)_2(s,\beta) + 6H^+ + 2e^- = U^{4+} + 4H_2O$	14.96	
$(UO_2)_2(OH)_2^{2+} + 10H^+ + 4e^- = 2U^{4+} + 6H_2O$	23.95	
$(UO_2)_3(OH)_5^+ + 17H^+ + 6e^- = 3U^{4+} + 11H_2O$	43.15	
$(UO_2)_3(OH)_7^- + 19H^+ + 6e^- = 3U^{4+} + 13H_2O$	58.30	
$USiO_4$(coffinite) $+ 4H^+ = U^{4+} + SiO_2^o + 2H_2O$	(-9.20)	
$UO_2SiO(OH)_3^+ + 5H^+ + 2e^- = U^{4+} + SiO_2^o + 4H_2O$	(11.58)	

VANADIUM

$V(s) + 4H_2O = VO_4^{3-} + 8H^+ + 5e^-$	-8.66	
$V^{3+} + 4H_2O = VO_4^{3-} + 8H^+ + 2e^-$	-51.04	
$VOSO_4(s) + 3H_2O = VO_4^{3-} + SO_4^{2-} + 6H^+ + e^-$	-43.82	
$VOSO_4^o + 3H_2O = VO_4^{3-} + SO_4^{2-} + 6H^+ + e^-$	-47.77	18
$(VO)_3(PO_4)_2(s) + 9H_2O = 3VO_4^{3-} + 2PO_4^{3-} + 18H^+ + 3e^-$	-161.10	18
$VCl_2(s) + 4H_2O = VO_4^{3-} + 2Cl^- + 8H^+ + 3e^-$	-33.74	
$VCl_3(s) + 4H_2O = VO_4^{3-} + 3Cl^- + 8H^+ + 2e^-$	-29.26	
$VO(s) + 3H_2O = VO_4^{3-} + 6H^+ + 3e^-$	-37.94	
$VO^{2+} + 3H_2O = VO_4^{3-} + 6H^+ + e^-$	-45.33	
$VO_2^+ + 2H_2O = VO_4^{3-} + 4H^+$	-28.41	
$VO_3^- + H_2O = VO_4^{3-} + 2H^+$	-21.32	
V_2O_3(karelianite) $+ 5H_2O = 2VO_4^{3-} + 10H^+ + 4e^-$	-92.25	
$V_2O_4(s) + 4H_2O = 2VO_4^{3-} + 8H^+ + 2e^-$	-82.13	
$V_2O_5(s) + 3H_2O = 2VO_4^{3-} + 6H^+$	-58.28	
$V_2O_7^{4-} + H_2O = 2VO_4^{3-} + 2H^+$	-27.77	

VANADIUM

Reaction	Log K	Ref.
$V_3O_5(s) + 7H_2O = 3VO_4^{3-} + 14H^+ + 5e^-$	-136.40	
$V_3O_9^{3-} + 3H_2O = 6H^+ + 3VO_4^{3-}$	-71.61	18
$V_4O_7(s) + 9H_2O = 4VO_4^{3-} + 18H^+ + 6e^-$	-177.05	
$V_4O_{12}^{4-} + 4H_2O = 8H^+ + 4VO_4^{3-}$	-95.34	2
$V_{10}O_{27}^{4-} + 13H_2O = 10VO_4^{3-} + 26H^+$	-346.08	18(20°,0.1)
$V_{10}O_{28}^{6-} + 12H_2O = 10VO_4^{3-} + 24H^+$	-334.80	18(20°,0.1)
$HVO_4^{2-} = H^+ + VO_4^{3-}$	-13.27	
$H_2VO_4^- = 2H^+ + VO_4^{3-}$	-21.33	
$H_3VO_4^o = 3H^+ + VO_4^{3-}$	-25.33	18
$H_4VO_4^+ = 4H^+ + VO_4^{3-}$	-28.42	
$HV_2O_7^{3-} + H_2O = 3H^+ + 2VO_4^{3-}$	-40.53	
$H_3V_2O_7^- + H_2O = 5H^+ + 2VO_4^{3-}$	-53.06	
$HV_{10}O_{28}^{5-} + 12H_2O = 25H^+ + 10VO_4^{3-}$	-341.74	
$H_2V_{10}O_{28}^{4-} + 12H_2O = 26H^+ + 10VO_4^{3-}$	-345.41	
$VOH^{2+} + 3H_2O = VO_4^{3-} + 7H^+ + 2e^-$	-48.79	
$V(OH)_2^+ + 2H_2O = VO_4^{3-} + 6H^+ + 2e^-$	(-45.20)	
$V(OH)_3^o + H_2O + VO_4^{3-} + 5H^+ + 2e^-$	(-40.09)	
$V(OH)_3(s) + H_2O = VO_4^{3-} + 5H^+ + 2e^-$	-43.46	18
$V_2(OH)_2^{4+} + 6H_2O = 2VO_4^{3-} + 14H^+ + 4e^-$	-98.29	18
$VOOH^+ + 2H_2O = VO_4^{3-} + 5H^+ + e^-$	-39.67	
$VO(OH)_2(s) + H_2O = VO_4^{3-} + 4H^+ + e^-$	-40.85	18
$VO(OH)_3^o = VO_4^{3-} + 3H^+$	-25.11	2
$VO(OH)_2^{3+} + H_2O + 2e^- = VO_4^{3-} + 4H^+$	24.28	
$(VO)_2(OH)_2^{2+} + 4H_2O = 2VO_4^{3-} + 10H^+ + 2e^-$	-83.99	18
$VO_2HO_2^o + 2e^- = VO_4^{3-} + H^+$	26.98	
$VO_2H_2O_2^+ + 2e^- = VO_4^{3-} + 2H^+$	26.76	
$VO_2(OH)_2^- = VO_4^{3-} + 2H^+$	-22.81	2
$VO_3(OH)^{2-} = VO_4^{3-} + H^+$	-14.26	2
$V_2O_6(OH)_2^{4-} = 2VO_4^{3-} + 2H^+$	-26.54	2
$V_{10}O_{26}(OH)_2^{4-} + 12H_2O = 10VO_4^{3-} + 26H^+$	-273.43	2
$V_{10}O_{27}(OH)^{5-} + 12H_2O = 10VO_4^{3-} + 25H^+$	-269.83	2

YTTRIUM

Reaction	Log K	Ref.
$Y(s) = Y^{3+} + 3e^-$	121.55	
$YSO_4^+ = Y^{3+} + SO_4^{2-}$	-3.47	18
$Y(SO_4)_2^- = Y^{3+} + 2SO_4^{2-}$	-5.3	18
$Y_2(SO_4)_3(s) = 2Y^{3+} + 3SO_4^{2-}$	-0.944	
$Y_2(SO_4)_3 \cdot 8H_2O(s) = 2Y^{3+} + 3SO_4^{2-} + 8H_2O$	-9.65	
$YNO_3^{2+} = Y^{3+} + NO_3^-$	0.04	
$Y_2(CO_3)_3(s) = 2Y^{3+} + 3CO_3^{2-}$	-31.00	
$YF^{2+} = Y^{3+} + F^-$	-4.8	18
$YF_2^+ = Y^{3+} + 2F^-$	-8.5	18
$YF_3^o = Y^{3+} + 3F^-$	-12.1	18
$YF_3(s) = Y^{3+} + 3F^-$	-18.91	
$YCl^{2+} = Y^{3+} + Cl^-$	-1.12	
$YCl_3 \cdot 6H_2O(s) = Y^{3+} + 3Cl^- + 6H_2O$	5.78	
$Y(OH)_2Cl(s) + 2H^+ = Y^{3+} + Cl^- + 2H_2O$	9.26	
$Y(OH)_5Cl(s) + 5H^+ + 3e^- = Y^{3+} + Cl^- + 5H_2O$	-94.38	
$YBr^{2+} = Y^{3+} + Br^-$	-0.70	
$Y_2O_3(s,cubic) + 6H^+ = 2Y^{3+} + 3H_2O$	49.45	
$YH_2(s) = Y^{3+} + 2H^+ + 5e^-$	101.17	
$YH_3(s) = Y^{3+} + 3H^+ + 6e^-$	97.22	
$YOH^{2+} + H^+ = Y^{3+} + H_2O$	7.7	2
$Y(OH)_3(s) + 3H^+ = Y^{3+} + 3H_2O$	17.5	2
$Y_2(OH)_2^{4+} + 2H^+ = 2Y^{3+} + 2H_2O$	14.26	
$Y_3(OH)_5^{4+} + 5H^+ = 3Y^{3+} + 5H_2O$	31.55	18
$YZn(s) = Y^{3+} + Zn^{2+} + 5e^-$	133.87	
$YZn_2(s,\alpha) = Y^{3+} + 2Zn^{2+} + 7e^-$	150.14	
$YZn_3(s) = Y^{3+} + 3Zn^{2+} + 9e^-$	172.86	
$YZn_4(s) = Y^{3+} + 4Zn^{2+} + 11e^-$	195.30	
$YZn_5(s) = Y^{3+} + 5Zn^{2+} + 13e^-$	216.55	
$YZn_{11}(s) = Y^{3+} + 11Zn^{2+} + 25e^-$	355.76	
$Y_2Zn_{17}(s) = 2Y^{3+} + 17Zn^{2+} + 40e^-$	585.51	
$YH_2PO_4^{2+} = Y^{3+} + 2H^+ + PO_4^{3-}$	-22.17	18

ZINC

Reaction	Log K	Ref.
$Zn(s) = Zn^{2+} + 2e^-$	25.80	
$ZnS(sphalerite) + 4H_2O = Zn^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-45.08	
$ZnS(wurtzite) + 4H_2O = Zn^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-42.78	
$ZnS(amorphous) + 4H_2O = Zn^{2+} + SO_4^{2-} + 8H^+ + 8e^-$	-42.67	3
$Zn(HS)_2^o + 8H_2O = Zn^{2+} + 2SO_4^{2-} + 18H^+ + 16e^-$	-82.17	3
$Zn(HS)_3^- + 12H_2O = Zn^{2+} + 3SO_4^{2-} + 27H^+ + 24e^-$	-116.94	3
$ZnSO_4(zinkosite) = Zn^{2+} + SO_4^{2-}$	3.57	
$ZnSO_4^o = Zn^{2+} + SO_4^{2-}$	-2.37	
$ZnSO_4 \cdot H_2O(s) = Zn^{2+} + SO_4^{2-} + H_2O$	-0.54	
$ZnSO_4 \cdot 6H_2O(bianchite) = Zn^{2+} + SO_4^{2-} + 6H_2O$	-1.69	
$ZnSO_4 \cdot 7H_2O(goslarite) = Zn^{2+} + SO_4^{2-} + 7H_2O$	-1.89	
$Zn(SO_4)_2^{2-} = Zn^{2+} + 2SO_4^{2-}$	-3.28	3
$ZnO \cdot 2ZnSO_4(s) + 2H^+ = 3Zn^{2+} + 2SO_4^{2-} + H_2O$	19.14	
$Zn_2(OH)_2SO_4(s) + 2H^+ = 2Zn^{2+} + 2H_2O + SO_4^{2-}$	7.56	
$Zn_4(OH)_6SO_4(s) + 6H^+ = 4Zn^{2+} + 6H_2O + SO_4^{2-}$	28.4	3
$ZnHPO_4^o = Zn^{2+} + H^+ + PO_4^{3-}$	-14.71	18(37,0.15)
$ZnH_2PO_4^+ = Zn^{2+} + 2H^+ + PO_4^{3-}$	-20.72	18(37,0.15)
$Zn_3PO_4)_2 \cdot 4H_2O(s) = 3Zn^{2+} + 2PO_4^{3-} + 4H_2O$	-35.3	18
$ZnMoO_4(s) = Zn^{2+} + MoO_4^{2-}$	-6.07	
$ZnCO_3(smithsonite) = Zn^{2+} + CO_3^{2-}$	-9.88	
$ZnCO_3^o = Zn^{2+} + CO_3^{2-}$	-5.3	3
$ZnCO_3 \cdot H_2O(s) = Zn^{2+} + CO_3^{2-} + H_2O$	-10.26	3
$Zn(CO_3)_2^{2-} = Zn^{2+} + 2CO_3^{2-}$	-9.63	3
$ZnHCO_3^+ = Zn^{2+} + H^+ + CO_3^{2-}$	-12.43	3
$ZnNO_3^+ = Zn^{2+} + NO_3^-$	-0.4	18
$Zn(NO_3)_2^o = Zn^{2+} + 2NO_3^-$	0.3	18
$Zn(NO_3)_2 \cdot 6H_2O(s) = Zn^{2+} + 2NO_3^- + 6H_2O$	3.44	3
$Zn_5(OH)_8(NO_3)_2(s) + 8H^+ = 5Zn^{2+} + 2NO_3^- + 8H_2O$	42.74	
$ZnF^+ = Zn^{2+} + F^-$	-1.15	3
$ZnF_2(s) = Zn^{2+} + 2F^-$	-1.52	3
$ZnBr^+ = Zn^{2+} + Br^-$	0.623	
$ZnBr_2(s) = Zn^{2+} + 2Br^-$	7.554	
$ZnBr^+ = Zn^{2+} + 2Br^-$	0.98	3
$ZnBr_2 \cdot 2H_2O(s) = Zn^{2+} + 2Br^- + 2H_2O$	5.249	

ZINC (cont)

Reaction	Log K	Ref.
$ZnBr_3^- = Zn^{2+} + 3Br^-$	1.802	
$ZnI^+ = Zn^{2+} + I^-$	3.009	
$ZnI_2(s) = Zn^{2+} + 2I^-$	7.384	
$ZnI_2^o = Zn^{2+} + 2I^-$	1.69	3
$ZnI_3^- = Zn^{2+} + 3I^-$	1.994	
$ZnI_4^{2-} = Zn^{2+} + 4I^-$	2.587	
$ZnCl^+ = Zn^{2+} + Cl^-$	-0.43	3
$ZnCl_2(s) = Zn^{2+} + 2Cl^-$	7.03	3
$ZnCl_2^o = Zn^{2+} + 2Cl^-$	-0.45	3
$ZnCl_3^- = Zn^{2+} + 3Cl^-$	-0.5	3
$ZnCl_4^{2-} = Zn^{2+} + 4Cl^-$	-0.2	3
$Zn(OH)Cl^o + H^+ = Zn^{2+} + Cl^- + H_2O$	7.513	
$Zn_2(OH)_3Cl(s) + 3H^+ = 2Zn^{2+} + Cl^- + 3H_2O$	15.249	
$Zn_5(OH)_8Cl_2(s) + 8H^+ = 5Zn^{2+} + 8H_2O + Cl^-$	38.5	3
$ZnO(zincite) + 2H^+ = Zn^{2+} + H_2O$	11.20	
$ZnO(active) + 2H^+ = Zn^{2+} + H_2O$	11.31	3
$ZnO_2^{2-} + 4H^+ = Zn^{2+} + 2H_2O$	41.57	
$ZnOH^+ + H^+ = Zn^{2+} + H_2O$	8.96	3
$Zn(OH)_2(s,\gamma) + 2H^+ = Zn^{2+} + 2H_2O$	11.86	
$Zn(OH)_2(s,\beta) + 2H^+ = Zn^{2+} + 2H_2O$	11.91	
$Zn(OH)_2(s,\varepsilon) + 2H^+ = Zn^{2+} + 2H_2O$	11.64	
$Zn(OH)_2(amorphous) + 2H^+ = Zn^{2+} + 2H_2O$	12.46	18
$Zn(OH)_2(cryst) + 2H^+ = Zn^{2+} + 2H_2O$	12.2	3
$Zn(OH)_2^o + 2H^+ = Zn^{2+} + 2H_2O$	16.88	18
$Zn(OH)_3^- + 3H^+ = Zn^{2+} + 3H_2O$	28.80	
$Zn(OH)_4^{2-} + 4H^+ = Zn^{2+} + 4H_2O$	41.55	
$HZnO_2^- + 3H^+ = Zn^{2+} + 2H_2O$	28.81	
$Zn_2OH^{3+} + H^+ = 2Zn^{2+} + H_2O$	8.99	18
$Zn_2(OH)_6^{2-} + 6H^+ = 2Zn^{2+} + 6H_2O$	57.8	2
$ZnSe(s) + 3H_2O = Zn^{2+} + SeO_3^{2-} + 6H^+ + 6e^-$	-62.64	
$ZnSeO_3 \cdot H_2O(s) = Zn^{2+} + SeO_3^{2-} + H_2O$	-6.76	
$ZnSiO_3(s) + 2H^+ = Zn^{2+} + SiO_2^o + H_2O$	-19.85	3
$Zn_2SiO_4(willemite) + 4H^+ = 2Zn^{2+} + SiO_2^o + 2H_2O$	13.89	

ZINC (cont)

Reaction	Log K	Ref.
$ZnFe_2O_4(s) + 8H^+ + 2e^- = Zn^{2+} + 2Fe^{2+} + 4H_2O$	33.29	
$ZnTe(s) = Zn^{2+} + Te^{2-}$	(-33.3)	18
Zn_2TiO_4(Zn-Ti spinel) $+ 8H^+ + e^- = 2Zn^{2+} + Ti^{3+} + 4H_2O$	3.22	

ZIRCONIUM

$Zr(s) = Zr^{4+} + 4e^-$	101.46	
$ZrSO_4^{2+} = Zr^{4+} + SO_4^{2-}$	-3.79	15
$ZrNO_3^{3+} = Zr^{4+} + NO_3^-$	-0.3	15
$ZrF^{3+} = Zr^{4+} + F^-$	-9.80	15
ZrF_4(s,β monoclinic) $= Zr^{4+} + 4F^-$	-18.72	
$ZrCl^{3+} = Zr^{4+} + Cl^-$	-0.30	15
$ZrCl_4(s) = Zr^{4+} + 4Cl^-$	37.53	
$ZrH_2(s) = Zr^{4+} + 2H^+ + 6e^-$	78.88	
ZrO_2(baddeleyite) $+ 4H^+ = Zr^{4+} + 2H_2O$	1.86	18
$ZrOH^{3+} + H^+ = Zr^{4+} + H_2O$	-0.3	15
$Zr(OH)_2^{2+} + 2H^+ = Zr^{4+} + 2H_2O$	1.7	15
$Zr(OH)_3^+ + 3H^+ = Zr^{4+} + 3H_2O$	5.1	15
$Zr(OH)_4^o + 4H^+ = Zr^{4+} + 4H_2O$	9.7	15
$Zr(OH)_5^- + 5H^+ = Zr^{4+} + 5H_2O$	16.0	15
$Zr_3(OH)_4^{8+} + 4H^+ = 3Zr^{4+} + 4H_2O$	0.6	15
$Zr_3(OH)_5^{7+} + 5H^+ = 3Zr^{4+} + 5H_2O$	-3.7	15
$Zr_4(OH)_8^{8+} + 8H^+ = 4Zr^{4+} + 8H_2O$	-6.0	2
$ZrSiO_4$(zircon) $+ 4H^+ = Zr^{4+} + SiO_2^o + 2H_2O$	-5.64	

TABLE 3. BASIS SPECIES

Ag^{+}	H^{+}	Pu^{4+}
Al^{3+}	H_2O	SO_4^{2-}
Am^{4+}	Hf^{4+}	SbO^{+}
Ba^{2+}	I^{-}	SeO_3^{2-}
Br^{-}	K^{+}	SiO_2°
CO_3^{2-}	La^{3+}	Sm^{3+}
Ca^{2+}	Mg^{2+}	Sn^{2+}
Cd^{2+}	Mn^{2+}	Sr^{2+}
Ce^{3+}	MoO_4^{2-}	TcO^{2+}
Cm^{4+}	NO_3^{-}	Te^{2-}
CrO^{2-}	Na^{+}	Th^{4+}
Cs^{+4}	Nd^{2+}	Ti^{3+}
Cu^{2+}	Ni^{2+}	U^{4+}
Cl^{-}	Np^{4+}	VO_4^{3-}
e^{-}	PO_4^{3-}	Y^{3+}
Eu^{3+}	Pb^{2+}	Zn^{2+}
F^{-}	Pd^{2+}	Zr^{3+}
Fe^{2+}	Pm^{3+}	Ra^{2+}
Gd^{3+}	Pr^{3+}	Rb^{+}
		Ru^{2+}