Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K

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A great deal of solution chemistry can be summarized in a table of standard electrode potentials of the elements in the solvent of interest. In this work, standard electrode potentials and temperature coefficients in water at 298.15 K, based primarily on the "NBS Tables of Chemical Thermodynamic Properties," are given for nearly 1700 half-reactions at $p\mathrm{H} = 0.000$ and $p\mathrm{H} = 13.996$. The data allow the calculation of the thermodynamic changes and equilibrium constants associated with ~1.4 million complete cell reactions over the normal temperature range of liquid water. Estimated values are clearly distinguished from experimental values, and half-reactions involving doubtful chemical species are duly noted. General and specific methods of estimation of thermodynamic quantities are summarized.

Key words: electrochemical cell reaction; equilibrium constant; half-reaction; standard electrode potential; standard enthalpy, entropy and Gibbs energy change; temperature coefficient; third-law entropy

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1. Introduction

A standard electrode potential E^0 is defined as the potential (in volts, V) of a half-reaction relative to a reference electrode at a specified temperature, all chemical species being in their standard states at unit activity. These states may be arbitrarily defined as pure crystalline solids, pure liquids, ideal gases at one atmosphere fugacity ($1.013\,25 \times 10^5$ Pa), and ideal solutes at unit molality. The most common temperature for the tabulation of standard electrode potentials, as for other thermodynamic data, is 25 °C (298.15 K).

For the solvent water, the usual reference electrode is the standard hydrogen electrode (SHE), E^0 for the half-reaction

$$2\mathrm{H}^+(\mathrm{aq}) + 2e^- \rightarrow \mathrm{H}_2(\mathrm{g}) \qquad (1)$$

being assigned a value of zero volts at all temperatures. The SHE may be abbreviated as $E^0[\mathrm{H}^+/\mathrm{H}_2(\mathrm{g})]$. The symbol e^- in a conventional half-reaction represents one electrochemical equivalent (i.e., one mole of electrons).

The classic reference for standard electrode potentials in water is Latimer's "Oxidation Potentials,"[1] which provides E^0 values for a large number of half-reactions at 298.15 K. de Bethune and others[2–4] have shown that the temperature dependence of E^0 is approximately linear between 273.15 and 373.15 K, and have extended Latimer's work over the normal temperature range of liquid water by tabulating temperature coefficients of standard electrode potentials dE^0/dT:

$$E^0_T = E^0_{298} + (T - 298.15)\cdot\left(\frac{dE^0}{dT}\right)_{298} \quad (2)$$

Temperature coefficients may be conveniently expressed in millivolts per kelvin, mV/K. As with E^0 values, dE^0/dT values are defined relative to dE^0/dT for the SHE being equal to zero at all temperatures. The accuracy of Eq. (2) depends on the assumption that E^0 is a linear function of temperature. This is not quite true, although the errors incurred are often small. Deviations from linearity are discussed in Sec. 8.

The works of Latimer[1] and de Bethune *et al.*[2–4] have been widely quoted. Unfortunately, however, their primary reference is the Circular 500 of the United States National Bureau of Standards (NBS),[5] now, the National Institute of Standards and Technology (NIST), which has been rendered obsolete through modern publications by the Institute.[6,7] The need exists for a table of standard electrode potentials and temperature coefficients in water at 298.15 K which is based on the modern NBS tables.

2. Sources of Thermodynamic Data

Standard electrode potentials and temperature coefficients at 298.15 K are presented in Table 1. The elements are arranged by Periodic Table family for easy access. The primary sources of thermodynamic data used in this report are the "NBS Technical Note 270" series[6] and the "NBS Tables of Chemical Thermodynamic Properties."[7] The data tabulated in Refs. 6 and 7 are not yet supported by a published bibliography; information about the selection of thermodynamic values for specific chemical species may be obtained by writing to the Director, Chemical Thermodynamics Data Center, Room A158, Chemistry Building, National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899. Reference 7 contains a detailed discussion of the problems of internal consistency encountered when combining thermodynamic data from different sources. In this report, an attempt has been made to keep non-NIST sources to a minimum, calling upon them only when the values are clearly superior to NIST, or when NIST provides no data.

Auxiliary references which provide much data not given by NIST are "The Hydrolysis of Cations" by Baes and Mesmer,[8(a)] a follow-up paper by the same authors,[8(b)] and "Standard Potentials in Aqueous Solution," edited by Bard, Parsons, and Jordan.[9] (For reasons discussed below, the latter reference has been used with discretion.) Some thermodynamic data used in this report have been taken from "Advanced Inorganic Chemistry" by Cotton and Wilkinson,[10] but this popular text has served mainly as a rich source of descriptive chemistry for the estimation of thermodynamic quantities (*vide infra*). Thermodynamic prediction methods developed by the author[11–13] have aided in the compilation of standard electrode potentials and temperature coefficients of the lanthanides and actinides, and, with appropriate modification, for a few other elements. Thirteen standard Gibbs energies of formation and eight standard entropies (none of which has been superseded by NBS[6,7]) have been taken or deduced from Latimer.[1] The standard enthalpy of formation of FeO_4^{2-} has been taken from de Bethune *et al.*[2]

2.1. Uncertainties

Following NBS,[6,7] the probable uncertainties associated with the E^0 and dE^0/dT values in this report are implied by the number of digits tabulated. E^0 and dE^0/dT values in Table 1 are believed to be uncertain by less than ten units in the last digit tabulated. For experimentally based values, the number of digits tabulated reflects the cumulative uncertainties in the thermodynamic data. For estimated values (enclosed in parentheses), the number of digits tabulated reflects the uncertainty in the method of prediction (*vide infra*). The author accepts full responsibility for all estimated values in this report.

It is necessary to discuss Ref. 9 in some detail at this point, because ostensibly it has already accomplished the goal of this report. (However, the present work contains many more temperature coefficients of electrode potentials than does Ref. 9.) It can be verified from personal experience that it is a colossal undertaking to assemble a critically evaluated table of thermodynamic data for inorganic compounds; the approach taken by Bard *et al.*[9] has been to divide the work among several chapter authors. Unfortunately, some of the authors have taken or deduced E^0 and/or dE^0/dT values from Latimer,[1] de Bethune *et al.*,[2–4] and the NBS Circular 500,[5] although such values have been superseded by the more recent NIST publications.[6,7] The following chapters in Ref. 9 contain extensive tables of such outdated values: Chap. 5 (E^0 and dE^0/dT for F and E^0 for I); Chap. 6 (dE^0/dT for S–Te); Chap. 7 (E^0 for N and P); Chap. 8 (E^0 and dE^0/dT for C–Pb); Chap. 9 (E^0 and dE^0/dT for Ga and Tl); Chap. 17 (E^0 for Nb and Ta); Chap. 18 (E^0 for Ti–Hf); Chap. 22 (dE^0/dT for Mg–Ra); Chap. 23 (E^0 and dE^0/dT for Li–Cs). Admittedly, in some cases, the absolute differences between the old[1–5] and new[6,7] E^0 or dE^0/dT values are less than the sums of their assigned uncertainties. However, it would appear that a simple retabulation of the old values undermines the primary objective of Ref. 9, which can be construed from the preface as "to incorporate a wealth of new data in order to provide critically selected values and the best estimates now available."

On the other hand, over 100 of the E^0 values in Ref. 9 differ significantly from the values listed in Table 1. Examples include E^0 [Te(c), H^+/H_2Te] = −0.740 V (Table 1: −0.46 V); E^0 [N_2(g),H^+/HN_3] = −3.10 V (Table 1: −3.334 V); E^0 [$H_2SiO_4^{2-}/Si(c), OH^-$] = −1.69 V (Table 1: −1.834 V); E^0 [Ta_2O_5 [(c,β),H^+/Ta(c)] = −0.81 V (Table 1: −0.752 V); E^0 [$Ti(OH)_2^{2+}$, H^+/Ti(c)] = −0.86 V (Table 1: −1.00 V), and E^0 [Cs^+/Cs(c)] = −2.923 V (Table 1: −3.026 V). The application of Latimer's equilibrium data[1] on H_2Te, $H_2SiO_4^{2-}$, and $Ti(OH)_2^{2+}$ to the modern NBS tables[6,7] instead of to the NBS Circular 500[5] yields E^0 values in essential agreement with Table 1; the other E^0 values in Table 1 (involving HN_3, Ta_2O_5, and Cs^+) have been calculated directly from the modern NBS tables.

Some of the data in Ref. 9 disagree with that in Table 1 because they have been calculated or assigned incorrectly. For example, the E^0 values given for those vanadium species which predominate in basic solution (p. 523) have been calculated for unit activity H^+ (aq) and are 0.8–2.9 V more

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Hydrogen[6, 7]					
$H^+ / H_2(g)$	0.0000	0.0000	$H_2O(liq) / H_2(g), OH^-$	-0.8280	-0.8360
H^+ / H_2	-0.091	-0.378	$H_2(g) / H^-$	(-2.40)[a]	(-1.48)
$H^+ / H(g)$	-2.1067	0.5111	$H_2O(liq) / H(g), OH^-$	-2.9347	-0.3249
$H_2(g) / H^-$	(-2.40)[a]	(-1.48)			
Lithium[6-8]					
$Li^+, H_2(g) / LiH(c)$	-2.331	-1.285	$LiOH(c) / Li(c), OH^-$	-2.920	-0.930
$Li^+ / Li(c)$	-3.040	-0.514	$Li^+ / Li(c)$	-3.040	-0.514
			$LiOH / Li(c), OH^-$	-3.060	-0.59
Sodium[6-8]					
$Na^+, H_2(g) / NaH(c)$	-2.367	-1.550	$NaOH / Na(c), OH^-$	-2.704	-0.73
$Na^+ / Na(c)$	-2.7143	-0.757	$Na^+ / Na(c)$	-2.7143	-0.757
Potassium[6-8]					
$K^+, H_2(g) / KH(c)$	(-2.58)[b]	(-1.90)	$KOH / K(c), OH^-$	-2.909	(-0.9)
$K^+ / K(c)$	-2.936	-1.074	$K^+ / K(c)$	-2.936	-1.074
Rubidium[6, 7]					
$Rb^+, H_2(g) / RbH(c)$	(-2.66)[b]	(-1.99)	$RbOH / Rb(c), OH^-$	(-2.91)	
$Rb^+ / Rb(c)$	-2.943	-1.140	$Rb^+ / Rb(c)$	-2.943	-1.140
Cesium[6-8]					
$Cs^+, H_2(g) / CsH(c)$	(-2.72)[b]	(-2.04)	$CsOH / Cs(c), OH^-$	(-2.97)	
$Cs^+ / Cs(c)$	-3.026	-1.172	$Cs^+ / Cs(c)$	-3.026	-1.172
Francium[6, 7]					
$Fr^+, H_2(g) / FrH(c)$	(-2.75)	(-2.1)	$FrOH / Fr(c), OH^-$	(-2.8)	
$Fr^+ / Fr(c)$	(-2.9)	(-1.2)	$Fr^+ / Fr(c)$	(-2.9)	(-1.2)
Beryllium[6-8]					
$BeOH^+, H^+ / Be(c)$	-1.808	(0.3)	$Be(OH)_4^{2-} / Be(c), OH^-$	-2.517	-0.751
$Be_3(OH)_3^{3+}, H^+ / Be(c)$	-1.880		$Be(OH)_3^- / Be(c), OH^-$	-2.52	
$Be^{2+} / Be(c)$	-1.968	(0.60)	$Be(OH)_2(pt) / Be(c), OH^-$	(-2.58)[b]	(-1.05)
$Be^{2+}, H_2(g) / BeH_2(c)$	(-2.26)	(-0.05)	$Be(OH)_2(c, \alpha) / Be(c), OH^-$	-2.598	-1.022
			$BeO(c) / Be(c), OH^-$	-2.606	-1.174
			$Be(OH)_2(c, \beta) / Be(c), OH^-$	-2.609	-1.001
Magnesium[6-8]					
$MgOH^+, H^+ / Mg(c)$	-2.022	(0.25)	$MgO(c) / Mg(c), OH^-$	-2.550	-1.120
$Mg_4(OH)_4^{4+}, H^+ /$	-2.067		$Mg(OH)_2(pt) / Mg(c), OH^-$	(-2.68)[b]	(-0.98)
$Mg(c)$			$Mg(OH)_2(c) / Mg(c), OH^-$	-2.690	-0.946
$Mg^{2+}, H_2(g) / MgH_2(c)$	-2.173	-0.486			
$Mg^{2+} / Mg(c)$	-2.360	0.199			
Calcium[6-8]					
$Ca^{2+}, H_2(g) / CaH_2(c)$	-2.105	-0.86	$CaOH^+ / Ca(c), OH^-$	-2.902	-0.46
$CaOH^+, H^+ / Ca(c)$	-2.488	-0.05	$Ca(OH)_2(c) / Ca(c), OH^-$	-3.022	-0.991
$Ca^{2+} / Ca(c)$	-2.868	-0.186			

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Strontium[6-8]					
$Sr^{2+}, H_2(g) / SrH_2(c)$	(-2.16)[b]	(-0.90)	$SrOH^+ / Sr(c), OH^-$	-2.920	
$SrOH^+, H^+ / Sr(c)$	-2.506		$Sr(OH)_2 \cdot 8H_2O(c) /$	(-3.03)[b]	(0.36)
$Sr^{2+} / Sr(c)$	-2.899	-0.237	$Sr(c), OH^-$		
Barium[6-8]					
$Ba^{2+}, H_2(g) / BaH_2(c)$	(-2.18)[b]	(-1.06)	$BaOH^+ / Ba(c), OH^-$	-2.921	
$BaOH^+, H^+ / Ba(c)$	-2.507		$Ba(OH)_2 \cdot 8H_2O(c) /$	-3.00	0.29
$Ba^{2+} / Ba(c)$	-2.906	-0.401	$Ba(c), OH^-$		
Radium[6, 7, 11-13]					
$Ra^{2+}, H_2(g) / RaH_2(c)$	(-2.19)	(-1.09)	$RaOH^+ / Ra(c), OH^-$	(-2.81)	
$RaOH^+, H^+ / Ra(c)$	(-2.40)		$Ra(OH)_2 \cdot 8H_2O(c) /$	(-2.89)	
$Ra^{2+} / Ra(c)$	(-2.80)	(-0.44)	$Ra(c), OH^-$		
Scandium[6-8, 11, 12]					
$Sc^{3+}, H_2(g) / ScH_3(c)$	(-1.75)	(-0.25)	$Sc(OH)_4^- / Sc(c), OH^-$	-2.68	(-1.16)
$Sc^{2+} / Sc(c)$	(-2.0)[a]	(-0.2)	$Sc(OH)_3(pt) / Sc(c), OH^-$	-2.69	-1.01
$ScOH^{2+}, H^+ / Sc(c)$	-2.01	0.24	$Sc(OH)_3(c) / Sc(c), OH^-$	-2.72	(-0.96)
$Sc_2(OH)_2^{4+}, H^+ / Sc(c)$	-2.03		$Sc_2O_3(c, \gamma) / Sc(c), OH^-$	-2.742	-1.164
$Sc^{3+} / Sc(c)$	-2.09	0.41	$ScOOH(c) / Sc(c), OH^-$	(-2.76)	(-1.10)
Sc^{3+} / Sc^{2+}	(-2.3)[a]	(1.6)			
Yttrium[6-9]					
$Y^{3+}, H_2(g) / YH_3(c)$	(-1.72)	(-0.32)	$Y(OH)_3(pt) / Y(c), OH^-$	(-2.87)	
$YOH^{2+}, H^+ / Y(c)$	-2.23	(0.2)	$Y(OH)_3(c) / Y(c), OH^-$	-2.90	-0.977
$Y^{3+} / Y(c)$	-2.38	0.34			
Lanthanum[1, 8, 9]					
$La^{3+}, H_2(g) / LaH_3(c)$	(-1.71)	(-0.41)	$La(OH)_3(pt) / La(c), OH^-$	-2.75	
$LaOH^{2+}, H^+ / La(c)$	-2.21	(0.1)	$La(OH)_3(c) / La(c), OH^-$	-2.80	-0.998
$La^{3+} / La(c)$	-2.379	0.242			
Cerium[6-9]					
Ce^{4+} / Ce^{3+}	1.72	1.54	$Ce_4O_7(c) / Ce(OH)_3(c), OH^-$	(-0.13)	(-2.03)
$CeOH^{3+}, H^+ / Ce^{3+}$	1.68	-0.13	$CeO_2(pt) /$	(-0.5)	
$CeO_2(pt), H^+ / Ce^{3+}$	(1.66)	(-2.1)	$Ce(OH)_3(pt), OH^-$		
$Ce_2(OH)_2^{6+}, H^+ / Ce^{3+}$	(1.64)		$CeO_2(c) / Ce(OH)_3(c), OH^-$	-0.70	(-1.54)
$CeO_2(c), H^+ / Ce^{3+}$	1.304	-2.00	$CeO_2(c) / Ce_4O_7(c), OH^-$	(-1.27)	(-1.04)
$CeO_2(c), H^+ / CeOH^{2+}$	0.81		$Ce(OH)_3(pt) / Ce(c), OH^-$	(-2.73)	
$CeOH^{2+}, H^+ / Ce(c)$	-2.17		$Ce(OH)_3(c) / Ce(c), OH^-$	-2.77	(-0.99)
$Ce^{3+} / Ce(c)$	-2.336	0.280			
Praseodymium[6-9, 11, 12]					
Pr^{4+} / Pr^{3+}	(3.2)	(1.4)	$Pr_6O_{11}(c) /$	(0.94)[b]	(-1.91)
$PrO_2(pt), H^+ / Pr^{3+}$	(3.0)		$Pr(OH)_3(c), OH^-$		
$PrO_2(c), H^+ / Pr^{3+}$	(2.67)[b]	(-2.17)	$PrO_2(pt) /$	(0.9)	
$PrO_2(c), H^+ / PrOH^{2+}$	(2.18)		$Pr(OH)_3(pt), OH^-$		
$Pr^{2+} / Pr(c)$	(-2.0)[a]	(-0.4)	$PrO_2(c) / Pr(OH)_3(c), OH^-$	(0.70)[b]	(-1.67)
$PrOH^{2+}, H^+ / Pr(c)$	-2.19		$PrO_2(c) / Pr_6O_{11}(c), OH^-$	(0.22)[b]	(-1.19)
$Pr^{3+} / Pr(c)$	-2.353	0.291	$Pr(OH)_3(pt) / Pr(c), OH^-$	(-2.76)	
Pr^{3+} / Pr^{2+}	(-3.1)[a]	(1.6)	$Pr(OH)_3(c) / Pr(c), OH^-$	-2.80	-0.990

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E° (V)	dE°/dT (mV/K)	Basic Solutions (pH = 13.996)	E° (V)	dE°/dT (mV/K)
Neodymium[6-9, 11, 12]					
Nd^{2+} / Nd (c)	(-2.1)[a]	(-0.4)	$Nd(OH)_3$ (pt) / Nd (c), OH^-	(-2.74)	
$NdOH^{2+}$, H^+ / Nd (c)	-2.16		$Nd(OH)_3$ (c) / Nd (c), OH^-	-2.78	-0.990
Nd^{3+} / Nd (c)	-2.323	0.282			
Nd^{3+} / Nd^{2+}	(-2.7)[a]	(1.6)			
Promethium[9, 11, 12]					
$PmOH^{2+}$, H^+ / Pm (c)	(-2.14)		$Pm(OH)_3$ (pt) / Pm (c), OH^-	(-2.74)	
Pm^{2+} / Pm (c)	(-2.2)[a]	(-0.3)	$Pm(OH)_3$ (c) / Pm (c), OH^-	(-2.78)	(-0.99)
Pm^{3+} / Pm (c)	(-2.30)	(0.29)			
Pm^{3+} / Pm^{2+}	(-2.6)[a]	(1.5)			
Samarium[6-9]					
Sm^{3+} / Sm^{2+}	-1.55	(1.4)	$Sm(OH)_3$ (pt) / Sm (c), OH^-	(-2.75)	
$SmOH^{2+}$, H^+ / Sm (c)	-2.15		$Sm(OH)_2 \cdot H_2O$ (c) / Sm (c), OH^-	(-2.77)[a]	(-0.9)
Sm^{3+} / Sm (c)	-2.304	0.279			
Sm^{2+} / Sm (c)	-2.68	(-0.28)	$Sm(OH)_3$ (c) / Sm (c), OH^-	-2.78	(-0.98)
			$Sm(OH)_3$ (c) / $Sm(OH)_2 \cdot H_2O$ (c), OH^-	(-2.8)[a]	(-1.2)
Europium[6-9]					
$EuOH^{2+}$, H^+ / Eu^{2+}	0.11		Eu(OH)$_3$ (c) / Eu(OH)$_2 \cdot H_2O$ (c), OH^-	(-1.6)	(-1.1)
Eu^{3+} / Eu^{2+}	-0.35	1.53			
$EuOH^{2+}$, H^+ / Eu (c)	-1.84		$Eu(OH)_3$ (pt) / Eu (c), OH^-	(-2.44)	
Eu^{3+} / Eu (c)	-1.991	0.338	$Eu(OH)_3$ (c) / Eu (c), OH^-	-2.48	-0.934
Eu^{2+} / Eu (c)	-2.812	-0.26	$Eu(OH)_2 \cdot H_2O$ (c) / Eu (c), OH^-	(-2.92)	(-0.85)
Gadolinium[6-9]					
$GdOH^{2+}$, H^+ / Gd (c)	-2.12		$Gd(OH)_3$ (pt) / Gd (c), OH^-	(-2.74)	
Gd^{3+} / Gd (c)	-2.279	0.315	$Gd(OH)_3$ (c) / Gd (c), OH^-	-2.78	-0.990
Terbium[6-9]					
Tb^{4+} / Tb^{3+}	(3.1)	(1.5)	Tb_4O_7 (c) / $Tb(OH)_3$ (c), OH^-	(1.04)[b]	(-2.27)
TbO_2 (pt), H^+ / Tb^{3+}	(2.7)		TbO_2 (pt) / Tb(OH)$_3$ (pt), OH^-	(0.8)	
TbO_2 (c), H^+ / Tb^{3+}	(2.44)[b]	(-2.36)			
TbO_2 (c), H^+ / $TbOH^{2+}$	(1.97)		TbO_2 (c) / $Tb(OH)_3$ (c), OH^-	(0.64)[b]	(-1.72)
$TbOH^{2+}$, H^+ / Tb (c)	-2.12		TbO_2 (c) / Tb_4O_7 (c), OH^-	(0.24)[b]	(-1.16)
Tb^{3+} / Tb (c)	-2.28	0.350	$Tb(OH)_3$ (pt) / Tb (c), OH^-	(-2.75)	
			$Tb(OH)_3$ (c) / Tb (c), OH^-	-2.78	-0.979
Dysprosium[6-9, 11, 12]					
$DyOH^{2+}$, H^+ / Dy (c)	-2.14		$Dy(OH)_3$ (pt) / Dy (c), OH^-	(-2.77)	
Dy^{2+} / Dy (c)	(-2.2)[a]	(-0.3)	$Dy(OH)_3$ (c) / Dy (c), OH^-	-2.81	(-0.98)
Dy^{3+} / Dy (c)	-2.295	0.373			
Dy^{3+} / Dy^{2+}	(-2.6)[a]	(1.6)			

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E° (V)	dE°/dT (mV/K)	Basic Solutions (pH = 13.996)	E° (V)	dE°/dT (mV/K)
Holmium[6-9, 11, 12]					
Ho^{2+} / Ho (c)	(-2.1)[a]	(-0.2)	$Ho(OH)_3$ (pt) / Ho (c), OH^-	(-2.82)	
$HoOH^{2+}$, H^+ / Ho (c)	-2.18		$Ho(OH)_3$ (c) / Ho (c), OH^-	-2.85	-0.977
Ho^{3+} / Ho (c)	-2.33	0.371			
Ho^{3+} / Ho^{2+}	(-2.8)[a]	(1.6)			
Erbium[6-9, 11, 12]					
Er^{2+} / Er (c)	(-2.0)[a]	(-0.2)	$Er(OH)_3$ (pt) / Er (c), OH^-	(-2.83)	
$ErOH^{2+}$, H^+ / Er (c)	-2.18		$Er(OH)_3$ (c) / Er (c), OH^-	-2.86	(-0.98)
Er^{3+} / Er (c)	-2.331	0.388			
Er^{3+} / Er^{2+}	(-3.0)[a]	(1.6)			
Thulium[6-9, 11, 12]					
$TmOH^{2+}$, H^+ / Tm (c)	-2.17		$Tm(OH)_3$ (pt) / Tm (c), OH^-	(-2.82)	
Tm^{3+} / Tm^{2+}	(-2.2)[a]	(1.6)	$Tm(OH)_3$ (c) / Tm (c), OH^-	-2.85	(-0.97)
Tm^{3+} / Tm (c)	-2.319	0.394			
Tm^{2+} / Tm (c)	(-2.4)[a]	(-0.2)			
Ytterbium[6-9, 11, 12]					
Yb^{3+} / Yb^{2+}	-1.05	(1.4)	$Yb(OH)_3$ (c) / Yb(OH)$_2$ (c), OH^-	(-2.3)	(-1.0)
$YbOH^{2+}$, H^+ / Yb (c)	-2.04				
Yb^{3+} / Yb (c)	-2.19	0.363	$Yb(OH)_3$ (pt) / Yb (c), OH^-	(-2.70)	
Yb^{2+} / Yb (c)	-2.76	(-0.16)	$Yb(OH)_3$ (c) / Yb (c), OH^-	-2.73	(-1.00)
			$Yb(OH)_2$ (c) / Yb (c), OH^-	(-2.94)	(-1.0)
Lutetium[6-9, 11, 12]					
$LuOH^{2+}$, H^+ / Lu (c)	-2.13		$Lu(OH)_3$ (pt) / Lu (c), OH^-	(-2.79)	
Lu^{3+} / Lu (c)	-2.28	0.412	$Lu(OH)_3$ (c) / Lu (c), OH^-	-2.82	(-0.97)
Actinium[9, 11-13]					
Ac^{3+}, H_2 (g) / AcH_3 (c)	(-1.70)	(-0.46)	$Ac(OH)_3$ (pt) / Ac (c), OH^-	(-2.53)	
Ac^{3+} / Ac (c)	(-2.20)	(0.19)	$Ac(OH)_3$ (c) / Ac (c), OH^-	(-2.57)	(-1.01)
Thorium[6-9]					
Th^{4+}, H_2 (g) / Th_4H_{15} (c)	-1.468	-0.075	ThO_2 (pt) / Th (c), OH^-	-2.55	(-1.21)
			ThO_2 (c) / Th (c), OH^-	-2.627	-1.181
$ThOH^{3+}$, H^+ / Th (c)	-1.779	0.31			
$Th_2(OH)_2^{6+}$, H^+ / Th (c)	-1.78				
Th^{4+} / Th (c)	-1.826	0.557			
Protactinium[6-9, 11-13]					
$PaOOH^{2+}$, H^+ / Pa^{4+}	-0.1	(-3.3)	Pa_2O_5 (c) / PaO_2 (c), OH^-	(-1.0)	(-1.2)
PaO_2OH (pt), H^+ / Pa^{4+}	(-0.1)		$PaO(OH)_4^-$ / PaO_2 (pt), OH^-	(-1.2)	
Pa_2O_5 (c), H^+ / PaO_2 (c)	(-0.2)	(-0.4)	PaO_2OH (pt) / PaO_2 (pt), OH^-	(-1.3)	
$PaOOH^{2+}$, H^+ / Pa (c)	-1.21	(-0.23)			
PaO_2OH (pt), H^+ / Pa (c)	(-1.22)		$PaO(OH)_4^-$ / Pa (c), OH^-	(-2.04)	
Pa_2O_5 (c), H^+ / Pa (c)	(-1.24)	(-0.37)	PaO_2OH (pt) / Pa (c), OH^-	(-2.05)	
Pa^{3+} / Pa (c)	(-1.34)[a]	(0.14)	Pa_2O_5 (c) / Pa (c), OH^-	(-2.07)	(-1.21)
Pa^{4+} / Pa (c)	-1.49	(0.53)	PaO_2 (pt) / Pa (c), OH^-	(-2.24)	
PaO_2 (c), H^+ / Pa (c)	-1.50	-0.37	PaO_2 (c) / Pa (c), OH^-	-2.33	-1.21
Pa^{4+} / Pa^{3+}	(-1.9)[a]	(1.7)			
PaO_2 (c), H^+ / Pa^{3+}	(-2.0)[a]	(-1.9)			

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Uranium[6-9, 11-13]					
UO_2^+ / UO_2 (c)	0.66	(0.3)	UO_2OH (c) / UO_2 (c), OH^-	(0.1)[a]	
$UO_2OH^+, H^+ / UO_2$ (c)	0.58	0.00	$UO_2(OH)_2^- / UO_2$ (pt), OH^-	(-0.1)[a]	
$(UO_2)_3(OH)_5^+, H^+ /$ UO_2 (c)	0.564	0.16	$UO_2(OH)_2$ (c, β) / U_3O_8 (c, α), OH^-	-0.139	-0.57
$(UO_2)_2(OH)_2^{2+}, H^+ /$ UO_2 (c)	0.493	0.16	$UO_2(OH)_4^{2-} / UO_2$ (c), OH^-	(-0.22)	
			$UO_2(OH)_2$ (c, β) / UO_2 (c), OH^-	-0.252	-1.05
UO_2^{2+} / UO_2 (c)	0.410	0.232			
$UO_2^+, H^+ / U^{4+}$	0.39	(-3.4)	U_3O_8 (c, α) / UO_2 (c), OH^-	-0.309	-1.284
$UO_2^{2+}, H^+ / U^{4+}$	0.273	-1.582	$UO_2(OH)_4^{2-} / UO_2$ (pt), OH^-	(-0.43)	
$UO_2^{2+}, H^+ / UOH^{3+}$	0.254	-0.92	$UO_2(OH)_4^{2-}$ / UO_2OH (c), OH^-	(-0.5)[a]	
UO_2^{2+} / UO_2^+	0.16	(0.2)			
$UOH^{3+}, H^+ / U^{3+}$	-0.539	0.29	$UO_2(OH)_2$ (c, β) / UO_2OH (c), OH^-	(-0.6)[a]	
U^{4+} / U^{3+}	-0.577	1.61			
UO_2 (c), H^+ / U^{3+}	-0.851	-2.02	$UO_2(OH)_4^{2-}$ / $UO_2(OH)_2^-$, OH^-	(-0.7)[a]	
U^{3+}, H_2 (g) / UH_3 (c)	-1.390	-0.47			
UO_2 (c), H^+ / U (c)	-1.444	-0.384	$U(OH)_3$ (pt) / U (c), OH^-	(-2.04)[a]	
U^{3+} / U (c)	-1.642	0.16	$U(OH)_3$ (c) / U (c), OH^-	(-2.08)[a]	(-1.10)
			UO_2 (pt) / U (c), OH^-	(-2.16)	
			UO_2 (c) / U (c), OH^-	-2.272	-1.220
			UO_2 (pt) / $U(OH)_3$ (pt), OH^-	(-2.6)[a]	
			UO_2 (c) / $U(OH)_3$ (c), OH^-	(-2.9)[a]	(-1.6)
Neptunium[8, 9, 11-13]					
$NpO_3^+, H^+ / NpO_2^{2+}$	2.04		$NpO_4(OH)_2^{3-}$ / $NpO_2(OH)_2$ (c), OH^-	(0.61)	
$NpO_2OH^+, H^+ / NpO_2^+$	1.54				
$(NpO_2)_2(OH)_2^{2+}, H^+ /$ NpO_2^+	1.43		$NpO_4(OH)_2^{3-}$ / $NpO_2(OH)_4^{2-}$, OH^-	0.58	
NpO_2^{2+} / NpO_2^+	1.236	0.058	$NpO_2(OH)_4^{2-}$ / NpO_2OH (c), OH^-	(0.5)	
NpO_2^+ / NpO_2 (c)	1.092	0.33			
$NpO_2^+, H^+ / Np^{4+}$	0.567	-3.30	$NpO_2(OH)_2$ (c) / NpO_2OH (c), OH^-	(0.5)	(-1.1)
$NpO_2^+, H^+ / NpOH^{3+}$	0.479				
$NpOH^{3+}, H^+ / Np^{3+}$	0.245		$NpO_2(OH)_4^{2-}$ / NpO_2 (c), OH^-	(0.49)	
Np^{4+} / Np^{3+}	0.157	1.53			
NpO_2 (c), H^+ / Np^{3+}	-0.369	-2.10	$NpO_2(OH)_2$ (c) / NpO_2 (c), OH^-	(0.48)[b]	(-1.10)
NpO_2 (c), H^+ / Np (c)	-1.418	-0.392			
Np^{3+} / Np (c)	-1.768	0.18	NpO_2OH (c) / NpO_2 (c), OH^-	(0.4)	(-1.1)
			$NpO_2(OH)_4^{2-}$ / $NpO_2(OH)_2^-$, OH^-	(0.4)[a]	
			$NpO_2(OH)_4^{2-}$ / NpO_2 (pt), OH^-	(0.22)	
			$NpO_2(OH)_2^-$ / NpO_2 (pt), OH^-	(0.1)[a]	
			NpO_2 (pt) / $Np(OH)_3$ (pt), OH^-	(-1.9)	
			NpO_2 (pt) / Np (c), OH^-	(-2.11)	
			$Np(OH)_3$ (pt) / Np (c), OH^-	(-2.18)	
			$Np(OH)_3$ (c) / Np (c), OH^-	-2.22	(-1.09)
			NpO_2 (c) / Np (c), OH^-	-2.246	-1.228
			NpO_2 (c) / $Np(OH)_3$ (c), OH^-	-2.33	(-1.6)

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Plutonium[8, 9, 11-13]					
$PuO_3^+, H^+ / PuO_2^{2+}$	(2.4)		$PuO_4(OH)_2^{3-}$ / $PuO_2(OH)_4^{2-}$, OH^-	0.95	
PuO_2^+ / PuO_2 (c)	1.585	0.39			
$PuO_2OH^+, H^+ / PuO_2$ (c)	1.44		PuO_2OH (c) / PuO_2 (c), OH^-	(0.9)	
$(PuO_2)_2(OH)_2^{2+}, H^+ /$ PuO_2 (c)	1.40		$PuO_2(OH)_4^{2-} / PuO_2$ (c), OH^-	(0.57)	
			$PuO_2(OH)_2^- / PuO_2$ (pt), OH^-	(0.5)[a]	
$PuO_2OH^+, H^+ / PuO_2^+$	1.29		$PuO_2(OH)_4^{2-}$ / PuO_2OH (c), OH^-	(0.3)	
PuO_2^{2+} / PuO_2 (c)	1.275	0.21			
$(PuO_2)_2(OH)_2^{2+}, H^+ /$ PuO_2^+	1.21		$PuO_2(OH)_4^{2-}$ / PuO_2 (pt), OH^-	(0.29)	
$PuO_2OH^+, H^+ / Pu^{3+}$	1.11		$PuO_2(OH)_4^{2-}$ / $PuO_2(OH)_2^-$, OH^-	(0.1)[a]	
$(PuO_2)_2(OH)_2^{2+}, H^+ /$ Pu^{3+}	1.08				
$PuOH^{3+}, H^+ / Pu^{3+}$	1.036		PuO_2 (pt) / $Pu(OH)_3$ (pt), OH^-	(-1.0)	
$PuO_2^+, H^+ / Pu^{4+}$	1.035	-3.26	PuO_2 (c) / $Pu(OH)_3$ (c), OH^-	-1.47	(-1.7)
$PuO_2^+, H^+ / Pu^{3+}$	1.021	-0.91	PuO_2 (pt) / Pu (c), OH^-	(-2.06)	
Pu^{4+} / Pu^{3+}	1.006	1.441	PuO_2 (c) / Pu (c), OH^-	-2.197	-1.22
$PuO_2^+, H^+ / PuOH^{3+}$	1.005		$Pu(OH)_3$ (pt) / Pu (c), OH^-	(-2.40)	
$PuO_2^{2+}, H^+ / Pu^{3+}$	1.002	-0.596	$Pu(OH)_3$ (c) / Pu (c), OH^-	-2.44	(-1.05)
$PuO_2^{2+}, H^+ / Pu^{4+}$	1.000	-1.615			
$PuO_2^{2+}, H^+ / PuOH^{3+}$	0.985				
PuO_2^{2+} / PuO_2^+	0.966	0.03			
PuO_2 (c), H^+ / Pu^{3+}	0.457	-2.20			
PuO_2 (c), H^+ / Pu (c)	-1.369	-0.38			
Pu^{2+} / Pu (c)	(-1.6)[a]	(-0.4)			
Pu^{3+} / Pu (c)	-1.978	0.23			
Pu^{3+} / Pu^{2+}	(-2.8)[a]	(1.5)			
Americium[9, 11-13]					
$AmO_3^+, H^+ / AmO_2^{2+}$	(2.8)		$AmO_4(OH)_2^{3-}$ / $AmO_2(OH)_4^{2-}$, OH^-	(1.3)	
Am^{4+} / Am^{3+}	(2.60)	(1.4)			
AmO_2 (pt), H^+ / Am^{3+}	(2.56)		$AmO_2(OH)_4^{2-}$ / AmO_2OH (c), OH^-	(0.9)	
AmO_2 (c), H^+ / Am^{3+}	(1.95)[b]	(-2.4)			
$AmO_2^+, H^+ / Am^{3+}$	1.698	-0.97	$AmO_2(OH)_4^{2-}$ / $AmO_2(OH)_2^-$, OH^-	(0.7)[a]	
$AmO_2^{2+}, H^+ / Am^{3+}$	1.662	-0.64			
AmO_2^{2+} / AmO_2^+	1.589	0.01	AmO_2OH (c) / AmO_2 (c), OH^-	(0.7)	
AmO_2^+ / AmO_2 (c)	(1.44)[b]	(0.4)	$AmO_2(OH)_4^{2-}$ / $Am(OH)_3$ (c), OH^-	(0.54)	
AmO_2^+ / AmO_2 (pt)	(0.84)				
$AmO_2^+, H^+ / Am^{4+}$	(0.80)	(-3.3)	AmO_2 (pt) / $Am(OH)_3$ (pt), OH^-	(0.5)	
Am^{2+} / Am (c)	(-1.9)[a]	(-0.5)			
Am^{3+} / Am (c)	-2.048	0.28	$AmO_2(OH)_4^{2-}$ / $Am(OH)_3$ (pt), OH^-	(0.50)	
Am^{3+} / Am^{2+}	(-2.3)[a]	(1.8)			
			$AmO_2(OH)_2^-$ / $Am(OH)_3$ (pt), OH^-	(0.4)[a]	
			$AmO_2(OH)_2^-$ / AmO_2 (pt), OH^-	(0.2)[a]	
			AmO_2 (c) / $Am(OH)_3$ (c), OH^-	(0.06)	(-1.8)
			$Am(OH)_3$ (pt) / Am (c), OH^-	(-2.48)	
			$Am(OH)_3$ (c) / Am (c), OH^-	-2.52	(-1.01)

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E° (V)	dE°/dT (mV/K)	Basic Solutions (pH = 13.996)	E° (V)	dE°/dT (mV/K)
Curium[9, 11-13]					
Cm^{4+} / Cm^{3+}	(3.0)	(1.7)	CmO_2 (pt) / $Cm(OH)_3$ (pt), OH^-	(0.9)	
CmO_2 (pt), H^+ / Cm^{3+}	(2.9)				
CmO_2 (c), H^+ / Cm^{3+}	(2.3)[b]	(-2.1)	CmO_2 (c) / $Cm(OH)_3$ (c), OH^-	(0.4)	(-1.5)
Cm^{3+} / Cm (c)	-2.04	0.29	$Cm(OH)_3$ (pt) / Cm (c), OH^-	(-2.48)	
			$Cm(OH)_3$ (c) / Cm (c), OH^-	-2.52	(-1.00)
Berkelium[9, 11-13]					
Bk^{4+} / Bk^{3+}	1.67	(1.6)	BkO_2 (pt) / $Bk(OH)_3$ (pt), OH^-	(-0.4)	
BkO_2 (pt), H^+ / Bk^{3+}	(1.5)				
BkO_2 (c), H^+ / Bk^{3+}	(0.9)	(-2.2)	BkO_2 (c) / $Bk(OH)_3$ (c), OH^-	(-0.9)	(-1.7)
Bk^{2+} / Bk (c)	(-1.6)[a]	(-0.3)	$Bk(OH)_3$ (pt) / Bk (c), OH^-	(-2.43)	
Bk^{3+} / Bk (c)	-1.98	0.32	$Bk(OH)_3$ (c) / Bk (c), OH^-	-2.47	(-0.99)
Bk^{3+} / Bk^{2+}	(-2.8)[a]	(1.6)			
Californium[9, 11-13]					
Cf^{4+} / Cf^{3+}	(3.3)	(1.6)	CfO_2 (pt) / $Cf(OH)_3$ (pt), OH^-	(1.2)	
CfO_2 (pt), H^+ / Cf^{3+}	(3.1)		CfO_2 (c) / $Cf(OH)_3$ (c), OH^-	(0.7)	(-1.7)
CfO_2 (c), H^+ / Cf^{3+}	(2.5)	(-2.3)	$Cf(OH)_2$ (c) / Cf (c), OH^-	(-2.2)[a]	(-1.0)
Cf^{3+} / Cf^{2+}	-1.6	(1.6)	$Cf(OH)_3$ (pt) / Cf (c), OH^-	(-2.40)	
Cf^{3+} / Cf (c)	-1.94	0.33	$Cf(OH)_3$ (c) / Cf (c), OH^-	-2.44	(-0.99)
Cf^{2+} / Cf (c)	-2.12	(-0.3)	$Cf(OH)_3$ (c) / $Cf(OH)_2$ (c), OH^-	(-2.9)[a]	(-0.9)
Einsteinium[9, 11-13]					
Es^{3+} / Es^{2+}	-1.3	(1.6)	$Es(OH)_2$ (c) / Es (c), OH^-	(-2.3)[a]	(-1.0)
Es^{3+} / Es (c)	(-1.91)	(0.37)	$Es(OH)_3$ (pt) / Es (c), OH^-	(-2.38)	
Es^{2+} / Es (c)	(-2.23)	(-0.3)	$Es(OH)_3$ (c) / Es (c), OH^-	(-2.42)	(-0.95)
			$Es(OH)_3$ (c) / $Es(OH)_2$ (c), OH^-	(-2.6)[a]	(-0.9)
Fermium[9, 11-13]					
Fm^{3+} / Fm^{2+}	-1.1	(1.6)	$Fm(OH)_3$ (pt) / Fm (c), OH^-	(-2.37)	
Fm^{3+} / Fm (c)	(-1.89)	(0.38)	$Fm(OH)_3$ (c) / $Fm(OH)_2$ (c), OH^-	(-2.4)	(-0.9)
Fm^{2+} / Fm (c)	(-2.30)	(-0.3)			
			$Fm(OH)_3$ (c) / Fm (c), OH^-	(-2.40)	(-0.95)
			$Fm(OH)_2$ (c) / Fm (c), OH^-	(-2.4)	(-1.0)
Mendelevium[9, 11-13]					
Md^{3+} / Md^{2+}	-0.1	(1.6)	$Md(OH)_3$ (c) / $Md(OH)_2$ (c), OH^-	(-1.4)	(-0.9)
Md^{3+} / Md (c)	(-1.65)	(0.38)			
Md^{2+} / Md (c)	(-2.40)	(-0.2)	$Md(OH)_3$ (pt) / Md (c), OH^-	(-2.13)	
			$Md(OH)_3$ (c) / Md (c), OH^-	(-2.17)	(-0.96)
			$Md(OH)_2$ (c) / Md (c), OH^-	(-2.5)	(-1.0)
Nobelium[9, 11-13]					
No^{3+} / No^{2+}	1.4	(1.5)	$No(OH)_3$ (c) / $No(OH)_2$ (c), OH^-	(0.1)	(-1.0)
No^{3+} / No (c)	(-1.20)	(0.34)			
No^{2+} / No (c)	(-2.50)	(-0.2)	$No(OH)_3$ (pt) / No (c), OH^-	(-1.69)	
			$No(OH)_3$ (c) / No (c), OH^-	(-1.72)	(-1.01)
			$No(OH)_2$ (c) / No (c), OH^-	(-2.6)	(-1.0)

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E° (V)	dE°/dT (mV/K)	Basic Solutions (pH = 13.996)	E° (V)	dE°/dT (mV/K)
Lawrencium[9, 11-13]					
Lr^{3+} / Lr (c)	(-1.96)	(0.37)	$Lr(OH)_3$ (pt) / Lr (c), OH^-	(-2.46)	
			$Lr(OH)_3$ (c) / Lr (c), OH^-	(-2.49)	(-0.98)
Titanium[1, 6-8]					
$Ti(OH)_2^{2+}$, H^+ / Ti^{3+}	0.1	(-0.6)	$TiO_2(OH)_2^{2-}$ / TiOOH (c), OH^-	(-1.2)	
TiO_2 (pt), H^+ / Ti^{3+}	0.1	(-2.7)			
TiO_2 (c, rutile), H^+ / Ti^{3+}	-0.2	(-2.7)	Ti_3O_5 (c, α) / TiOOH (c), OH^-	(-1.3)	(-1.9)
			Ti_3O_5 (c, α) / Ti_2O_3 (c), OH^-	-1.320	-1.267
Ti^{3+} / Ti^{2+}	(-0.9)	(1.5)	TiO_2 (c, rutile) / Ti_2O_3 (c), OH^-	-1.383	-1.264
$Ti(OH)_2^{2+}$, H^+ / Ti (c)	-1.00	0.14			
TiO_2 (pt), H^+ / Ti (c)	-1.01	-0.37	TiO_2 (c, rutile) / TiOOH (c), OH^-	(-1.4)	(-1.5)
TiO_2 (c, rutile), H^+ / Ti (c)	1.076	0.365			
			TiO_2 (c, rutile) / Ti_3O_5 (c, α), OH^-	-1.418	-1.262
Ti^{3+} / Ti (c)	-1.37	(0.40)			
Ti^{2+} / Ti (c)	(-1.60)	(-0.16)	$TiO_2(OH)_2^{2-}$ / $Ti(OH)_3$ (pt), OH^-	(-1.5)	
			$TiO_2(OH)_2^{2-}$ / $Ti(OH)_4^-$, OH^-	(-1.6)	
			$Ti(OH)_3$ (pt) / $Ti(OH)_2$ (pt), OH^-	(-1.8)[a]	
			$TiO_2(OH)_2^{2-}$ / Ti (c), OH^-	(-1.87)	
			Ti_2O_3 (c) / TiO (c, α), OH^-	-1.901	-1.04
			TiO_2 (c, rutile) / Ti (c), OH^-	-1.904	-1.201
			TiOOH (c) / $Ti(OH)_2$ (c), OH^-	(-2.0)[a]	
			$Ti(OH)_4^-$ / Ti (c), OH^-	(-2.0)	
			$Ti(OH)_3$ (pt) / Ti (c), OH^-	(-2.00)	
			Ti_2O_3 (c) / Ti (c), OH^-	2.076	-1.180
			TiOOH (c) / Ti (c), OH^-	(-2.08)	(-1.11)
			$Ti(OH)_2$ (pt) / Ti (c), OH^-	(-2.10)[a]	
			$Ti(OH)_2$ (c) / Ti (c), OH^-	(-2.13)[a]	
			TiO (c, α) / Ti (c), OH^-	-2.164	-1.25
Zirconium[6-8]					
Zr^{4+} / Zr (c)	-1.45	(0.67)	$Zr(OH)_5^-$ / Zr (c), OH^-	-2.22	
$ZrOH^{3+}$, H^+ / Zr (c)	-1.45		ZrO_2 (pt) / Zr (c), OH^-	-2.28	-1.19
$Zr_4(OH)_8^{8+}$, H^+ / Zr (c)	-1.47		ZrO_2 (c, α) / Zr (c), OH^-	-2.301	-1.180
ZrO_2 (c, α), H^+ / Zr (c)	-1.473	-0.344			
Hafnium[6-8]					
$HfOH^{3+}$, H^+ / Hf (c)	(-1.55)		$Hf(OH)_5^-$ / Hf (c), OH^-	-2.31	
Hf^{4+} / Hf (c)	-1.55	(0.68)	HfO_2 (pt) / Hf (c), OH^-	-2.37	-1.20
$Hf_4(OH)_8^{8+}$, H^+ / Hf (c)	(-1.57)		HfO_2 (c) / Hf (c), OH^-	-2.419	-1.191
HfO_2 (c), H^+ / Hf (c)	-1.591	-0.355			

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K — Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Vanadium[6, 7, 9]					
$VO_2^+, H^+ / VO^{2+}$	1.001	-0.901	VO_2 (c, α) / V_3O_5 (c), OH^-	-0.50	-1.10
VO_2OH (pt), H^+ / VO^{2+}	0.96	-1.51	VO_2 (c, α) / V_2O_3 (c), OH^-	-0.527	-1.172
V_2O_5 (c), H^+ / VO^{2+}	0.957	-1.656	V_3O_5 (c) / V_2O_3 (c), OH^-	-0.57	-1.31
$VO^{2+}, H^+ / V^{3+}$	0.337	(-1.6)	$VO_2(OH)_2^{2-}$ / V_2O_3 (c), OH^-	(-0.6)	
$VO_2^+, H^+ / V$ (c)	-0.233	-0.239	$VO_2(OH)_2^{2-}$ / V_3O_5 (c), OH^-	(-0.6)	
VO_2OH (pt), H^+ / V (c)	-0.24	-0.36	$VO_2(OH)_2^{2-}$ / VOOH (c), OH^-	(-0.6)	
V_2O_5 (c), H^+ / V (c)	-0.242	-0.390	V_3O_5 (c) / VOOH (c), OH^-	(-0.7)	(-2.0)
V^{3+} / V^{2+}	-0.255	(1.5)	VO_4^{3-} / V_2O_3 (c), OH^-	-0.704	(-0.72)
V^{2+} / V (c)	-1.125	(-0.11)	VO_4^{3-} / VOOH (c), OH^-	(-0.72)	(-0.8)
			VO_4^{3-} / $VO_2(OH)_2^{2-}$, OH^-	(-0.8)	
			VO_4^{3-} / VO_2 (c, α), OH^-	-0.882	(-0.27)
			$VO_2(OH)_2^{2-}$ / $V(OH)_3$ (pt), OH^-	(-0.9)	
			$VO_2(OH)_2^{2-}$ / $V(OH)_4^-$, OH^-	(-1.0)	
			$V(OH)_4^-$ / $V(OH)_2$ (c), OH^-	(-1.0)	
			$V(OH)_4^-$ / $V(OH)_2$ (pt), OH^-	(-1.0)	
			$V(OH)_3$ (pt) / $V(OH)_2$ (pt), OH^-	(-1.2)	
			VO_4^{3-} / V (c), OH^-	-1.222	(-1.02)
			VOOH (c) / $V(OH)_2$ (c), OH^-	(-1.3)	(-1.3)
			V_2O_3 (c) / VO (c), OH^-	-1.314	-1.256
			$V(OH)_2$ (pt) / V (c), OH^-	(-1.63)	
			$V(OH)_2$ (c) / V (c), OH^-	(-1.66)	(-1.05)
			VO (c) / V (c), OH^-	-1.693	-1.202
Niobium[6-8]					
$Nb(OH)_2^{2+}, H^+ / Nb^{3+}$	(-0.1)		$Nb_6O_{19}^{8-}$ / NbO_2 (c), OH^-	(-1.34)	
$Nb(OH)_4^+, H^+ / Nb^{3+}$	(-0.2)		$Nb(OH)_3$ (pt) / Nb (c), OH^-	(-1.4)	
NbO_2 (pt), H^+ / Nb^{3+}	(-0.2)		NbO_2 (pt) / Nb (c), OH^-	(-1.47)	
$Nb(OH)_4^+, H^+$ / $Nb(OH)_2^{2+}$	(-0.2)		NbO_2 (c) / NbO (c), OH^-	-1.474	-1.183
Nb_2O_5 (c), H^+ / NbO_2 (c)	-0.248	-0.460	$Nb_6O_{19}^{8-}$ / Nb (c), OH^-	(-1.48)	
NbO_2OH (pt), H^+ / Nb^{3+}	(-0.3)		$Nb_6O_{19}^{8-}$ / NbO_2 (pt), OH^-	(-1.5)	
NbO_2 (c), H^+ / Nb^{3+}	(-0.4)		NbO_2 (c) / Nb (c), OH^-	-1.518	-1.197
NbO_2OH (pt), H^+ / NbO_2 (pt)	(-0.5)		NbO (c) / Nb (c), OH^-	-1.561	-1.211
$Nb(OH)_4^+, H^+$ / Nb (c)	-0.537		NbO_2 (pt) / $Nb(OH)_3$ (pt), OH^-	(-1.6)	
NbO_2OH (pt), H^+ / Nb (c)	(-0.60)	(-0.35)			
Nb_2O_5 (c), H^+ / Nb (c)	-0.601	-0.381			
$Nb(OH)_2^{2+}, H^+$ / Nb (c)	(-0.62)				
NbO_2 (pt), H^+ / Nb (c)	(-0.64)				
NbO_2 (c), H^+ / NbO (c)	-0.646	-0.347			
NbO_2 (c), H^+ / Nb (c)	-0.690	-0.361			
NbO (c), H^+ / Nb (c)	-0.733	-0.375			
Nb^{3+} / Nb (c)	(-0.8)				
Nb^{3+} / NbO (c), H^+	(-0.9)				

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K — Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Tantalum[6-8]					
Ta^{3+} / Ta (c)	(-0.6)[a]		$Ta(OH)_3$ (pt) / Ta (c), OH^-	(-1.3)[a]	
$Ta(OH)_2^{2+}, H^+$ / Ta (c)	(-0.64)		TaO_2 (pt) / Ta (c), OH^-	(-1.50)	
TaO_2 (pt), H^+ / Ta (c)	(-0.67)		TaO_2 (c) / Ta (c), OH^-	(-1.56)	(-1.19)
$Ta(OH)_2^{2+}, H^+ / Ta^{3+}$	(-0.7)[a]		$Ta_6O_{19}^{8-}$ / Ta (c), OH^-	(-1.60)	
$Ta(OH)_4^+, H^+$ / Ta (c)	-0.702		$Ta_6O_{19}^{8-}$ / TaO_2 (c), OH^-	(-1.8)	
TaO_2 (c), H^+ / Ta (c)	(-0.73)	(-0.36)	$Ta_6O_{19}^{8-}$ / TaO_2 (pt), OH^-	(-2.0)	
TaO_2OH (pt), H^+ / Ta (c)	(-0.75)	(-0.35)	TaO_2 (pt) / $Ta(OH)_3$ (pt), OH^-	(-2.1)[a]	
Ta_2O_5 (c, β), H^+ / Ta (c)	-0.752	-0.377			
TaO_2 (pt), H^+ / Ta^{3+}	(-0.8)[a]				
Ta_2O_5 (c, β), H^+ / TaO_2 (c)	(-0.8)	(-0.45)			
$Ta(OH)_4^+, H^+$ / $Ta(OH)_2^{2+}$	(-1.0)				
TaO_2 (c), H^+ / Ta^{3+}	(-1.1)[a]				
TaO_2OH (pt), H^+ . TaO_2 (pt)	(-1.1)				
Chromium[1, 6-9]					
$Cr(OH)_2^{2+}, H^+ / Cr^{3+}$	(1.8)		CrO_2 (c) / CrOOH (c), OH^-	(0.25)[b]	(-1.5)
CrO_2 (pt), H^+ / Cr^{3+}	(1.7)		CrO_2 (c) / Cr_2O_3 (c, α), OH^-	(0.24)[b]	(-1.3)
CrO_2 (c), H^+ / Cr^{3+}	(1.48)[b]	(-2.9)	CrO_2 (pt) / $Cr(OH)_3$ (pt, aged), OH^-	(0.2)	
$HCrO_4^-, H^+ / Cr^{3+}$	1.37	-1.38	CrO_2 (pt) / $Cr(OH)_3$ (pt, fresh), OH^-	(0.1)	
$Cr_2O_7^{2-}, H^+ / Cr^{3+}$	1.36	-1.32	$Cr(OH)_6^{2-}$ / $Cr(OH)_4^-$, OH^-	(0.1)	
$HCrO_4^-, H^+ / Cr_2(OH)_2^{4+}$	1.31		CrO_4^{2-} / CrO_4^{3-}	0.1	
Cr_2O_5 (c), H^+ / CrO_2 (c)	(1.3)	(-0.4)	CrO_4^{2-} / CrOOH (c), OH^-	(-0.01)[b]	(-1.57)
$Cr_2O_7^{2-}, H^+ / Cr_2(OH)_2^{4+}$	1.30		CrO_4^{2-} / Cr_2O_3 (c, α), OH^-	-0.016	1.499
$Cr_2O_7^{2-}, H^+ / CrO_2$ (c)	(1.30)[b]	(-0.54)	CrO_4^{2-} / $Cr(OH)_3$ (pt, aged), OH^-	-0.09	-1.66
$H_3CrO_4, H^+ / CrO_2$ (pt)	(1.3)		CrO_4^{2-} / $Cr(OH)_3$ (pt, fresh), OH^-	-0.12	(-1.62)
$Cr_2O_7^{2-}, H^+ / Cr_2O_5$ (c)	(1.3)	(-0.7)	CrO_4^{2-} / $Cr(OH)_4^-$, OH^-	-0.14	(-1.52)
$HCrO_4^-, H^+ / CrOH^{2+}$	1.29	-1.17	CrO_4^{2-} / CrO_2 (c), OH^-	(-0.14)[b]	(-1.61)
$Cr_2O_7^{2-}, H^+ / CrOH^{2+}$	1.28	-1.10	CrO_4^{3-} / CrO_2 (c), OH^-	(-0.4)	
$H_3CrO_4, H^+ / Cr(OH)_2^{2+}$	(1.2)		CrO_4^{3-} / CrO_2 (pt), OH^-	(-0.6)	
$Cr_2O_7^{2-}, H^+ / H_3CrO_4$	(1.1)		CrO_4^{3-} / $Cr(OH)_6^{2-}$, OH^-	(-0.6)	
$HCrO_4^-, H^+$ / Cr (c)	0.318	-0.471	CrO_4^{2-} / Cr (c), OH^-	-0.722	-1.354
$Cr_2O_7^{2-}, H^+$ / Cr (c)	0.310	-0.439	$Cr(OH)_4^-$ / $Cr(OH)_2$ (c), OH^-	-1.14	(-1.4)
$CrOH^{2+}, H^+ / Cr^{2+}$	-0.19	(0.7)	$Cr(OH)_4^-$ / $Cr(OH)_2$ (pt), OH^-	-1.20	
$Cr_2(OH)_2^{4+}, H^+ / Cr^{2+}$	-0.26		$Cr(OH)_3$ (pt, fresh) / $Cr(OH)_2$ (pt), OH^-	-1.26	
Cr^{3+} / Cr^{2+}	-0.42	(1.4)	Cr_2O_3 (c, α) / Cr_3O_4 (c), OH^-	(-1.27)[b]	(-1.07)
$CrOH^{2+}, H^+$ / Cr (c)	-0.66	0.22	$Cr(OH)_4^-$ / Cr (c), OH^-	-1.31	(-1.19)
$Cr_2(OH)_2^{4+}, H^+$ / Cr (c)	-0.68		CrOOH (c) / Cr_3O_4 (c), OH^-	(-1.31)[b]	(-0.43)
Cr^{3+} / Cr (c)	-0.74	0.44	$Cr(OH)_3$ (pt, fresh) / Cr (c), OH^-	-1.33	(-1.09)
Cr^{2+} / Cr (c)	-0.89	(-0.04)	$Cr(OH)_3$ (pt, aged) / $Cr(OH)_2$ (pt), OH^-	-1.35	
			$Cr(OH)_3$ (pt, aged) / Cr (c), OH^-	-1.36	-1.05

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E° (V)	dE°/dT (mV/K)	Basic Solutions (pH = 13.996)	E° (V)	dE°/dT (mV/K)
Chromium -- Continued					
			$Cr(OH)_2$ (pt) / Cr (c), OH^-	-1.36	
			CrO (c) / Cr (c), OH^-	(-1.38)[a]	(-1.23)
			$Cr(OH)_2$ (c) / Cr (c), OH^-	-1.39	(-1.08)
			Cr_2O_3 (c, α) / Cr (c), OH^-	-1.427	-1.209
			CrOOH (c) / Cr (c), OH^-	(-1.43)[b]	(-1.14)
			Cr_3O_4 (c) / Cr (c), OH^-	(-1.45)[b]	(-1.23)
			Cr_2O_3 (c, α) / $Cr(OH)_2$ (c), OH^-	-1.50	(-1.5)
			CrOOH (c) / $Cr(OH)_2$ (c), OH^-	(-1.5)	(-1.3)
			Cr_2O_3 (c, α) / CrO (c), OH^-	(-1.5)[a]	(-1.2)
			Cr_3O_4 (c) / $Cr(OH)_2$ (c), OH^-	(-1.6)	(-1.7)
			Cr_3O_4 (c) / CrO (c), OH^-	(-1.6)[a]	(-1.2)
Molybdenum[6-9]					
MoO_3 (c), H^+ / Mo_2O_5 (c)	(0.7)[a]	(-0.4)	MoO_4^{3-} / MoO_2 (c), OH^-	(-0.6)[a]	
			$Mo(OH)_3$ (pt) / Mo (c), OH^-	(-0.8)	
H_2MoO_4 (c), H^+ / Mo_2O_5 (c)	(0.6)[a]	(-0.1)	MoO_4^{2-} / MoO_2 (c), OH^-	-0.818	-1.69
			MoO_4^{3-} / MoO_2 (pt), OH^-	(-0.9)[a]	
$H_3Mo_7O_{24}^{3-}$, H^+ / $Mo_2O_4^{2+}$	(0.6)		MoO_2 (pt) / Mo (c), OH^-	(-0.92)	
			MoO_4^{2-} / Mo (c), OH^-	-0.926	-1.36
MoO_3 (c), H^+ / MoO_2 (c)	0.530	-0.477	MoO_4^{2-} / MoO_2 (pt), OH^-	(-0.94)	
$H_3Mo_7O_{24}^{3-}$, H^+ / $MoO(OH)_3$ (pt)	(0.5)[a]		MoO_2 (c) / Mo (c), OH^-	-0.980	-1.196
			MoO_4^{2-} / MoO_4^{3-}	(-1.0)[a]	
H_2MoO_4 (c), H^+ / MoO_2 (c)	(0.49)[b]	(-0.33)	MoO_2 (pt) / $Mo(OH)_3$ (pt), OH^-	(-1.3)	
$H_3Mo_7O_{24}^{3-}$, H^+ / MoO_2 (pt)	(0.43)				
$H_3Mo_7O_{24}^{3-}$, H^+ / $Mo_2O_2^{4+}$	(0.4)				
Mo_2O_5 (c), H^+ / MoO_2 (c)	(0.4)[a]	(-0.6)			
$MoO(OH)_3$ (pt), H^+ / MoO_2 (pt)	(0.4)[a]				
$Mo_2O_4^{2+}$, H^+ / $Mo_2O_2^{4+}$	(0.2)				
$Mo_2O_2^{4+}$, H^+ / Mo^{3+}	(0.1)				
$H_3Mo_7O_{24}^{3-}$, H^+ / Mo (c)	0.082	-0.384			
MoO_3 (c), H^+ / Mo (c)	0.075	-0.399			
H_2MoO_4 (c), H^+ / Mo (c)	(0.06)[b]	(-0.35)			
MoO_2 (pt), H^+ / Mo^{3+}	(0.0)				
$Mo_2O_2^{4+}$, H^+ / Mo (c)	(-0.07)				
MoO_2 (pt), H^+ / Mo (c)	(-0.09)				
Mo_2^{4+} / Mo (c)	(-0.1)				
Mo^{3+} / Mo (c)	(-0.13)				
MoO_2 (c), H^+ / Mo (c)	-0.152	-0.360			
Mo^{3+} / Mo_2^{4+}	(-0.2)				
MoO_2 (c), H^+ / Mo^{3+}	(-0.2)				

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E° (V)	dE°/dT (mV/K)	Basic Solutions (pH = 13.996)	E° (V)	dE°/dT (mV/K)
Tungsten[6-9]					
W^{3+} / W (c)	(0.1)[a]		$W(OH)_3$ (pt) / W (c), OH^-	(-0.6)[a]	
H_2WO_4 (c), H^+ / WO_2 (c)	(0.06)[b]	(-0.31)	WO_2 (pt) / W (c), OH^-	(-0.92)	
WO_3 (c), H^+ / WO_2 (c)	0.036	-0.446	WO_2 (c) / W (c), OH^-	-0.982	-1.197
$H_2W_6O_{21}^{4-}$, H^+ / WO_2 (pt)	(0.01)		WO_4^{2-} / W (c), OH^-	-1.060	-1.36
			WO_4^{2-} / WO_2 (c), OH^-	-1.217	-1.69
$W(OH)_2^{2+}$, H^+ / W (c)	(-0.05)		WO_4^{2-} / WO_2 (pt), OH^-	(-1.34)	
$H_2W_6O_{21}^{4-}$, H^+ / W (c)	(-0.06)	(-0.33)	WO_2 (pt) / $W(OH)_3$ (pt), OH^-	(-1.7)[a]	
$H_2W_6O_{21}^{4-}$, H^+ / $W(OH)_2^{2+}$	(-0.07)				
H_2WO_4 (c), H^+ / W (c)	(-0.08)[b]	(-0.34)			
WO_2 (pt), H^+ / W (c)	(-0.09)				
WO_3 (c), H^+ / W (c)	-0.091	-0.389			
WO_2 (c), H^+ / W (c)	-0.154	-0.361			
$W(OH)_2^{2+}$, H^+ / W^{3+}	(-0.5)[a]				
WO_2 (pt), H^+ / W^{3+}	(-0.7)[a]				
WO_2 (c), H^+ / W^{3+}	(-0.9)[a]				
Manganese[6-10]					
H_3MnO_4, H^+ / MnO_2 (c, β)	(2.9)		MnO_4^{3-} / MnO_2 (c, β), OH^-	0.93	
			MnO_4^{3-} / MnO_2 (pt), OH^-	(0.76)	
H_3MnO_4, H^+ / MnO_2 (pt)	(2.7)		MnO_4^{3-} / $Mn(OH)_6^{2-}$, OH^-	(0.7)	
H_3MnO_4, H^+ / $Mn(OH)_2^{2+}$	(2.5)		MnO_4^{2-} / MnO_2 (c, β), OH^-	0.60	-1.65
			MnO_4^- / MnO_2 (c, β), OH^-	0.588	-1.785
$HMnO_4^-$, H^+ / MnO_2 (c, β)	(2.09)		MnO_4^- / MnO_4^{2-}	0.56	-2.05
			MnO_4^- / MnO_2 (pt), OH^-	(0.53)[b]	(-1.78)
$HMnO_4^-$, H^+ / MnO_2 (pt)	(2.00)		MnO_4^{2-} / MnO_2 (pt), OH^-	(0.51)[b]	(-1.64)
$HMnO_4^-$, H^+ / $Mn(OH)_2^{2+}$	(1.9)		MnO_4^- / $Mn(OH)_6^{2-}$, OH^-	(0.50)	
			MnO_4^{2-} / $Mn(OH)_6^{2-}$, OH^-	(0.5)	
MnO_4^-, H^+ / MnO_2 (c, β)	1.692	-0.671	MnO_4^{2-} / MnO_4^{3-}	0.27	
MnO_4^-, H^+ / MnO_2 (pt)	(1.63)[b]	(-0.66)	MnO_2 (c, β) / MnOOH (c), OH^-	0.15	(-1.4)
MnO_4^-, H^+ / $Mn(OH)_2^{2+}$	(1.57)				
Mn^{3+} / Mn^{2+}	1.56	(1.8)	MnO_2 (c, β) / Mn_2O_3 (c), OH^-	0.146	-1.128
MnO_4^-, H^+ / Mn^{2+}	1.507	-0.646			
Mn_2O_3 (c), H^+ / Mn^{2+}	1.485	-0.926	$Mn(OH)_3$ (pt) / $Mn(OH)_2$ (pt), OH^-	(0.05)	(-0.9)
MnOOH (c), H^+ / Mn^{2+}	1.48	(-0.7)			
$Mn(OH)_2^{2+}$, H^+ / Mn^{2+}	(1.41)		MnO_2 (pt) / $Mn(OH)_2$ (pt), OH^-	(0.04)[b]	(-1.28)
MnO_4^-, H^+ / $MnOH^+$	1.382	-0.648			
MnO_2 (pt), H^+ / Mn^{2+}	(1.32)[b]	(-0.62)	MnO_2 (pt) / $Mn(OH)_3$ (pt), OH^-	(0.03)	(-1.7)
$HMnO_4^-$, H^+ / H_3MnO_4	(1.3)				
$Mn(OH)_2^{2+}$, H^+ / Mn^{3+}	(1.3)		Mn_2O_3 (c) / Mn_3O_4 (c), OH^-	0.002	-1.256
MnO_2 (c, β), H^+ / Mn^{2+}	1.230	-0.609			
MnO_2 (pt), H^+ / Mn^{3+}	(1.08)	(-3.0)	MnOOH (c) / Mn_3O_4 (c), OH^-	-0.02	(-0.6)
MnO_2 (c, β), H^+ / MnOOH (c)	0.98	(-0.5)			
MnO_2 (c, β), H^+ / Mn_2O_3 (c)	0.974	-0.292	MnO_2 (c, β) / $Mn(OH)_2$ (c), OH^-	-0.044	-1.31
			$Mn(OH)_6^{2-}$ / $Mn(OH)_4^-$, OH^-	(-0.1)	
MnO_2 (c, β), H^+ / $MnOH^+$	0.916	-0.614			
MnO_4^-, H^+ / $HMnO_4^-$	(0.90)		$Mn(OH)_4^-$ / $Mn(OH)_4^{2-}$	(-0.1)	

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E° (V)	dE°/dT (mV/K)	Basic Solutions (pH = 13.996)	E° (V)	dE°/dT (mV/K)
Manganese -- Continued					
MnO_2 (c, β), H^+ / Mn^{3+}	0.90	(-3.0)	MnO_2 (c, β) / MnO (c), OH^-	-0.129	-1.116
Mn_2O_3 (c), H^+ / $MnOH^+$	0.858	-0.935	Mn_2O_3 (c) /	-0.234	-1.49
MnOOH (c), H^+ / $MnOH^+$	0.85	(-0.7)	$Mn(OH)_2$ (c), OH^-		
$MnOH^+$, H^+ / Mn (c)	-0.869	-0.125	MnOOH (c) /	-0.24	(-1.3)
Mn^{2+} / Mn (c)	-1.182	-0.129	$Mn(OH)_2$ (c), OH^-		
			Mn_3O_4 (c) /	-0.352	-1.61
			$Mn(OH)_2$ (c), OH^-		
			Mn_2O_3 (c) / MnO (c), OH^-	-0.404	-1.104
			Mn_3O_4 (c) / MnO (c), OH^-	-0.607	-1.028
			$Mn(OH)_4^{2-}$ / Mn (c), OH^-	-1.42	
			MnO (c) / Mn (c), OH^-	-1.480	-1.294
			$Mn(OH)_2$ (pt) / Mn (c), OH^-	-1.560	-1.14
			$Mn(OH)_2$ (c) / Mn (c), OH^-	-1.565	-1.10
Technetium[9]					
TcO_3 (c), H^+ / TcO_2 (c)	(0.76)[a]	(-0.5)	TcO_4^{2-} / TcO_2 (c), OH^-	-0.26	
TcO_4^-, H^+ / TcO_2 (c)	0.738	(-0.70)	TcO_4^{2-} / TcO_2 (pt), OH^-	(-0.29)	
TcO_4^-, H^+ / TcO_2 (pt)	(0.72)	(-0.68)	TcO_4^- / TcO_2 (c), OH^-	-0.366	(-1.82)
TcO_4^-, H^+ / TcO_3 (c)	(0.70)[a]	(-1.2)	TcO_4^- / TcO_2 (pt), OH^-	(-0.38)	(-1.80)
TcO_4^-, H^+ / $Tc(OH)_2^{2+}$	(0.62)		Tc$(OH)_3$ (pt) / Tc (c), OH^-	(-0.4)	
TcO_3 (c), H^+ / $Tc(OH)_2^{2+}$	(0.58)[a]		TcO_4^{2-} / $Tc(OH)_6^{2-}$, OH^-	(-0.4)	
$Tc(OH)_2^{2+}$, H^+ / Tc^{3+}	(0.5)		TcO_4^- / $Tc(OH)_6^{2-}$, OH^-	(-0.46)	
TcO_4^-, H^+ / Tc (c)	0.472	(-0.51)	TcO_4^- / Tc (c), OH^-	-0.474	(-1.46)
$Tc(OH)_2^{2+}$, H^+ / Tc (c)	(0.36)		$Tc(OH)_6^{2-}$ / Tc (c), OH^-	(-0.48)	
Tc^{3+} / Tc^{2+}	(0.3)[a]		TcO_2 (pt) / Tc (c), OH^-	(-0.55)	(-1.21)
Tc^{2+} / Tc (c)	(0.3)[a]		TcO_2 (c) / Tc (c), OH^-	-0.556	(-1.20)
TcO_2 (pt), H^+ / Tc (c)	(0.28)	(-0.37)	TcO_4^- / TcO_4^{2-}	-0.57	
TcO_2 (c), H^+ / Tc (c)	0.272	(-0.36)	$Tc(OH)_6^{2-}$ /	(-0.8)	
TcO_2 (pt), H^+ / Tc^{3+}	(0.2)		Tc$(OH)_3$ (pt), OH^-		
TcO_2 (c), H^+ / Tc^{3+}	(0.2)		TcO_2 (pt) / Tc$(OH)_3$ (pt), OH^-	(-1.1)	
Rhenium[6, 7, 9, 10]					
ReO_4^-, H^+ / ReO_3 (c)	(0.72)[b]	(-1.17)	Re$(OH)_3$ (pt) /	(-0.28)[b]	(-1.07)
ReO_4^-, H^+ / ReO_2 (c)	0.510	(-0.70)	Re (c), OH^-		
Re^{3+} / Re (c)	(0.5)		Re_2O_5 (c) /	(-0.4)	(-1.3)
ReO_4^-, H^+ / ReO_2 (pt)	(0.49)[b]	(-0.68)	ReO_2 (c), OH^-		
ReO_3 (c), H^+ / Re_2O_5 (c)	(0.4)	(-0.4)	$Re(OH)_6^{2-}$ / Re (c), OH^-	(-0.47)	
ReO_3 (c), H^+ / ReO_2 (c)	(0.40)[b]	(-0.47)	ReO_4^{2-} / ReO_2 (c), OH^-	(-0.5)	
Re_2O_5 (c), H^+ / ReO_2 (c)	(0.4)	(-0.5)	ReO_4^{2-} / ReO_2 (pt), OH^-	(-0.5)	
$Re(OH)_2^{2+}$, H^+ / Re (c)	(0.39)		ReO_2 (pt) / Re (c), OH^-	(-0.54)[b]	(-1.21)
ReO_4^-, H^+ / Re (c)	0.376	-0.506	ReO_2 (c) / Re (c), OH^-	-0.552	(-1.20)
ReO_4^-, H^+ / $Re(OH)_2^{2+}$	(0.36)		ReO_4^- / Re (c), OH^-	-0.570	-1.461
ReO_2 (pt), H^+ / Re (c)	(0.29)[b]	(-0.37)	ReO_4^- / ReO_2 (c), OH^-	-0.594	(-1.82)
ReO_2 (c), H^+ / Re (c)	0.276	(-0.36)	ReO_4^{2-} / Re_2O_5 (c), OH^-	(-0.6)	
ReO_3 (c), H^+ /	(0.18)		ReO_4^- / ReO_2 (pt), OH^-	(-0.61)[b]	(-1.80)
$Re(OH)_2^{2+}$			ReO_4^{2-} / $Re(OH)_6^{2-}$, OH^-	(-0.7)	
$Re(OH)_2^{2+}$, H^+ / Re^{3+}	(0.0)		ReO_4^- / $Re(OH)_6^{2-}$, OH^-	(-0.70)	
Re (c), H^+ / ReH	-0.1[a]	1.3	ReO_4^- / ReO_4^{2-}	(-0.8)	
ReO_2 (pt), H^+ / Re^{3+}	(-0.3)		Re (c) / ReH, OH^-	-0.9[a]	0.5

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E° (V)	dE°/dT (mV/K)	Basic Solutions (pH = 13.996)	E° (V)	dE°/dT (mV/K)
Rhenium -- Continued					
ReO_2 (c), H^+ / Re^{3+}	(-0.4)		$Re(OH)_6^{2-}$ /	(-1.0)	
			Re$(OH)_3$ (pt), OH^-		
			ReO_2 (pt) /	(-1.3)[b]	(-1.6)
			Re$(OH)_3$ (pt), OH^-		
Iron[2, 6-9]					
$HFeO_4^-$, H^+ / Fe_2O_3 (c, α)	(2.09)		FeO_4^{2-} / Fe_2O_3 (c, α), OH^-	(0.81)[b]	(-1.52)
$HFeO_4^-$, H^+ / FeOOH (c)	(2.08)		FeO_4^{2-} / FeOOH (c), OH^-	(0.80)[b]	(-1.59)
$HFeO_4^-$, H^+ / Fe^{3+}	(2.07)		FeO_4^{2-} / Fe$(OH)_3$ (pt), OH^-	(0.71)[b]	(-1.67)
$HFeO_4^-$, H^+ / $Fe_2(OH)_2^{4+}$	(2.04)		FeO_4^{2-} / $Fe(OH)_4^-$, OH^-	(0.64)	(-1.55)
$HFeO_4^-$, H^+ / $FeOH^{2+}$	(2.03)		Fe$(OH)_3$ (pt) /	-0.55	(-0.94)
$FeOH^{2+}$, H^+ / Fe^{2+}	0.900	0.096	Fe$(OH)_2$ (pt), OH^-		
$Fe_2(OH)_2^{4+}$, H^+ / Fe^{2+}	0.858	0.485	FeOOH (c) / Fe_3O_4 (c), OH^-	(-0.56)[b]	(-0.38)
Fe^{3+} / Fe^{2+}	0.771	1.175	Fe_2O_3 (c, α) / Fe_3O_4 (c), OH^-	-0.615	-0.992
FeOOH (c), H^+ / Fe^{2+}	(0.74)[b]	(1.05)	$Fe(OH)_4^-$ / $Fe(OH)_4^{2-}$	0.68	
Fe_2O_3 (c, α), H^+ / Fe^{2+}	0.72	-1.25	$Fe(OH)_4^-$ / Fe (c), OH^-	-0.71	(-1.18)
FeOOH (c), H^+ / $FeOH^+$	(0.18)[b]	(-1.06)	$Fe(OH)_4^{2-}$ / Fe (c), OH^-	-0.73	
Fe_2O_3 (c, α), H^+ / $FeOH^+$	0.16	-1.26	Fe$(OH)_3$ (pt) / Fe (c), OH^-	-0.776	-1.062
$FeOH^+$, H^+ / Fe (c)	-0.16	0.07	FeOOH (c) /	(-0.84)[b]	(-1.23)
Fe^{2+} / Fe (c)	-0.44	0.07	Fe$(OH)_2$ (c), OH^-		
			Fe_2O_3 (c, α) /	-0.86	-1.43
			Fe$(OH)_2$ (c), OH^-		
			$Fe_{0.947}O$ (c) / Fe (c), OH^-	-0.870	-1.314
			FeOOH (c) / Fe (c), OH^-	(-0.87)[b]	(-1.14)
			Fe_2O_3 (c, α) / Fe (c), OH^-	-0.881	-1.207
			Fe$(OH)_2$ (pt) / Fe (c), OH^-	-0.89	(-1.12)
			Fe$(OH)_2$ (c) / Fe (c), OH^-	-0.89	-1.09
			Fe_2O_3 (c, α) /	-0.909	-0.952
			$Fe_{0.947}O$ (c), OH^-		
			Fe_3O_4 (c) / Fe (c), OH^-	-0.914	-1.234
			Fe_3O_4 (c) / Fe$(OH)_2$ (c), OH^-	-0.98	-1.65
			Fe_3O_4 (c) / $Fe_{0.947}O$ (c), OH^-	-1.085	-0.927
Ruthenium[6-10]					
RuO_4^-, H^+ / RuO_3 (c)	(1.9)[a]		RuO_4OH^- / RuO_4^-, OH^-	0.85	
RuO_4^-, H^+ / RuO_2 (c)	(1.66)		RuO_4OH^- / RuO_2 (c), OH^-	(0.63)	
RuO_4^-, H^+ / RuO_2^{2+}	(1.6)[a]		RuO_4^- / RuO_4^{2-}	0.59	
RuO_4^-, H^+ / $Ru(OH)_2^{2+}$	1.53		RuO_4OH^- / RuO_2 (pt), OH^-	0.54	
RuO_3 (c), H^+ / RuO_2 (c)	(1.5)[a]		RuO_4OH^- / $Ru(OH)_6^{2-}$, OH^-	(0.54)	
RuO_2^{2+}, H^+ / $Ru(OH)_2^{2+}$	(1.5)[a]		RuO_4^{2-} / RuO_2 (c), OH^-	(0.54)	
RuO_4 (c), H^+ / RuO_2 (c)	(1.48)[b]	(-0.58)	RuO_4^{2-} / RuO_2 (pt), OH^-	0.35	
RuO_4 (c), H^+ / RuO_3 (c)	(1.4)[a]		RuO_4^{2-} / $Ru(OH)_6^{2-}$	(0.3)	
RuO_4, H^+ / $Ru(OH)_2^{2+}$	1.40		RuO_4OH^- / Ru (c), OH^-	0.193	
RuO_4, H^+ / RuO_2^{2+}	(1.3)[a]		$Ru(OH)_4^-$ / Ru (c), OH^-	(0.0)	
RuO_4, H^+ / Ru (c)	1.038	-0.446	Ru$(OH)_3$ (pt) / Ru (c), OH^-	(-0.06)	
RuO_4 (c), H^+ / Ru (c)	1.032	-0.467	$Ru(OH)_6^{2-}$ / Ru (c), OH^-	(-0.15)	
RuO_4 / RuO_4^-	0.99		RuO_2 (pt) / Ru (c), OH^-	-0.15	
RuO_4 (c) / RuO_4^-	0.94		RuO_2 (c) / Ru (c), OH^-	(-0.25)[b]	(-1.20)

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Ruthenium -- Continued					
$Ru(OH)_2^{2+}, H^+ / Ru^{3+}$	(0.9)		RuO_2 (pt) / $Ru(OH)_3$ (pt), OH^-	(-0.4)	
Ru^{2+} / Ru (c)	(0.8)		$Ru(OH)_6^{2-} / Ru(OH)_4^-, OH^-$	(-0.6)	
$Ru(OH)_2^{2+}, H^+ / Ru$ (c)	0.68				
Ru^{3+} / Ru (c)	(0.60)				
RuO_2 (c), H^+ / Ru (c)	(0.38)[b]	(-0.36)			
RuO_2 (c), H^+ / Ru^{3+}	(0.5)				
Ru^{3+} / Ru^{2+}	0.24				
Osmium[1, 6-9]					
OsO_2^{2+} / OsO_2 (pt)	(1.2)[a]		$OsO_3(OH)_3^{2-}$ / $OsO_2(OH)_4^{2-}, OH^-$	(0.3)	
OsO_3 (c), H^+ / OsO_2 (c)	(1.1)[a]				
$OsO_2^{2+}, H^+ / Os(OH)_2^{2+}$	(1.1)[a]		$OsO_4OH^- / OsO_2(OH)_4^{2-}, OH^-$	(0.3)	
OsO_4 (c, y), H^+ / OsO_2 (c)	1.02	(-0.56)	$OsO_4OH^- / OsO_3(OH)_3^{2-}$	(0.2)	
$OsO_4, H^+ / OsO_2$ (pt)	0.964		$Os(OH)_6^{3-} / Os$ (c), OH^-	(0.2)	
$OsO_4, H^+ / Os(OH)_2^{2+}$	(0.91)		OsO_4OH^- / OsO_2 (c), OH^-	0.17	
OsO_4 (c, y), H^+ / OsO_3 (c)	(0.9)[a]		OsO_4OH^- / OsO_2 (pt), OH^-	0.108	
Os^{3+} / Os (c)	(0.9)		$Os(OH)_3$ (pt) / Os (c), OH^-	(0.1)	
$OsO_4, H^+ / Os$ (c)	0.838	-0.514	$OsO_2(OH)_4^{2-} / OsO_2$ (c), OH^-	(0.1)	
OsO_4 (c, y), H^+ / Os (c)	0.834	-0.458	$OsO_4OH^- / Os(OH)_6^{2-}, OH^-$	(0.09)	
$Os(OH)_2^{2+}, H^+ / Os$ (c)	(0.76)		OsO_4OH^- / Os (c), OH^-	-0.004	
OsO_2 (pt), H^+ / Os (c)	0.712		$Os(OH)_6^{2-} / Os$ (c), OH^-	(-0.09)	
$OsO_4, H^+ / OsO_2^{2+}$	(0.7)[a]		$OsO_2(OH)_4^{2-} / OsO_2$ (pt), OH^-	(-0.1)	
OsO_2 (c), H^+ / Os (c)	0.65	(-0.36)	$OsO_2(OH)_4^{2-}$ / $Os(OH)_6^{2-}, OH^-$	(-0.1)	
$Os(OH)_2^{2+}, H^+ / Os^{3+}$	(0.4)				
OsO_2 (pt), H^+ / Os^{3+}	(0.2)		OsO_2 (pt) / Os (c), OH^-	-0.116	
OsO_2 (c), H^+ / Os^{3+}	(-0.1)		OsO_2 (c) / Os (c), OH^-	-0.18	(-1.20)
			OsO_2 (pt) / $Os(OH)_3$ (pt), OH^-	(-0.8)	
			$Os(OH)_6^{2-} / Os(OH)_6^{3-}$	(-0.8)	
Cobalt[6-9]					
$H_3CoO_4, H^+ / CoO_2$ (c)	(3.0)[a]		CoO_4^{3-} / CoO_2 (c), OH^-	(1.0)[a]	
Co^{3+} / Co^{2+}	1.92	1.23	CoO_2 (c) / Co_2O_3 (c), OH^-	(0.9)	(-1.2)
CoOOH (c), H^+ / Co^{2+}	(1.76)[b]	(-1.01)	CoO_2 (c) / CoOOH (c), OH^-	(0.8)	(-1.4)
CoO_2 (c), H^+ / Co_2O_3 (c)	(1.7)	(-0.4)	$CoO_4^{3-} / Co(OH)_3$ (pt), OH^-	(0.7)[a]	
CoO_2 (c), H^+ / Co^{2+}	(1.7)	(-0.8)	$CoO_4^{3-} / Co(OH)_4^-, OH^-$	(0.7)[a]	
Co_2O_3 (c), H^+ / Co^{2+}	(1.6)	(-1.2)	CoOOH (c) / Co_3O_4 (c), OH^-	(0.70)[b]	(-0.55)
CoO_2 (c), H^+ / CoOOH (c)	(1.6)	(-0.6)	$Co(OH)_3$ (pt) / $Co(OH)_2$ (pt, pk), OH^-	(0.5)	(-1.1)
CoO_2 (c), H^+ / $Co_4(OH)_4^{4+}$	(1.5)		$Co(OH)_3$ (pt) / $Co(OH)_2$ (pt, bl), OH^-	(0.4)	
CoO_2 (c), H^+ / Co^{3+}	(1.4)	(-2.8)			
CoO_2 (c), $H^+ / CoOH^+$	(1.4)	(-0.7)	Co_2O_3 (c) / Co_3O_4 (c), OH^-	(0.3)	(-1.1)
CoOOH (c), H^+ / $Co_4(OH)_4^{4+}$	(1.31)		CoOOH (c) / $Co(OH)_2$ (c), OH^-	(0.20)[b]	(-1.35)
			$Co(OH)_4^- / Co(OH)_4^{2-}$	(0.2)	
Co_2O_3 (c), H^+ / $Co_4(OH)_4^{4+}$	(1.2)		Co_2O_3 (c) / $Co(OH)_2$ (c), OH^-	(0.1)	(-1.5)
			Co_2O_3 (c) / CoO (c), OH^-	(0.0)	(-1.0)
CoOOH (c), $H^+ / CoOH^+$	(1.19)[b]	(-0.80)	Co_3O_4 (c) / $Co(OH)_2$ (c), OH^-	-0.05	-1.75
Co_2O_3 (c), $H^+ / CoOH^+$	(1.1)	(-1.0)	Co_3O_4 (c) / CoO (c), OH^-	-0.16	-1.00
$CoOH^+, H^+ / Co$ (c)	0.003	-0.04	$Co(OH)_4^{2-} / Co$ (c), OH^-	-0.57	
$Co_4(OH)_4^{4+}, H^+ / Co$ (c)	-0.06		$Co(OH)_2$ (pt, bl) / Co (c), OH^-	-0.703	
Co^{2+} / Co (c)	-0.282	0.065	CoO (c) / Co (c), OH^-	-0.709	-1.269
			$Co(OH)_2$ (pt, pk) / Co (c), OH^-	-0.722	-1.04
			$Co(OH)_2$ (c) / Co (c), OH^-	-0.746	-1.02

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Rhodium[6-9]					
RhO_3 (c), H^+ / RhO_2 (c)	(1.8)[a]		RhO_4^{2-} / RhO_2 (c), OH^-	(0.9)[a]	
RhO_3 (c), H^+ / $Rh(OH)_2^{2+}$	(1.6)[a]		RhO_4^{2-} / RhO_2 (pt), OH^-	(0.8)[a]	
			$RhO_4^{2-} / Rh(OH)_6^{2-}, OH^-$	(0.7)[a]	
$Rh(OH)_2^{2+}, H^+ / Rh^{3+}$	(1.6)		RhO_2 (c) / Rh_2O_3 (c), OH^-	(0.4)	(-1.0)
RhO_2 (pt), H^+ / Rh^{3+}	(1.5)		RhO_2 (pt) / $Rh(OH)_3$ (pt, br), OH^-	(0.3)	
RhO_2 (c), H^+ / Rh^{3+}	(1.3)	(-2.5)			
RhO_2 (c), H^+ / Rh_2O_3 (c)	(1.2)	(-0.2)	$Rh(OH)_6^{2-} / Rh(OH)_4^-, OH^-$	(0.3)	
RhO_2 (c), $H^+ / RhOH^{2+}$	(1.1)		$Rh(OH)_4^- / Rh$ (c), OH^-	(0.12)	
Rh^+ / Rh (c)	(1.0)[a]		$Rh(OH)_3$ (pt, y) / Rh (c), OH^-	0.11	
$RhOH^{2+}, H^+ / Rh$ (c)	0.83				
Rh_2^{4+} / Rh (c)	(0.8)		RhO_2 (pt) / $Rh(OH)_3$ (pt, y), OH^-	(0.1)	
Rh_2O_3 (c), H^+ / Rh (c)	(0.77)[b]	(-0.41)			
Rh^{3+} / Rh (c)	0.76	(0.4)	$Rh(OH)_3$ (pt, br) / Rh (c), OH^-	(0.04)	
Rh^{3+} / Rh_2^{4+}	(0.7)				
Rh_2^{4+} / Rh^+	(0.6)[a]		Rh_2O_3 (c) / Rh (c), OH^-	(0.06)[b]	(-1.25)
Iridium[6, 7, 10]					
IrO_3 (c), H^+ / IrO_2 (c)	(1.5)[a]		$IrO_2(OH)_4^{2-} / IrO_2$ (c), OH^-	(0.6)[a]	
IrO_3 (c), H^+ / $Ir(OH)_2^{2+}$	(1.3)[a]		$IrO_2(OH)_4^{2-} / IrO_2$ (pt), OH^-	(0.5)[a]	
			$IrO_2(OH)_4^{2-} / Ir(OH)_6^{2-}, OH^-$	(0.4)[a]	
Ir^{3+} / Ir (c)	(1.0)		$Ir(OH)_6^{3-} / Ir$ (c), OH^-	(0.2)	
$Ir(OH)_2^{2+}, H^+ / Ir$ (c)	(0.84)		$Ir(OH)_3$ (pt) / Ir (c), OH^-	(0.2)	
Ir_2O_3 (c), H^+ / Ir (c)	(0.8)[a]	(-0.42)	$Ir(OH)_6^{2-} / Ir$ (c), OH^-	(0.01)	
IrO_2 (pt), H^+ / Ir (c)	(0.79)		Ir_2O_3 (c) / Ir (c), OH^-	(0.0)[a]	(-1.25)
IrO_2 (c), H^+ / Ir (c)	0.73	(-0.36)	IrO_2 (pt) / Ir (c), OH^-	(-0.04)	
$Ir(OH)_2^{2+}, H^+ / Ir^{3+}$	(0.4)		IrO_2 (c) / Ir (c), OH^-	-0.10	(-1.19)
IrO_2 (c), H^+ / Ir_2O_3 (c)	(0.3)[a]	(-0.2)	IrO_2 (c) / Ir_2O_3 (c), OH^-	(-0.5)[a]	(-1.0)
IrO_2 (pt), H^+ / Ir^{3+}	(0.2)		$Ir(OH)_6^{2-} / Ir(OH)_6^{3-}$	(-0.6)	
IrO_2 (c), H^+ / Ir^{3+}	(-0.1)		IrO_2 (pt) / $Ir(OH)_3$ (pt), OH^-	(-0.7)	
Nickel[6-9]					
Ni^{3+} / Ni^{2+}	(2.3)	(1.1)	NiOOH (c, β) / Ni_3O_4 (c), OH^-	(1.0)	(-0.6)
NiOOH (c, β), H^+ / Ni^{2+}	2.05	(-1.17)			
Ni_2O_3 (c), H^+ / Ni^{2+}	(1.9)	(-1.4)	NiO_2 (c) / Ni_2O_3 (c), OH^-	(0.9)[a]	(-1.2)
NiO_2 (c), H^+ / Ni^{2+}	(1.8)[a]	(-0.9)	$Ni(OH)_4^-$ / Ni(OH)$_2$ (pt), OH^-	(0.7)	
NiO_2 (c), H^+ / Ni_2O_3 (c)	(1.7)[a]	(-0.4)			
NiOOH (c, β), H^+ / $Ni_4(OH)_4^{4+}$	1.64	(-1.0)	NiO_2 (c) / NiOOH (c, β), OH^-	(0.7)[a]	(-1.4)
			NiOOH (c, β) / $Ni(OH)_2$ (c), OH^-	0.52	(-1.35)
NiO_2 (c), H^+ / $Ni_4(OH)_4^{4+}$	(1.6)[a]	(-0.8)			
NiO_2 (c), H^+ / NiOOH (c, β)	(1.5)[a]	(-0.6)	Ni_2O_3 (c) / Ni_3O_4 (c), OH^-	(0.5)	(-1.2)
			$Ni(OH)_4^- / Ni(OH)_4^{2-}$	(0.5)	
NiO_2 (c), $H^+ / NiOH^+$	(1.5)[a]	(-0.7)	Ni_2O_3 (c) / $Ni(OH)_2$ (c), OH^-	(0.4)	(-1.5)
Ni_2O_3 (c), H^+ / $Ni_4(OH)_4^{4+}$	(1.5)	(-1.2)	Ni_2O_3 (c) / NiO (c), OH^-	(0.3)	(-1.2)
			Ni_3O_4 (c) / $Ni(OH)_2$ (c), OH^-	(0.3)	(-1.7)
			Ni_3O_4 (c) / NiO (c), OH^-	(0.2)	(-1.2)
NiOOH (c, β), $H^+ / NiOH^+$	1.47	(-0.9)	$Ni(OH)_4^{2-} / Ni$ (c), OH^-	(-0.56)	
Ni_2O_3 (c), $H^+ / NiOH^+$	(1.3)	(-1.1)	$Ni(OH)_2$ (pt) / Ni (c), OH^-	-0.688	-1.09
NiO_2 (c), H^+ / Ni^{3+}	(1.3)[a]	(-2.9)	NiO (c) / Ni (c), OH^-	-0.696	-1.193
$NiOH^+, H^+ / Ni$ (c)	0.055	(0.0)	$Ni(OH)_2$ (c) / Ni (c), OH^-	-0.714	-1.02
$Ni_4(OH)_4^{4+}, H^+ / Ni$ (c)	-0.031	0.06			
Ni^{2+} / Ni (c)	-0.236	0.146			

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Palladium[6-10]					
PdO_3 (c), H^+ / PdO_2 (c)	(2.0)[a]		PdO_3 (c) / PdO_2 (c), OH^-	(1.2)[a]	
PdO_3 (c), H^+ / $Pd(OH)_2^{2+}$	(1.8)[a]		PdO_4^{2-} / PdO_2 (pt), OH^-	(1.2)[a]	
$Pd(OH)_2^{2+}$, H^+ / Pd^{2+}	(1.54)		PdO_4^{2-} / $Pd(OH)_6^{2-}$, OH^-	(1.1)[a]	
PdO_2 (c), H^+ / PdO (c)	1.47	(-0.4)	PdO_2 (c) / PdO (c), OH^-	0.64	(-1.2)
PdO_2 (pt), H^+ / PdO (pt)	(1.41)[b]	(-0.4)	$Pd(OH)_6^{2-}$ / $Pd(OH)_4^{2-}$, OH^-	(0.59)	
PdO_2 (c), H^+ / $PdOH^+$	1.27		PdO_2 (pt) / PdO (pt), OH^-	(0.58)[b]	(-1.2)
$PdOH^+$, H^+ / Pd (c)	0.983		$Pd(OH)_4^{2-}$ / Pd (c), OH^-	(0.10)	
Pd^{2+} / Pd (c)	0.915	0.12	PdO (pt) / Pd (c), OH^-	0.069	-1.28
PdO (pt), H^+ / Pd (c)	0.897	-0.45	PdO (c) / Pd (c), OH^-	-0.04	-1.16
PdO (c), H^+ / Pd (c)	0.79	-0.33			
Platinum[1, 6, 7, 9, 10]					
PtO_3 (c), H^+ / PtO_2 (c)	(1.7)[a]		PtO_3 (c) / PtO_2 (c), OH^-	(0.9)[a]	
PtO_3 (c), H^+ / $Pt(OH)_2^{2+}$	(1.5)[a]		$PtO_2(OH)_4^{2-}$ / PtO_2 (pt), OH^-	(0.8)[a]	
$PtOH^+$, H^+ / Pt (c)	(1.2)		$PtO_2(OH)_4^{2-}$ / $Pt(OH)_6^{2-}$, OH^-	(0.8)[a]	
Pt^{2+} / Pt (c)	1.18	(-0.05)	$Pt(OH)_4^{2-}$ / Pt (c), OH^-	(0.20)	
$Pt(OH)_2^{2+}$, H^+ / Pt (c)	(1.05)		PtO_2 (pt) / PtO (pt), OH^-	0.18	
PtO_2 (pt), H^+ / PtO (pt)	1.01		$Pt(OH)_6^{2-}$ / Pt (c), OH^-	(0.18)	
PtO_2 (pt), H^+ / Pt (c)	1.00		PtO_2 (pt) / Pt (c), OH^-	0.17	
PtO (pt), H^+ / Pt (c)	0.98	-0.53	PtO (pt) / Pt (c), OH^-	0.15	-1.37
PtO (c), H^+ / Pt (c)	(0.94)	(-0.38)	$Pt(OH)_6^{2-}$ / $Pt(OH)_4^{2-}$, OH^-	(0.15)	
PtO_2 (c), H^+ / Pt (c)	0.92	(-0.36)	PtO (c) / Pt (c), OH^-	(0.11)	(-1.22)
$Pt(OH)_2^{2+}$, H^+ / Pt^{2+}	(0.91)		PtO_2 (c) / Pt (c), OH^-	0.09	(-1.19)
PtO_2 (c), H^+ / PtO (c)	(0.91)	(-0.33)	PtO_2 (c) / PtO (c), OH^-	(0.08)	(-1.17)
PtO_2 (c), H^+ / $PtOH^+$	(0.6)				
Copper[6-8]					
Cu^{3+} / Cu^{2+}	(2.4)	(1.5)	$Cu(OH)_4^-$ / $Cu(OH)_4^{2-}$	(0.8)	
Cu_2O_3 (c), H^+ / Cu^{2+}	(2.0)	(-1.1)	Cu_2O_3 (c) / CuO (c), OH^-	(0.7)	(-1.2)
Cu_2O_3 (c), H^+ / $Cu_2(OH)_2^{2+}$	(1.7)		Cu_2O_3 (c) / $Cu(OH)_2$ (c), OH^-	(0.7)	(-1.5)
			$Cu(OH)_4^{2-}$ / $Cu(OH)_2^-$, OH^-	(-0.1)	
Cu_2O_3 (c), H^+ / $CuOH^+$	(1.5)		$Cu(OH)_2$ (c) / Cu_2O (c), OH^-	-0.110	(-0.77)
$CuOH^+$ / Cu_2O (c)	0.676		$Cu(OH)_4^{2-}$ / Cu (c), OH^-	-0.152	
$CuOH^+$, H^+ / Cu (c)	0.574		CuO (c) / Cu_2O (c), OH	-0.187	-1.109
Cu^+ / Cu (c)	0.518	-0.754	$Cu(OH)_2^-$ / Cu (c), OH^-	(-0.2)	
$Cu_2(OH)_2^{2+}$ / Cu_2O (c)	0.513		$Cu(OH)_2$ (pt) / Cu (c), OH^-	(-0.22)	(-1.08)
$Cu_2(OH)_2^{2+}$, H^+ / Cu (c)	0.493		$Cu(OH)_2$ (c) / Cu (c), OH^-	-0.233	(-1.03)
Cu_2O (c), H^+ / Cu (c)	0.473	-0.453	CuO (pt) / Cu (c), OH^-	(-0.25)	
Cu^{2+} / Cu (c)	0.339	0.011	CuO (c) / Cu (c), OH^-	-0.271	-1.199
Cu^{2+} / Cu_2O (c), H^+	0.206	0.476	Cu_2O (c) / Cu (c), OH^-	-0.355	-1.289
Cu^{2+} / Cu^+	0.161	0.776			
Silver[6-8]					
Ag^{2+} / Ag^+	1.989	0.99	Ag_2O_3 (c) / Ag_2O_2 (c), OH^-	0.887	-1.06
Ag^{3+} / Ag^+	(1.9)		$Ag(OH)_4^{2-}$ / $Ag(OH)_2^-$, OH^-	(0.8)	
Ag_2O_2 (c), H^+ / Ag^+	1.802	0.19	$Ag(OH)_4^-$ / $Ag(OH)_2^-$, OH^-	(0.75)	
Ag^{3+} / Ag^{2+}	(1.8)		Ag_2O_3 (c) / Ag_2O (c), OH^-	0.744	-1.10
Ag_2O_3 (c), H^+ / Ag^+	1.738	-0.02	$Ag(OH)_4^-$ / $Ag(OH)_4^{2-}$	(0.7)	
Ag_2O_3 (c), H^+ / Ag_2O_2 (c)	1.715	-0.23	Ag_2O_2 (c) / Ag_2O (c), OH^-	0.602	-1.13
Ag^+ / Ag (c)	0.7993	-0.989	$Ag(OH)_2^-$ / Ag (c), OH^-	0.563	
			Ag_2O (c) / Ag (c), OH^-	0.343	-1.338

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Gold[1, 6-8, 10]					
Au^{2+} / Au^+	(1.8)[a]		$Au(OH)_2^-$ / Au (c), OH^-	(1.0)	
Au^+ / Au (c)	1.69	(-1.1)	$Au(OH)_4^-$ / Au (c), OH^-	0.600	(-1.2)
Au^{3+} / Au (c)	(1.50)		Au_2O_3 (pt) / Au (c), OH^-	0.535	-1.279
$AuOH^{2+}$, H^+ / Au (c)	1.44		Au_2O_3 (c) / Au (c), OH^-	(0.52)	-1.203
Au^{3+} / Au^+	(1.41)		$Au(OH)_4^-$ / $Au(OH)_2^-$, OH^-	(0.4)	
Au_2O_3 (pt), H^+ / Au (c)	1.363	-0.443	Au (c) / Au^-	(-2.4)[a]	
Au_2O_3 (c), H^+ / Au (c)	(1.35)	-0.367			
$AuOH^{2+}$, H^+ / Au^+	1.32				
Au_2O_3 (pt), H^+ / Au^+	1.20	(-0.1)			
Au_2O_3 (c), H^+ / Au^+	(1.18)	(0.0)			
Au^{3+} / Au^{2+}	(1.0)[a]				
Au (c) / Au^-	(-2.4)[a]				
Zinc[6-8]					
$ZnOH^+$, H^+ / Zn (c)	-0.497	0.03	$Zn(OH)_4^{2-}$ / Zn (c), OH^-	-1.199	
Zn^{2+} / Zn (c)	-0.762	0.119	$Zn(OH)_2$ (pt) / Zn (c), OH^-	-1.222	(-1.04)
			$Zn(OH)_2$ (c, ε) / Zn (c), OH^-	-1.249	-0.999
			ZnO (c) / Zn (c), OH^-	-1.260	-1.160
Cadmium[1, 6-8]					
$CdOH^+$, H^+ / Cd (c)	-0.104	0.02	$Cd(OH)_4^{2-}$ / Cd (c), OH^-	-0.658	
Cd_2^{2+} / Cd (c)	(-0.2)[a]		CdO (c) / Cd (c), OH^-	-0.783	-1.166
Cd^{2+} / Cd (c)	-0.402	-0.029	$Cd(OH)_2$ (pt) / Cd (c), OH^-	-0.808	(-1.06)
Cd^{2+} / Cd_2^{2+}	(-0.6)[a]		$Cd(OH)_2$ (c, β) / Cd (c), OH^-	-0.826	-1.020
Mercury[6-8]					
$Hg(OH)_2$, H^+ / Hg (liq)	1.034	-0.40	$Hg(OH)_3^-$ / Hg (liq), OH^-	0.231	
Hg^{2+} / Hg_2^{2+}	0.908	0.095	$Hg(OH)_2$ / Hg (liq), OH^-	0.206	-1.24
Hg^{2+} / Hg (liq)	0.852	-0.116	HgO (pt) / Hg (liq), OH^-	(0.11)	(-1.17)
$Hg(OH)_2$, H^+ / Hg	0.830	-0.43	HgO (c, γ) / Hg (liq), OH^-	0.0983	-1.125
Hg_2^{2+} / Hg (liq)	0.796	-0.327	HgO (c, r) / Hg (liq), OH^-	0.0977	-1.1206
Hg_2^{2+} / Hg	0.648	0.14			
Hg_2^{2+} / Hg	0.389	-0.38			
Boron[6-8]					
B_{12} (c), H^+ / B_2H_6 (g)	-0.150	-0.296	B_2H_6 (g) / BH_4^-, OH^-	-0.782	-1.123
B_{12} (c), H^+ / BH_4^-	-0.237	-0.460	B_{12} (c) / BH_4^-, OH^-	-0.899	-1.129
B_2H_6 (g), H^+ / BH_4^-	-0.368	-0.705	B_{12} (c) / B_2H_6 (g), OH^-	-0.978	-1.132
$B(OH)_3$, H^+ / BH_4^-	-0.481	-0.472	$B(OH)_4^-$ / BH_4^-, OH^-	-1.241	-1.140
$B(OH)_3$ (c), H^+ / BH_4^-	-0.482	-0.377	$B(OH)_4^-$ / B_2H_6 (g), OH^-	-1.394	-1.146
$B(OH)_3$, H^+ / B_2H_6 (g)	-0.519	-0.394	$B_2(OH)_6^{2-}$ / B_{12} (c), OH^-	(-1.7)	
$B(OH)_3$ (c), H^+ / B_2H_6 (g)	-0.520	-0.267	$B_3O_3(OH)_4^-$ / B_{12} (c), OH^-	-1.763	-1.26
			$B(OH)_4^-$ / B_{12} (c), OH^-	-1.811	-1.160
$B_2(OH)_4$, H^+ / B_{12} (c)	(-0.8)	(-0.49)	$B(OH)_4^-$ / $B_2(OH)_6^{2-}$, OH^-	(-2.0)	
$B_2(OH)_4$ (c), H^+ / B_{12} (c)	(-0.8)	(-0.23)			
$B_3O_3(OH)_4^-$, H^+ / B_{12} (c)	-0.843	-0.33			
$B(OH)_3$, H^+ / B_{12} (c)	-0.889	-0.492			
$B(OH)_3$ (c), H^+ / B_{12} (c)	-0.890	-0.239			
$B(OH)_3$, H^+ / $B_2(OH)_4$	(-1.1)	(-0.50)			
$B(OH)_3$ (c), H^+ / $B_2(OH)_4$ (c)	(-1.1)	(-0.25)			

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Aluminum[6-9]					
$AlOH^{2+}$, H^+ / Al (c)	-1.579	0.28	$Al(OH)_3$ (pt) / Al (c), OH^-	-2.31	-0.97
$Al_2(OH)_2^{4+}$, H^+ / Al (c)	-1.60	0.32	$Al(OH)_4^-$ / Al (c), OH^-	-2.328	-1.13
Al^{3+} / Al (c)	-1.677	0.533	Al_2O_3 (c, α) / Al (c), OH^-	-2.332	-1.140
Al^{3+}, H_2 (g) / AlH_4^-	(-1.78)[a]	(-0.21)	$Al(OH)_3$ (c, α) / Al (c), OH^-	-2.338	-0.927
Al^{3+}, H_2 (g) / AlH_3 (c)	-1.838	-0.138	AlOOH (c, α) / Al (c), OH^-	-2.371	-1.054
Gallium[6-8]					
Ga^+ / Ga (c)	(-0.2)		Ga_2O (c) / Ga (c), OH^-	(-0.9)[a]	(-1.19)
Ga_2^{4+} / Ga (c)	(-0.4)		$Ga(OH)_3$ (pt) / Ga (c), OH^-	-1.242	-0.99
$GaOH^{2+}$, H^+ / Ga (c)	-0.498		GaOOH (c) / Ga (c), OH^-	-1.320	(-1.08)
Ga^{3+} / Ga (c)	-0.549	0.61	Ga_2O_3 (c, β) / Ga (c), OH^-	-1.323	-1.156
Ga_2^{4+} / Ga^+	(-0.6)		$Ga(OH)_4^-$ / Ga (c), OH^-	-1.326	
Ga^{3+} / Ga^+	(-0.7)		GaOOH (c) / Ga_2O (c), OH^-	(-1.5)[a]	(-1.03)
Ga^{3+} / Ga_2^{4+}	(-0.8)		Ga_2O_3 (c, β) / Ga_2O (c), OH^-	(-1.5)[a]	(-1.14)
			$Ga(OH)_4^-$ / Ga_2O (c), OH^-	(-1.5)[a]	
Indium[6-9]					
In^+ / In (c)	-0.126		In_2O (c) / In (c), OH^-	(-0.6)[a]	(-1.12)
$InOH^{2+}$, H^+ / In (c)	-0.259		$In(OH)_3$ (pt) / In (c), OH^-	-0.99	-0.95
In_2^{4+} / In (c)	-0.26		$In(OH)_4^-$ / In (c), OH^-	-1.007	
In^{3+} / In (c)	-0.338	0.42	In_2O_3 (c) / In (c), OH^-	-1.034	-1.131
In_2^{4+} / In^+	-0.40		InOOH (c) / In (c), OH^-	-1.066	(-1.06)
In^{3+} / In^+	-0.444		$In(OH)_4^-$ / In_2O (c), OH^-	(-1.2)[a]	
In^{3+} / In_2^{4+}	-0.49		In_2O_3 (c) / In_2O (c), OH^-	(-1.2)[a]	(-1.14)
			InOOH (c) / In_2O (c), OH^-	(-1.3)[a]	(-1.03)
Thallium[6-8]					
$TlOH^{2+}$, H^+ / Tl^+	1.299		$Tl(OH)_4^-$ / TlOH (c), OH^-	0.099	
Tl^{3+} / Tl^+	1.280	0.97	$Tl(OH)_4^-$ / TlOH, OH^-	0.091	
TlOOH (c), H^+ / Tl^+	1.225	(0.26)	TlOOH (c) / TlOH (c), OH^-	0.015	(-1.14)
Tl_2O_3 (c), H^+ / Tl^+	1.165	(0.15)	$Tl(OH)_3$ (pt) / Tl (c), OH^-	(-0.03)	(-1.00)
$TlOH^{2+}$, H^+ / Tl (c)	0.754		Tl_2O_3 (c) / TlOH (c), OH^-	-0.046	(-1.24)
Tl^{3+} / Tl (c)	0.741	0.21	$Tl(OH)_4^-$ / Tl (c), OH^-	-0.067	
TlOOH (c), H^+ / Tl (c)	0.705	(-0.26)	TlOOH (c) / Tl (c), OH^-	-0.123	(-1.10)
Tl_2O_3 (c), H^+ / Tl (c)	0.665	(-0.33)	Tl_2O_3 (c) / Tl (c), OH^-	-0.163	(-1.17)
Tl^+ / Tl (c)	-0.336	-1.312	TlOH / Tl (c), OH^-	-0.382	
			TlOH (c) / Tl (c), OH^-	-0.399	-1.029

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Carbon[1, 6, 7]					
CH_3OH, H^+ / CH_4 (g)	0.583	-0.039	CH_3OH / CH_4 (g), OH^-	-0.245	-0.875
$HCHO_2$, H^+ / C (c)	0.528	-0.77	CH_2O / CH_3OH, OH^-	-0.591	-1.35
CO (g), H^+ / C (c)	0.5184	-1.3084	CHO_2^- / C (c), OH^-	-0.603	-1.65
CH_3OH, H^+ / CH_4	0.498	-0.570	$C_2O_4^{2-}$ / CHO_2^-, OH^-	-0.683	-0.80
H_2CO_3, H^+ / C (c)	0.27	(-0.56)	C (c) / CH_4 (g), OH^-	-0.6965	-1.0452
CH_2O, H^+ / CH_3OH	0.237	-0.51	CO_3^{2-} / CH_4 (g), OH^-	-0.731	-1.135
CO_2, H^+ / C (c)	0.229	-0.604	CO_3^{2-} / C (c), OH^-	-0.766	-1.225
CO_2 (g), H^+ / C (c)	0.2073	-0.8530	CO_3^{2-} / CHO_2^-, OH^-	-0.930	-0.80
$H_2C_2O_4$, H^+ / $HCHO_2$	0.204	(-0.12)	C (c) / CH_3OH, OH^-	-1.148	-1.215
CO_2 (g), H^+ / CH_4 (g)	0.1694	-0.5311	CHO_2^- / CH_2O, OH^-	-1.160	-1.52
C (c), H^+ / CH_4 (g)	0.1315	-0.2092	CO_3^{2-} / $C_2O_4^{2-}$, OH^-	-1.176	-0.798
C (c), H^+ / CH_4	0.089	-0.475			
H_2CO_3, H^+ / $HCHO_2$	0.01	(-0.35)			
$HCHO_2$, H^+ / CH_2O	-0.029	-0.63			
CO_2, H^+ / $HCHO_2$	-0.070	-0.44			
CO_2 (g), H^+ / CO (g)	-0.1038	-0.3977			
CO_2 (g), H^+ / $HCHO_2$	-0.114	-0.94			
H_2CO_3, H^+ / $H_2C_2O_4$	-0.19	(-0.58)			
C (c), H^+ / CH_3OH	-0.320	-0.379			
CO_2, H^+ / $H_2C_2O_4$	-0.343	(-0.77)			
CO_2 (g), H^+ / $H_2C_2O_4$	-0.432	(-1.76)			
Silicon[6-8]					
Si (c), H^+ / SiH_4 (g)	-0.147	-0.196	Si (c) / SiH_4 (g), OH^-	-0.975	-1.032
SiO_2 (c, quartz), H^+ / SiH_4 (g)	-0.569	-0.285	$H_2SiO_4^{2-}$ / SiH_4 (g), OH^-	-1.405	(-1.03)
			SiO (c) / Si (c), OH^-	(-1.6)[a]	(-1.2)
SiO (c), H^+ / Si (c)	(-0.8)[a]	(-0.4)	$H_3SiO_4^-$ / Si (c), OH^-	-1.820	-1.19
H_4SiO_4, H^+ / Si (c)	-0.931	-0.395	$H_2SiO_4^{2-}$ / Si (c), OH^-	-1.834	(-1.03)
SiO_2 (pt), H^+ / Si (c)	-0.973	-0.40	$H_2SiO_4^{2-}$ / SiO (c), OH^-	(-2.0)[a]	(-0.8)
SiO_2 (c, quartz), H^+ / Si (c)	-0.990	-0.374			
SiO_2 (c, quartz), H^+ / SiO (c)	(-1.2)[a]	(-0.3)			
Germanium[6-8]					
$Ge(OH)_2$, H^+ / Ge (c)	0.11		$Ge(OH)_3^-$ / Ge (c), OH^-	(-0.87)	
Ge^{2+} / Ge (c)	(0.1)		$H_3GeO_4^-$ / Ge (c), OH^-	-0.936	
GeO (pt, y), H^+ / Ge (c)	0.04		$H_2GeO_4^{2-}$ / Ge (c), OH^-	-0.957	
GeO (c, br), H^+ / Ge (c)	0.000	-0.41	$H_3GeO_4^-$ / $Ge(OH)_3^-$, OH^-	(-1.01)	
H_4GeO_4, H^+ / Ge (c)	-0.039	-0.429	$H_2GeO_4^{2-}$ / $Ge(OH)_3^-$, OH^-	(-1.05)	
GeO_2 (c, hex), H^+ / Ge (c)	-0.059	-0.377	Ge (c) / GeH_4 (g), OH^-	-1.122	-1.031
GeO_2 (c, tetr), H^+ / Ge (c)	-0.104	(-0.34)			

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Germanium -- Continued					
GeO_2 (c, hex), H^+ / GeO (c, br)	-0.118	-0.34			
H_4GeO_4, H^+ / GeO (pt, y)	-0.12				
H_4GeO_4, H^+ / $Ge(OH)_2$	-0.19				
H_4GeO_4, H^+ / Ge^{2+}	(-0.2)				
GeO_2 (c, hex), H^+ / Ge^{2+}	(-0.2)				
GeO_2 (c, tetr), H^+ / GeO (c, br)	-0.207	(-0.26)			
Ge (c), H^+ / GeH_4 (g)	-0.294	-0.195			
GeO_2 (c, tetr), H^+ / Ge^{2+}	(-0.3)				
Tin[6-8]					
$Sn(OH)_3^+$, H^+ / Sn^{2+}	0.142		$Sn(OH)_3^-$ / Sn (c), OH^-	-0.892	
$Sn(OH)_2^{2+}$, H^+ / Sn^{2+}	(0.10)		$Sn(OH)_6^{2-}$ / SnO (pt), OH^-	(-0.90)	
SnO_2 (pt, α), H^+ / Sn^{2+}	(0.08)[b]	(-0.46)	$Sn(OH)_6^{2-}$ / Sn (c), OH^-	(-0.91)	
SnO_2 (pt, β), H^+ / Sn^{2+}	0.01		SnO (pt) / Sn (c), OH^-	-0.917	-1.32
$SnOH^+$, H^+ / Sn (c)	-0.041		$Sn(OH)_6^{2-}$ / $Sn(OH)_3^-$, OH^-	(-0.93)	
SnO_2 (c), H^+ / Sn^{2+}	-0.094	-0.31	SnO (c) / Sn (c), OH^-	-0.930	-1.176
SnO_2 (c), H^+ / Sn (c)	-0.117	-0.316	SnO_2 (c) / Sn (c), OH^-	-0.945	-1.152
Sn^{2+} / Sn (c)	-0.141	-0.32	SnO_2 (c) / SnO (c), OH^-	-0.961	-1.129
SnO_2 (c), H^+ / $SnOH^+$	-0.194		Sn (c) / SnH_4 (g), OH^-	-1.316	-1.057
Sn (c), H^+ / SnH_4 (g)	-0.488	-0.221			
Lead[6-8]					
$Pb(OH)_2^{2+}$, H^+ / Pb^{2+}	(1.70)		$Pb(OH)_6^{2-}$ / Pb(OH)$_2$ (pt), OH^-	(0.32)	
PbO_2 (c), H^+ / Pb^{2+}	1.458	-0.253			
PbO_2 (c), H^+ / $PbOH^+$	1.230		$Pb(OH)_6^{2-}$ / $Pb(OH)_3^-$, OH^-	(0.30)	
$PbOH^+$, H^+ / Pb (c)	0.102		PbO_2 (c) / Pb_3O_4 (c), OH^-	0.269	-1.136
Pb^{2+} / Pb (c)	-0.126	-0.395	PbO_2 (c) / PbO (c, r), OH^-	0.254	-1.161
Pb (c), H^+ / PbH_4 (g)	(-0.7)	(-0.22)	PbO_2 (c) / PbO (c, y), OH^-	0.248	-1.150
			PbO_2 (c) / $Pb(OH)_2$ (c), OH^-	0.247	-1.37
			Pb_3O_4 (c) / PbO (c, r), OH^-	0.224	-1.211
			Pb_3O_4 (c) / PbO (c, y), OH^-	0.207	-1.177
			Pb_3O_4 (c) / $Pb(OH)_2$ (c), OH^-	0.202	-1.86
			$Pb(OH)_3^-$ / Pb (c), OH^-	-0.538	
			$Pb(OH)_2$ (pt) / Pb (c), OH^-	(-0.56)	(-1.00)
			$Pb(OH)_2$ (c) / Pb (c), OH^-	-0.571	-0.95
			PbO (c, y) / Pb (c), OH^-	-0.573	-1.170
			PbO (c, r) / Pb (c), OH^-	-0.578	-1.159
			Pb (c) / PbH_4 (g), OH^-	(-1.5)	(-1.06)

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Nitrogen[1, 6, 7]					
$H_2N_2O_2$, H^+ / N_2 (g)	(2.65)[b]	(0.06)	$N_2O_2^{2-}$ / N_2 (g), OH^-	(1.52)[b]	(-0.65)
HN_3, H^+ / N_2 (g), NH_4^+	2.079	0.147	N_2O (g) / N_2 (g), OH^-	0.941	-1.297
N_2O (g), H^+ / N_2 (g)	1.769	-0.461	NO_2 (g) / NO_2^-	0.917	-1.712
NO (g), H^+ / N_2 (g)	1.678	-0.9098	N_2O_4 (g) / NO_2^-	0.892	-0.801
NO (g), H^+ / N_2O (g)	1.587	-1.359	NO (g) / N_2 (g), OH^-	0.850	-1.7458
HNO_2, H^+ / N_2 (g)	1.447	-0.390	NO (g) / N_2O (g), OH^-	0.759	-2.195
NH_3OH^+, H^+ / $N_2H_5^+$	(1.40)[b]	(-0.60)	N_3^- / N_2 (g), NH_3, OH^-	0.700	-0.921
NH_3OH^+, H^+ / NH_4^+	(1.33)[b]	(-0.44)	NH_2OH / N_2H_4, OH^-	(0.69)[b]	(-1.68)
$N_2H_5^+$, H^+ / NH_4^+	1.250	-0.28	NO_2^- / N_2 (g), OH^-	0.406	-1.462
NO_3^-, H^+ / N_2 (g)	1.244	-0.347	NH_2OH / NH_3, OH^-	(0.40)[b]	(-1.38)
NO_2 (g), H^+ / HNO_2	1.108	-1.582	NO_3^- / N_2 (g), OH^-	0.251	-1.350
N_2O_4 (g), H^+ / HNO_2	1.083	-0.671	NO (g) / $N_2O_2^{2-}$	(0.18)[b]	(-2.84)
HNO_2, H^+ / NO (g)	0.984	0.649	N_2H_4 / NH_3, OH^-	0.111	-1.07
NO_3^-, H^+ / NO (g)	0.955	0.028	NO_3^- / NO_2^-, OH^-	0.017	-1.183
NO_3^-, H^+ / HNO_2	0.940	-0.282	NO_3^- / NH_3, OH^-	-0.119	-1.391
NO_3^-, H^+ / NH_4^+	0.880	-0.448	NO_3^- / NO (g), OH^-	-0.149	-1.086
HNO_2, H^+ / NH_4^+	0.860	-0.503	NO_2^- / $N_2O_2^{2-}$, OH^-	(-0.15)[b]	(-1.87)
HNO_2, H^+ / $H_2N_2O_2$	(0.85)[b]	(-0.61)	NO_2^- / NH_3, OH^-	-0.165	-1.460
NO_3^-, H^+ / N_2O_4 (g)	0.798	0.107	NO_2^- / NO (g), OH^-	-0.481	-0.893
NO_3^-, H^+ / NO_2 (g)	0.773	1.018	N_2 (g) / NH_3, OH^-	-0.736	-1.459
NO (g), H^+ / $H_2N_2O_2$	(0.71)[b]	(-1.87)	$N_2O_2^{2-}$ / NH_2OH, OH^-	(-0.74)[b]	(-1.13)
$H_2N_2O_2$, H^+ / NH_3OH^+	(0.41)[b]	(-0.45)	NO_3^- / N_2O_4 (g), OH^-	-0.858	-1.565
N_2 (g), H^+ / NH_4^+	0.274	-0.616	NO_3^- / NO_2 (g), OH^-	-0.883	-0.654
N_2 (g), H^+ / $N_2H_5^+$	-0.214	-0.78	N_2 (g) / N_2H_4, OH^-	-1.160	-1.65
N_2 (g), H^+ / NH_3OH^+	(-1.83)[b]	(-0.96)	N_2 (g) / NH_2OH, OH^-	(-3.01)[b]	(-1.62)
N_2 (g), H^+ / HN_3	-3.334	-2.141	N_2 (g) / N_3^-	-3.608	-2.536
Phosphorus[1, 6, 7]					
$H_4P_2O_6$, H^+ / H_2PHO_3	(0.3)		$P_2O_6^{4-}$ / PHO_3^{2-}, OH^-	(-0.4)	
P_2H_4 (liq), H^+ / PH_3 (g)	(0.06)[b]	(0.48)	P_2H_4 (liq) / PH_3 (g), OH^-	(-0.77)[b]	(-0.36)
P_4 (c, w), H^+ / PH_3 (g)	-0.046	-0.093	P_4 (c, w) / PH_3 (g), OH^-	-0.874	-0.929
P (c, r), H^+ / PH_3 (g)	-0.088	-0.030	P (c, r) / PH_3 (g), OH^-	-0.916	-0.866
P_4 (c, w), H^+ / P_2H_4 (liq)	(-0.10)[b]	(-0.38)	P_4 (c, w) / P_2H_4 (liq), OH^-	(-0.93)[b]	(-1.22)
			P (c, r) / P_2H_4 (liq), OH^-	(-0.99)[b]	(-1.12)
HPH_2O_2, H^+ / PH_3 (g)	(-0.15)[b]	(-0.13)	PO_4^{3-} / PHO_3^{2-}, OH^-	(-1.14)[b]	(-0.53)
P (c, r), H^+ / P_2H_4 (liq)	(-0.16)[b]	(-0.28)	$PH_2O_2^-$ / PH_3 (g), OH^-	(-1.17)[b]	(-1.07)
H_2PHO_3, H^+ / PH_3 (g)	(-0.26)[b]	(-0.21)	PO_4^{3-} / PH_3 (g), OH^-	-1.247	-0.91
H_3PO_4, H^+ / PH_3 (g)	-0.269	-0.247	PHO_3^{2-} / PH_3 (g), OH^-	(-1.28)[b]	(-1.03)
H_3PO_4, H^+ / H_2PHO_3	(-0.30)[b]	(-0.36)	PO_4^{3-} / P (c, r), OH^-	-1.445	-0.93
HPH_2O_2, H^+ / P (c, r)	(-0.33)[b]	(-0.44)	PO_4^{3-} / P_4 (c, w), OH^-	-1.470	-0.89
H_3PO_4, H^+ / P (c, r)	-0.377	-0.378	PHO_3^{2-} / $PH_2O_2^-$, OH^-	(-1.51)[b]	(-0.95)
H_3PO_4, H^+ / P_4 (c, w)	-0.402	-0.340	PHO_3^{2-} / P (c, r), OH^-	(-1.65)[b]	(-1.20)
H_2PHO_3, H^+ / P (c, r)	(-0.43)[b]	(-0.39)	PHO_3^{2-} / P_4 (c, w), OH^-	(-1.69)[b]	(-1.13)
HPH_2O_2, H^+ / P_4 (c, w)	(-0.45)[b]	(-0.25)	PO_4^{3-} / $P_2O_6^{4-}$, OH^-	(-1.9)	
H_2PHO_3, H^+ / P_4 (c, w)	(-0.47)[b]	(-0.33)	$PH_2O_2^-$ / P (c, r), OH^-	(-1.92)[b]	(-1.70)
H_2PHO_3, H^+ / HPH_2O_2	(-0.48)[b]	(-0.37)	$PH_2O_2^-$ / P_4 (c, w), OH^-	(-2.04)[b]	(-1.51)
H_3PO_4, H^+ / $H_4P_2O_6$	(-0.9)				

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Arsenic[6-8]					
As_2O_4 (c), H^+ / As_4O_6 (c, cu)	(0.67)[b]	(-0.33)	$H_2AsO_3^-$ / As (c), OH^-	-0.674	-1.327
			$HAsO_3^{2-}$ / As (c), OH^-	-0.68	
As_2O_4 (c), H^+ / H_3AsO_3	(0.63)[b]	(0.05)	AsO_4^{3-} / As (c), OH^-	-0.702	-1.024
H_3AsO_4, H^+ / As_4O_6 (c, cu)	0.595	-0.447	AsO_4^{3-} / $HAsO_3^{2-}$, OH^-	-0.74	
			AsO_4^{3-} / $H_2AsO_3^-$, OH^-	-0.745	-0.570
H_3AsO_4, H^+ / H_3AsO_3	0.575	-0.257	As (c) / AsH_3 (g), OH^-	-1.066	-0.865
H_3AsO_4, H^+ / $As(OH)_2^+$	0.566				
H_3AsO_4, H^+ / As_2O_4 (c)	(0.52)[b]	(-0.56)			
$As(OH)_2^+$, H^+ / As (c)	0.253				
H_3AsO_3, H^+ / As (c)	0.2475	-0.505			
As_4O_6 (c, cu), H^+ / As (c)	0.2340	-0.378			
As (c), H^+ / AsH_3 (g)	-0.238	-0.029			
Antimony[6-8, 10]					
$Sb(OH)_5$, H^+ / Sb_2O_4 (c)	0.98	0.18	Sb_2O_4 (c) / Sb_4O_6 (c, cu), OH^-	-0.437	-1.237
Sb_2O_5 (c), H^+ / Sb_2O_4 (c)	0.76	-0.303			
$Sb(OH)_5$, H^+ / $Sb(OH)_2^+$	0.57		Sb_2O_4 (c) / Sb_2O_3 (c, rh), OH^-	-0.477	-1.172
Sb_2O_5 (c), H^+ / Sb_4O_6 (c, cu)	0.57	-0.352	$Sb(OH)_6^-$ / Sb_4O_6 (c, cu), OH^-	-0.48	
Sb_2O_5 (c), H^+ / Sb_2O_3 (c, rh)	0.55	-0.320	$Sb(OH)_6^-$ / Sb_2O_3 (c, rh), OH^-	-0.50	
$Sb(OH)_5$, H^+ / $Sb(OH)_3$	0.54	-0.34	$Sb(OH)_6^-$ / Sb_2O_4 (c), OH^-	-0.52	
Sb_2O_4 (c), H^+ / Sb_4O_6 (c, cu)	0.391	-0.401	$Sb(OH)_6^-$ / $Sb(OH)_4^-$, OH^-	-0.56	
Sb_2O_4 (c), H^+ / Sb_2O_3 (c, rh)	0.351	-0.336	$Sb(OH)_4^-$ / Sb (c), OH^-	-0.640	
			Sb_2O_3 (c, rh) / Sb (c), OH^-	-0.681	-1.205
$Sb(OH)_3$, H^+ / Sb (c)	0.231	-0.196	Sb_4O_6 (c, cu) / Sb (c), OH^-	-0.694	-1.183
$Sb(OH)_2^+$, H^+ / Sb (c)	0.208		Sb (c) / SbH_3 (g), OH^-	-1.338	-0.866
Sb_2O_4 (c), H^+ / $Sb(OH)_2^+$	0.169				
Sb_2O_3 (c, rh), H^+ / Sb (c)	0.147	-0.369			
Sb_4O_6 (c, cu), H^+ / Sb (c)	0.134	-0.347			
Sb (c), H^+ / SbH_3 (g)	-0.510	-0.030			
Bismuth[1, 6-8, 10]					
$Bi(OH)_5$, H^+ / Bi_2O_4 (c)	2.4		$Bi(OH)_6^-$ / Bi_2O_4 (c), OH^-	(1.0)	
Bi_2O_5 (c), H^+ / Bi_2O_4 (c)	(2.0)	(-0.3)	$Bi(OH)_6^-$ / BiOOH (c), OH^-	(0.8)	
$Bi(OH)_5$, H^+ / $Bi_6(OH)_{12}^{6+}$	2.0		$Bi(OH)_6^-$ / Bi_2O_3 (c), OH^-	(0.8)	
			$Bi(OH)_6^-$ / $Bi(OH)_3$ (pt), OH^-	(0.7)	
$Bi(OH)_5$, H^+ / Bi^{3+}	2.0		$Bi(OH)_6^-$ / $Bi(OH)_4^-$, OH^-	(0.7)	
$Bi(OH)_5$, H^+ / $BiOH^{2+}$	2.0		Bi_2O_4 (c) / Bi_4O_7 (c), OH^-	0.62	(-1.15)
Bi_2O_5 (c), H^+ / Bi^{3+}	(1.8)	(-1.1)	Bi_2O_4 (c) / BiOOH (c), OH^-	0.59	(-1.38)
Bi_2O_4 (c), H^+ / Bi^{3+}	1.59	(-2.0)	Bi_4O_7 (c) / BiOOH (c), OH^-	0.56	(-1.62)
Bi^+ / Bi (c)	(0.5)[a]		Bi_2O_4 (c) / Bi_2O_3 (c), OH^-	0.56	(-1.17)
$BiOH^{2+}$, H^+ / Bi (c)	0.329	(0.05)	Bi_4O_7 (c) / Bi_2O_3 (c), OH^-	0.51	(-1.19)
Bi^{3+} / Bi (c)	0.308	(0.18)	$Bi(OH)_4^-$ / Bi (c), OH^-	-0.366	
$Bi_6(OH)_{12}^{6+}$, H^+ / Bi (c)	0.307		$Bi(OH)_3$ (pt) / Bi (c), OH^-	(-0.38)[b]	(-1.04)
Bi^{3+} / Bi^+	(0.2)[a]		Bi_2O_3 (c) / Bi (c), OH^-	-0.452	-1.216
Bi (c), H^+ / BiH_3 (g)	(-0.8)	(-0.03)	BiOOH (c) / Bi (c), OH^-	-0.461	(-1.14)
			Bi (c) / BiH_3 (g), OH^-	(-1.6)	(-0.87)

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Oxygen[6, 7, 9]					
O_3^-, H^+ / O_2 (g), H_2O (liq)	(3.3)		O (g) / OH^-	1.6021	-1.9844
			O_3^- / O_2 (g), OH^-	(1.6)	
OH, H^+ / H_2O (liq)	(2.56)	(-1.0)	O^- / OH^-	(1.60)	
O (g), H^+ / H_2O (liq)	2.4301	-1.1484	O_3 (g) / O_2 (g), OH^-	1.247	-1.325
O_3 (g), H^+ / O_2 (g), H_2O (liq)	2.075	-0.489	O_3 (g) / O_3^-	(0.9)	
			HO_2^- / OH^-	0.867	-1.330
H_2O_2, H^+ / H_2O (liq)	1.763	-0.698	O_2 (g) / OH^-	0.4011	-1.6816
HO_2, H^+ / H_2O_2	1.44	(-0.7)	O_2^- / HO_2^-, OH^-	0.20	(-1.9)
O_2, H^+ / H_2O (liq)	1.272	-0.601	HO_2^- / O^-, OH^-	(0.13)	
O_2 (g), H^+ / H_2O (liq)	1.2291	-0.8456	O_2 (g) / HO_2^-, OH^-	-0.065	-2.033
H_2O_2, H^+ / OH, H_2O (liq)	(0.96)	(-0.4)	O_2 (g) / O_2^-	-0.33	(-2.2)
O_3 (g) / O_3^-	(0.9)				
O_2 (g), H^+ / H_2O_2	0.695	-0.993			
O_2 (g), H^+ / HO_2	-0.05	(-1.3)			
Sulfur[6, 7, 10]					
$HS_2O_4^-$, H^+ / $HS_2O_3^-$	(0.79)	(-0.50)	$S_4O_6^{2-}$ / $S_2O_3^{2-}$	0.024	-1.31
SO_2, H^+ / $S_4O_6^{2-}$	0.539	-1.11	$S_2O_4^{2-}$ / $S_2O_3^{2-}$, OH^-	-0.002	-1.27
$HS_2O_3^-$, H^+ / S_8 (c)	(0.47)	(-0.41)	$S_2O_6^{2-}$ / SO_3^{2-}	(-0.16)[b]	(-1.81)
SO_2, H^+ / S_8 (c)	0.450	-0.652	S_2^{2-} / SH^-, OH^-	(-0.45)[b]	(-0.71)
SO_2, H^+ / $HS_2O_3^-$	(0.43)	(-0.89)	S_8 (c) / SH^-, OH^-	-0.476	-0.934
$S_4O_6^{2-}$, H^+ / S_8 (c)	0.396	-0.38	S_8 (c) / S_2^{2-}	(-0.50)[b]	(-1.16)
$S_2O_6^{2-}$, H^+ / SO_2	(0.37)[b]	(0.90)	SO_3^{2-} / $S_2O_3^{2-}$, OH^-	-0.566	-1.06
SO_4^{2-}, H^+ / S_8 (c)	0.353	-0.173	S_8 (c) / S^{2-}	-0.57	-1.34
HSO_4^-, H^+ / S_8 (c)	0.333	-0.366	SO_3^{2-} / SH^-, OH^-	-0.598	-1.13
SO_4^{2-}, H^+ / $S_4O_6^{2-}$	0.321	-0.03	$S_2O_3^{2-}$ / SH^-, OH^-	-0.614	-1.16
H_2S_2 (liq), H^+ / H_2S (g)	(0.30)[b]	(0.60)	S_2^{2-} / S^{2-}	(-0.64)[b]	(-1.52)
HSO_4^-, H^+ / $S_4O_6^{2-}$	0.288	-0.36	SO_3^{2-} / S_8 (c), OH^-	-0.659	-1.23
H_2S_2, H^+ / H_2S	(0.27)	(-0.24)	SO_4^{2-} / SH^-, OH^-	-0.683	-1.200
S_8 (c), H^+ / H_2S (g)	0.174	0.224	SO_4^{2-} / S_8 (c), OH^-	-0.751	-1.288
SO_4^{2-}, H^+ / SO_2	0.158	0.784	$S_2O_3^{2-}$ / S_8 (c), OH^-	-0.752	-1.40
S_8 (c), H^+ / H_2S	0.144	-0.21	SO_3^{2-} / $S_4O_6^{2-}$, OH^-	-0.762	-0.98
$S_4O_6^{2-}$, H^+ / $HS_2O_3^-$	(0.10)	(-0.23)	SO_4^{2-} / $S_4O_6^{2-}$, OH^-	-0.862	-1.22
HSO_4^-, H^+ / SO_2	0.099	0.205	SO_4^{2-} / SO_3^{2-}, OH^-	-0.936	-1.41
SO_2, H^+ / $HS_2O_4^-$	0.068	(-1.28)	SO_3^{2-} / $S_2O_4^{2-}$, OH^-	-1.130	-0.85
S_8 (c), H^+ / H_2S_2 (liq)	(0.05)[b]	(-0.15)	SO_4^{2-} / $S_2O_6^{2-}$, OH^-	(-1.71)[b]	(-1.00)
S_8 (c), H^+ / H_2S_2	(0.02)	(-0.18)			
SO_4^{2-}, H^+ / $S_2O_6^{2-}$	(-0.05)[b]	(0.67)			
HSO_4^-, H^+ / $S_2O_6^{2-}$	(-0.17)[b]	(-0.49)			
Selenium[6, 7]					
SeO_4^{2-}, H^+ / H_2SeO_3	1.150	0.483	SeO_4^{2-} / SeO_3^{2-}, OH^-	0.030	-1.36
$HSeO_4^-$, H^+ / H_2SeO_3	1.094	0.011	SeO_3^{2-} / Se (c), OH^-	-0.357	-1.31
H_2SeO_3, H^+ / Se (c)	0.739	-0.562	Se (c) / Se_2^{2-}	(-0.61)	
Se (c), H^+ / H_2Se (g)	-0.082	0.238	Se (c) / SeH^-, OH^-	-0.642	-0.90
Se (c), H^+ / H_2Se	-0.114	(-0.19)	Se (c) / Se^{2-}	-0.67	(-1.2)
			Se_2^{2-} / SeH^-, OH^-	(-0.68)	
			Se_2^{2-} / Se^{2-}	(-0.73)	

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Tellurium[1, 6-8]					
H_6TeO_6, H^+ / TeO_2 (c, α)	(0.91)[b]	(-0.12)	$H_4TeO_6^{2-}$ / TeO_3^{2-}, OH^-	(0.15)[b]	(-0.63)
H_6TeO_6, H^+ / $Te(OH)_3^+$	(0.85)[b]	(-0.32)	TeO_3^{2-} / Te (c), OH^-	-0.47	-1.39
$Te(OH)_3^+$, H^+ / Te (c)	0.558	-0.294	Te (c) / Te_2^{2-}	-0.84	
TeO_2 (c, α), H^+ / Te (c)	0.529	-0.391	Te (c) / Te^{2-}	-0.90	(-1.0)
Te (c), H^+ / H_2Te (g)	-0.44	0.26	Te_2^{2-} / Te^{2-}	-0.96	
Te (c), H^+ / H_2Te	-0.46	(-0.16)			
Polonium[6, 7]					
H_6PoO_6, H^+ / PoO_2 (c, α)	(2.3)[a]		$H_4PoO_6^{2-}$ / PoO_3^{2-}, OH^-	(1.4)[a]	
H_6PoO_6, H^+ / $Po(OH)_3^+$	(2.2)[a]		PoO (c) / Po (c), OH^-	(-0.1)	
H_6PoO_6, H^+ / Po^{4+}	(2.1)[a]		PoO_3^{2-} / Po (c), OH^-	(-0.2)	
Po^{4+} / Po^{2+}	(0.9)		PoO_3^{2-} / PoO (c), OH^-	(-0.3)	
$Po(OH)_3^+$, H^+ / Po^{2+}	(0.8)		Po (c) / Po_2^{2-}	(-1.0)	
Po^{4+} / Po (c)	0.76		Po (c) / Po^{2-}	(-1.1)	(-0.9)
PoO_2 (c, α), H^+ / Po^{2+}	(0.7)		Po_2^{2-} / Po^{2-}	(-1.1)	
$Po(OH)_3^+$, H^+ / Po (c)	(0.7)				
PoO_2 (c, α), H^+ / Po (c)	(0.7)	(-0.37)			
Po^{2+} / Po (c)	(0.6)				
Po (c), H^+ / H_2Po (g)	(-0.7)	(0.26)			
Po (c), H^+ / H_2Po	(-0.7)				
Fluorine[6, 7]					
OF_2 (g), H^+ / O_2 (g), HF	3.294	-0.508	OF_2 (g) / O_2 (g), F^-	3.107	-1.570
OF_2 (g) / O_2 (g), F^-	3.107	-1.570	F_2 (g) / F^-	2.890	-1.870
F_2 (g), H^+ / HF	3.077	-0.808	OF_2 (g) / F^-, OH^-	1.754	-1.626
F_2 (g), H^+ / HF_2^-	2.996	-1.248	OF_2 (g) / F_2 (g), OH^-	0.618	-1.382
F_2 (g) / F^-	2.890	-1.870			
OF_2 (g), H^+ / HF	2.262	-0.677			
OF_2 (g), H^+ / F^-	2.168	-1.208			
OF_2 (g), H^+ / F_2 (g)	1.446	-0.546			
Chlorine[6, 7]					
$HClO_2$, H^+ / HClO	1.674	-0.55	Cl_2 (g) / Cl^-	1.3604	-1.248
HClO, H^+ / Cl_2 (g)	1.630	-0.27	ClO_2 / ClO_2^-	1.068	-1.335
HClO, H^+ / Cl_2	1.594	-0.80	ClO^- / Cl^-, OH^-	0.890	-1.08
ClO_3^-, H^+ / Cl_2 (g)	1.458	-0.347	ClO_2^- / Cl^-, OH^-	0.786	-1.267
Cl_3^- / Cl^-	1.416	(-0.8)	ClO_2^- / ClO^-, OH^-	0.681	-1.46
ClO_3^-, H^+ / HClO	1.415	-0.37	ClO_3^- / Cl^-, OH^-	0.614	-1.333
Cl_2 / Cl^-	1.396	-0.72	ClO_4^- / Cl^-, OH^-	0.560	-1.313
ClO_4^-, H^+ / Cl_2 (g)	1.392	-0.367	ClO_3^- / ClO^-, OH^-	0.476	-1.46
Cl_2 (g) / Cl^-	1.3604	-1.248	ClO_3^- / Cl_2 (g), OH^-	0.465	-1.350
Cl_2 / Cl_3^-	1.356	(-0.6)	ClO_4^- / Cl_2 (g), OH^-	0.446	-1.322
Cl_2 (g) / Cl_3^-	1.249	(-2.2)	ClO^- / Cl_2 (g), OH^-	0.420	-0.90
ClO_4^-, H^+ / ClO_3^-	1.226	-0.416	ClO_4^- / ClO_3^-, OH^-	0.398	-1.252
ClO_2, H^+ / $HClO_2$	1.184	-0.433	ClO_3^- / ClO_2^-, OH^-	0.271	-1.466
ClO_3^-, H^+ / $HClO_2$	1.157	-0.180	ClO_3^- / ClO_2, OH^-	-0.526	-1.598
ClO_3^-, H^+ / ClO_2	1.130	0.074			

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K -- Continued

Acid Solutions (pH = 0.000)	E^o (V)	dE^o/dT (mV/K)	Basic Solutions (pH = 13.996)	E^o (V)	dE^o/dT (mV/K)
Bromine[6, 7]					
BrO_4^-, H^+ / BrO_3^-	1.745	-0.511	Br_2 (liq) / Br^-	1.078	-0.611
HBrO, H^+ / Br_2 (liq)	1.604	-0.63	BrO_4^- / BrO_3^-, OH^-	0.917	-1.347
HBrO, H^+ / Br_2 (g)	1.588	-0.15	BrO^- / Br^-, OH^-	0.766	-0.94
HBrO, H^+ / Br_2	1.584	-0.75	BrO_3^- / Br^-, OH^-	0.613	-1.287
BrO_3^-, H^+ / Br_2 (liq)	1.513	-0.419	BrO_3^- / BrO^-, OH^-	0.536	-1.46
BrO_3^-, H^+ / Br_2 (g)	1.510	-0.323	BrO_3^- / Br_2 (liq), OH^-	0.520	-1.422
BrO_3^-, H^+ / HBrO	1.491	-0.37	BrO^- / Br_2 (liq), OH^-	0.455	-1.27
Br_2 / Br_3^-	1.171	-0.472			
Br_2 (g) / Br_3^-	1.159	-2.258			
Br_2 (liq) / Br_3^-	1.110	-0.810			
Br_2 / Br^-	1.098	-0.499			
Br_2 (g) / Br^-	1.094	-1.094			
Br_2 (liq) / Br^-	1.078	-0.611			
Br_3^- / Br^-	1.062	-0.512			
Iodine[6, 7, 10]					
IO_4^-, H^+ / IO_3^-	1.589	-0.85	IO_4^- / IO_3^-, OH^-	0.761	-1.69
H_5IO_6, H^+ / HIO_3	1.567	-0.12	$H_3IO_6^{2-}$ / IO_3^-, OH^-	0.589	-0.72
HIO, H^+ / I_2 (c)	1.430	-0.339	I_2 (c) / I^-	0.535	-0.125
I^+ / I_2 (c)	1.35		IO^- / I^-, OH^-	0.469	-0.546
HIO, H^+ / I_2	1.345	-0.230	IO^- / I_2 (c), OH^-	0.403	-0.966
IO_3^-, H^+ / I_2 (c)	1.210	-0.367	IO_3^- / I^-, OH^-	0.269	-1.163
HIO_3, H^+ / I_2 (c)	1.200	-0.468	IO_3^- / I_2 (c), OH^-	0.216	-1.370
HIO_3, H^+ / I^+	1.16		IO_3^- / IO^-, OH^-	0.169	-1.471
IO_3^-, H^+ / HIO	1.154	-0.374			
I_2 / I_3^-	0.789	-0.329			
I_2 / I^-	0.620	-0.234			
I_3^- / I^-	0.535	-0.186			
I_2 (c) / I^-	0.535	-0.125			
I_2 (c) / I_3^-	0.534	-0.002			
Astatine[9]					
AtO_4^-, H^+ / AtO_3^-	(2.7)[a]		AtO_4^- / AtO_3^-, OH^-	(1.9)[a]	
H_5AtO_6, H^+ / $HAtO_3$	(2.7)[a]		$H_3AtO_6^{2-}$ / AtO_3^-, OH^-	(1.8)[a]	
AtO_3^-, H^+ / HAtO	(1.5)		AtO_3^- / AtO^-, OH^-	(0.5)	
$HAtO_3$, H^+ / At^+	1.5		AtO^- / At (c), OH^-	(0.3)	
HAtO, H^+ / At (c)	(1.2)		At (c) / At^-	0.2	(0.0)
HAtO, H^+ / At_2	(1.1)				
At^+ / At (c)	1.0				
At_2 / At_3^-	(0.5)				
At_2 / At^-	(0.3)	(-0.1)			
At_3^- / At^-	(0.2)				
At (c) / At^-	0.2	(0.0)			
At (c) / At_3^-	(0.2)				

Table 1. Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K Continued

Acid Solutions (pH = 0.000)	E^0 (V)	dE^0/dT (mV/K)	Basic Solutions (pH = 13.996)	E^0 (V)	dE^0 (mV
			Krypton		
$KrO, H^+ / Kr(g)$	(2.5)[a]		$KrO_4 / KrO_3OH^-, OH^-$	(1.8)[a]	
$KrO_4, H^+ / KrO_3$	(2.5)[a]		$KrO / Kr(g), OH^-$	(1.7)[a]	
$KrO_3, H^+ / Kr(g)$	(2.4)[a]		$KrO_3OH^- / Kr(g), OH^-$	(1.5)[a]	
$KrO_3, H^+ / KrO$	(2.3)[a]		$KrO_3OH^- / KrO, OH^-$	(1.4)[a]	
			Xenon[6, 7, 9]		
$H_4XeO_6, H^+ / XeO_3$	2.38	(0.0)	$XeO / Xe(g), OH^-$	(1.5)[a]	
$XeO, H^+ / Xe(g)$	(2.3)[a]		$XeO_3OH^- / Xe(g), OH^-$	1.24	
$XeO_3, H^+ / Xe(g)$	2.10	0.34	$HXeO_6^{3-} / Xe(g), OH^-$	(1.17)	
$XeO_3, H^+ / XeO$	(2.0)[a]		$XeO_3OH^- / XeO\ OH^-$	(1.1)[a]	
			$HXeO_6^{3-} / XeO_3OH^-, OH^-$	(0.95)	
			Radon		
$H_4RnO_6, H^+ / RnO_3$	(3.4)[a]		$HRnO_6^{3-} / RnO_3OH^-, OH^-$	(2.1)[a]	
$RnO_3, H^+ / Rn^{2+}$	(2.4)[a]		$RnO_3OH^- / RnO, OH^-$	(1.5)[a]	
$Rn^{2+} / Rn(g)$	(2.0)[a]		$RnO / Rn(g), OH^-$	(1.2)[a]	

Notes to Table 1:

[a]This half-reaction involves at least one doubtful chemical species (See text).

[b]ΔH^0 is experimentally known for this half-reaction (See text).

positive than when calculated for unit activity OH^- (aq). Two of these half-reactions have been included in the master listing of E^0 values at the end of Ref. 9 (pp. 787–802) and are inconsistent with the other E^0 values found there. They are $E^0[VO_4^{3-}/V(c), OH^-] = 0.120$ V (Table 1: -1.222 V) and E^0 $[VO(c)/V(c), OH^-] = -0.82$ V (Table 1: -1.693 V). $E^0[CrO_4^{2-}/Cr(OH)_4^-, OH^-]$ has been given (p. 461) as -0.72 V (Table 1: -0.14 V), which actually applies to E^0 $[CrO_4^{2-}/Cr(c), OH^-]$. The incorrectly assigned value for this important half-reaction has also been included in the master listing.

It is hoped that the many individuals connected with Ref. 9 will understand that the above discussion has been given only because it is necessary for the justification of the present work.

3. Limitations and Scope: Formula Writing

Table 1 contains standard electrode potentials and temperature coefficients in water at 298.15 K for nearly 1700 half-reactions at $pH = 0.000$ and $pH = 13.996$. The data allow the calculation of the thermodynamic changes and equilibrium constants associated with about 1.4 million complete cell reactions.

In order to keep this report to a manageable size, it has been necessary to consider only chemical species which involve hydrogen, oxygen, and at most one other element. Chemical species containing O–O bonds have not been considered, except for H_2O_2, HO_2^-, HO_2, O_2^- and O_3^-. Physical states have been indicated by (c) = pure crystalline solid, (pt) = hydrous precipitate (amorphous solid with variable water content), (liq) = pure liquid, (g) = ideal gas at one atmosphere fugacity, and unspecified = ideal aqueous solute at one molal activity. A few crystalline solids have been further identified by the crystal system, thus cu = cubic, hex = hexagonal, rh = orthorhombic, and tetr = tetragonal. Also, the colors have been specified for a few substances, thus r = red, pk = pink, y = yellow, bl = blue, br = brown, and w = white.

An attempt has been made to represent realistically the chemical formulas of aqueous species in Table 1; thus S^{IV} and Se^{IV} in acid solution have been written as SO_2 and H_2SeO_3, respectively, and Ru^{VI} and Os^{VI} in basic solution have been written as RuO_4^{2-} and $OsO_2(OH)_4^{2-}$, respectively. However, attached water molecules have been omitted from chemical formulas; hence Al^{3+}, H^+, etc. (The aqueous species CO_2 and H_2CO_3 are two different chemical entities.[1,10]) Hydrolyzed M^{IV} in acid solution has usually been represented in Table 1 as $M(OH)_2^{2+}$, although in many cases this is an oversimplification.[8] For acids, ionizable hydrogens precede the central atom while nonionizable hydrogens follow it; thus phosphoric acid has been written as H_3PO_4, phosphorous acid as H_2PHO_3, and hypophosphorous acid as HPH_2O_2. Boric acid, which accepts OH^- rather than donates H^+, has been written as $B(OH)_3$ rather than as H_3BO_3 or as (structurally incorrect) HBO_2. Rhenium hydride species[10] (which include ReH_9^{2-}) are represented in Table 1 as ReH rather than as Re^-; as a result, the E^0 value for the Re/Re^{-I} half-reaction is calculated to decrease with increasing pH, avoiding the unlikely prediction[6,7] that metallic rhenium disproportionates above pH 6.

4. Standard Electrode Potentials of Half-Reactions and Complete Cell Reactions

In accord with the IUPAC-Gibbs-Stockholm convention,[2] E^0 for a half-reaction is considered positive in this report if the oxidized form at unit activity is a better oxidizing agent than H^+(aq, $a = 1$ m), and negative if the reduced form at unit activity is a better reducing agent than H_2(g, $f = 1$ atm). For example, for the half-reaction

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(liq), \quad (3)$$

MnO_4^- (aq, $a = 1$ m) is a better oxidizing agent than H^+ (aq, $a = 1$ m), and $E^0(MnO_4^-, H^+/Mn^{2+}) = 1.507$ V. For the half-reaction

$$Zn^{2+}(aq) + 2e^- \rightarrow Zn(c), \quad (4)$$

Zn (c) is a better reducing agent than H_2 (g, $f = 1$ atm), and $E^0[Zn^{2+}/Zn(c)] = -0.762$ V. For the complete cell reaction

$$2MnO_4^-(aq) + 16H^+(aq) + 5Zn(c) \rightarrow 2Mn^{2+}(aq) + 5Zn^{2+}(aq) + 8H_2O(liq), \quad (5)$$

$E^0_{cell}[Zn(c)/Zn^{2+}//MnO_4^-, H^+/Mn^{2+}] = 1.507 - (-0.762) = 2.269$ V. The positive sign of E^0_{cell} indicates

that the reaction described by Eq. (5) is spontaneous under standard conditions at 298.15 K.

For the half-reactions described by Eqs. (3) and (4), $(dE^0/dT)_{298} = -0.646$ and 0.119 mV/K, respectively. Therefore, for the reaction described by Eq. (5), $(dE^0/dT)_{298} = -0.646 - (0.119) = -0.765$ mV/K $= -0.000\,765$ V/K. From Eq. (2) (using $E^0_{298} = 2.269$ V),

$$E^0_{373} = 2.269 + (373.15 - 298.15)(-0.000\,765) = 2.212 \text{ V}. \quad (6)$$

This result is slightly in error because the variation of E^0 with temperature is only approximately linear. Deviations from linearity are discussed in Sec. 8.

5. Thermodynamic Changes Associated with Half-Reactions and Complete Cell Reactions

The standard Gibbs energy change associated with a half-reaction or a complete cell reaction at 298.15 K may be calculated by

$$\Delta G^0_{298} = -nFE^0_{298}, \quad (7)$$

where n is the number of electrochemical equivalents in the half-reaction or complete cell reaction and F is the Faraday constant [$9.648\,530\,9\times10^4$ J/(V·mol)].[14] By combining Eqs. (2) and (7), one may calculate approximately the standard Gibbs energy change associated with a half-reaction or a complete cell reaction at any temperature T:

$$\Delta G^0_T = -nFE^0_T = -nF[E^0_{298} + (T - 298.15)\cdot(dE^0/dT)_{298}]. \quad (8)$$

Using the reaction described by Eq. (5) as an example (with $n = 10$),

$$\Delta G^0_{298} = -(10)(9.648\,530\,9\times10^4)(2.269) = -2.189\times10^6 \text{ J} = -2189 \text{ kJ}. \quad (9)$$

$$\Delta G^0_{373} = -(10)(9.648\,530\,9\times10^4)[2.269 + (373.15 - 298.15)(-0.000\,765)] = -2.134\times10^6 \text{ J} = -2134 \text{ kJ}. \quad (10)$$

The changes in the standard entropy and enthalpy associated with a half-reaction or a complete cell reaction at 298.15 K may be calculated by

$$\Delta S^0_{298} = -d(\Delta G^0_{298})/dT = nF(dE^0/dT)_{298}, \quad (11)$$

$$\Delta H^0_{298} = \Delta G^0_{298} + 298.15\cdot\Delta S^0_{298} = nF[-E^0_{298} + 298.15(dE^0/dT)_{298}]. \quad (12)$$

Using the reaction described by Eq. (5) as an example,

$$\Delta S^0_{298} = (10)(9.648\,530\,9\times10^4)(-0.000\,765) = -738 \text{ J/K}, \quad (13)$$

$$\Delta H^0_{298} = (10)(9.648\,530\,9\times10^4)[-2.269 + 298.15(-0.000\,765)] = -2.409\times10^6 \text{ J} = -2409 \text{ kJ}. \quad (14)$$

6. Thermodynamic Properties of Individual Chemical Species

By convention, the thermodynamics of formation ($\Delta_f G^0$, $\Delta_f S^0$, and $\Delta_f H^0$) of free elements in their standard states, of H^+ (aq), and of e^- (electrochemical equivalent), are equal to zero at all temperatures. For the half-reaction

$$\tfrac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O(liq), \quad (15)$$

Table 1 gives $E^0_{298} = 1.2291$ V and $(dE^0/dT)_{298} = -0.8456$ mV/K. Thus, from Eqs. (7), (11), and (12), Eq. (15) gives $\Delta_f G^0(H_2O, liq) = -237.18$ kJ/mol, $\Delta_f S^0(H_2O, liq) = -163.18$ J/(K·mol) and $\Delta_f H^0(H_2O, liq) = -285.83$ kJ/mol at 298.15 K. For the half-reactions

$$H_2O(liq) + e^- \rightarrow \tfrac{1}{2}H_2(g) + OH^-(aq), \quad (16)$$

$$\tfrac{1}{4}O_2(g) + \tfrac{1}{2}H_2O(liq) + e^- \rightarrow OH^-(aq), \quad (17)$$

Table 1 gives $E^0_{298} = -0.8280$ V and $(dE^0/dT)_{298} = -0.8360$ mV/K for Eq. (16), and $E^0_{298} = 0.4011$ V and $(dE^0/dT)_{298} = -1.6816$ mV/K for Eq. (17). Thus, from Eqs. (7), (11), and (12), either Eq. (16) or (17) gives $\Delta_f G^0(OH^-, aq) = -157.29$ kJ/mol, $\Delta_f S^0(OH^-, aq) = -243.84$ J/(K mol) and $\Delta_f H^0(OH^-, aq) = -229.99$ kJ/mol at 298.15 K.

The thermodynamics of formation of H_2O(liq) and OH^-(aq) at 298.15 K may be used to retrieve standard Gibbs energies, entropies and enthalpies of formation of other chemical species at 298.15 K, by applying Eqs. (7), (11), and (12) to other half-reactions relating the species of interest to the free elements in their standard states. For example, for the half-reaction

$$\tfrac{1}{8}S_8(c) + H_2O(liq) + 2e^- \rightarrow SH^-(aq) + OH^-(aq), \quad (18)$$

Table 1 gives $E^0_{298} = -0.476$ V and $(dE^0/dT)_{298} = -0.934$ mV/K. From Eqs. (7), (11), and (12), ΔG^0_{298}, ΔS^0_{298} and ΔH^0_{298} for this half-reaction are 91.9 kJ/mol, -180.3 J/(K mol) and 38.1 kJ/mol, repectively. From the thermodynamics of formation of H_2O(liq) and OH^-(aq) given above, $\Delta_f G^0(SH^-, aq) = 12.0$ kJ/mol, $\Delta_f S^0(SH^-, aq) = -99.6$ J/(K mol) and $\Delta_f H^0(SH^-, aq) = -17.7$ kJ/mol at 298.15 K.

"Third-law" standard entropies of chemical species at 298.15 K may be calculated by combining standard entropies of formation derived through Eq. (11) with third-law standard entropies of the free elements in their standard states at 298.15 K. The latter are provided in Table 2, arranged by Periodic Table family for easy access. For example, for the reaction

$$\tfrac{1}{8}S_8(c) + H_2(g) \rightarrow SH^-(aq) + H^+(aq), \quad (19)$$

$\Delta S^0 = \Delta_f S^0(SH^-, aq) = -99.6$ J/(K mol); combination with $S^0(\tfrac{1}{8}S_8, c) = 31.8$ J/(K mol) and $S^0(H_2, g) = 130.574$ J/(K mol) from Table 2 gives $S^0(SH^-, aq) = 62.8$ J/(K mol).

7. Calculations for Nonstandard Conditions

The potential associated with a half-reaction or a complete cell reaction under nonstandard conditions may be calculated by the Nernst equation

Table 2. Third-Law Standard Entropies at 298.15 K[a]

Element	S^o (J/(K·mol))	Element	S^o (J/(K·mol))	Element	S^o (J/(K·mol))
H_2 (g)	130.574	Pu (c, α)	56.1[b]	Zn (c)	41.63
Li (c)	29.12	Am (c, α)	54.5[b]	Cd (c, γ)	51.76
Na (c)	51.21	Cm (c, α)	72.0[b]	Hg (liq)	76.02
K (c)	64.18	Bk (c, α)	78.2[b]	B_{12} (c, β)	70.3
Rb (c)	76.78	Cf (c)	(80.)[c]	Al (c)	28.33
Cs (c)	85.23	Es (c)	(90.)[c]	Ga (c)	40.88
Fr (c)	95.4	Fm (c)	(88.)[c]	In (c)	57.82
Be (c)	9.50	Md (c)	(84.)[c]	Tl (c)	64.18
Mg (c)	32.68	No (c)	(66.)[c]	C (c, graphite)	5.740
Ca (c, α)	41.42	Lr (c)	(56.)[c]	Si (c)	18.83
Sr (c, α)	52.3	Ti (c, α)	30.63	Ge (c)	31.09
Ba (c)	62.8	Zr (c)	38.99	Sn (c, I-white)	51.55
Ra (c)	71.	Hf (c)	43.56	Pb (c)	64.81
Sc (c)	34.64	V (c)	28.91	N_2 (g)	191.50
Y (c)	44.43	Nb (c)	36.40	P (c, red)	22.80
La (c, α)	57.0[b]	Ta (c)	41.51	P_4 (c, white)	164.3
Ce (c, γ)	72.0	Cr (c)	23.77	As (c, α-gray)	35.1
Pr (c, α)	73.2	Mo (c)	28.66	Sb (c, III-gray)	45.69
Nd (c)	71.5	W (c)	32.64	Bi (c)	56.74
Pm (c)	71.[b]	Mn (c, α)	32.01	O_2 (g)	205.029
Sm (c)	69.58	Tc (c)	(33.)[d]	S_8 (c, rhombic)	254.4
Eu (c)	77.78	Re (c)	36.86	Se (c, gray)	42.442
Gd (c)	68.07	Fe (c, α)	27.28	Te (c, α)	49.71
Tb (c)	73.22	Ru (c)	28.53	Po (c, α)	(60.)[d]
Dy (c)	74.77	Os (c)	32.6	F_2 (g)	202.67
Ho (c)	75.3	Co (c, α)	30.04	Cl_2 (g)	222.957
Er (c)	73.18	Rh (c)	31.51	Br_2 (liq)	152.231
Tm (c)	74.01	Ir (c)	35.48	I_2 (c)	116.135
Yb (c)	59.87	Ni (c)	29.87	At (c)	(65.)[d]
Lu (c)	50.96	Pd (c)	37.57	He (g)	126.041
Ac (c, α)	62.8[b]	Pt (c)	41.63	Ne (g)	146.219
Th (c, α)	53.39	Cu (c)	33.150	Ar (g)	154.734
Pa (c, α)	51.9	Ag (c)	42.55	Kr (g)	163.973
U (c, α)	50.21	Au (c)	47.40	Xe (g)	169.574
Np (c, α)	50.46[b]			Rn (g)	176.1

Notes to Table 2.

[a]References 6 and 7, except as noted.

[b]Reference 9.

[c]Reference 13.

[d]This work.

$$E_T = E^0_T - \frac{RT}{nF}\cdot \ln Q_T$$
$$= E^0_T - \frac{(\ln 10)\cdot RT}{nF}\cdot \log Q_T, \qquad (20)$$

where E^0_T is the standard electrode potential at the temperature under consideration, R is the gas constant [8.314 510 J/(K mol)],[14] T is the temperature in Kelvin, n is the number of electrochemical equivalents in the half-reaction or complete cell reaction, and F is the Faraday constant. Q_T is the activity quotient at the temperature T, which has the same form as the equilibrium constant K_T for the reaction under consideration, but uses the actual activities rather than the activities at equilibrium. ln 10 is the conversion factor between natural and common logarithms (2.302 585 093). Substituting the numerical values for the physical constants into Eq. (20)[14] gives, at 298.15 K,

$$E_{298} = E^0_{298} - (0.059\,159\,7/n)\cdot \log Q_{298}. \qquad (21)$$

Using the reaction described by Eq. (5) as an example,

$$E_{298} = 2.269 - \frac{0.059\,159\,7}{10}\cdot \log \frac{(a_{Mn2+})^2(a_{Zn2+})^5}{(a_{MnO4-})^2(a_{H+})^{16}}. \qquad (22)$$

Zinc and water do not appear in Eq. (22) because the activities of pure solids and liquids are taken as unity.

At equilibrium, $E_T = 0$ and $Q_T = K_T$. Making these substitutions into Eqs. (20) and (21) gives, upon rearrangement,

$$\log K_T = [nFE^0_T/(\ln 10)\cdot RT] \qquad (23)$$
$$\log K_{298} = (nE^0_{298}/0.059\,159\,7). \qquad (24)$$

For the reaction described by Eq. (5) (using $n = 10$ and $E^0_{298} = 2.269$ V), $\log K_{298} = 383.5$ and $K_{298} = 3\times 10^{383}$.

Combinations of Eqs. (2) and (23) gives

$$\log K_T = \left\{nF\left[E^0_{298} + (T-298.15)\cdot\left(\frac{dE^0}{dT}\right)_{298}\right]\Big/(\ln 10)\cdot RT\right\}. \qquad (25)$$

Subsituting the numerical values for the physical constants into Eq. (25)[14] gives

$$\log K_T = \left\{5039.75n\left[E^0_{298} + (T-298.15)\cdot\left(\frac{dE^0}{dT}\right)_{298}\right]\Big/T\right\}. \qquad (26)$$

For the reaction described by Eq. (5) [using $n = 10$, $E^0_{298} = 2.269$ V and $(dE^0/dT)_{298} = -0.765$ mV/K], $\log K_{373} = 298.7$ and $K_{373} = 5\times 10^{298}$.

8. Second Temperature Coefficients

All equations and examples given to this point for temperatures other than 298.15 K have assumed that Eq. (2) is perfectly accurate, i.e., that E^o is a linear function of temperature. This would be the case if the standard isobaric heat capacity change, ΔC^0_P, were equal to zero. In reality it is not, but the effect of ΔC^0_P on ΔG^0 and E^0 is less than that on ΔH^0 and ΔS^0 because $d\Delta H^0/dT$ and $d\Delta S^0/dT$ have the same algebraic sign. Salvi and de Bethune[3] have expanded Eq. (2) as

$$E^0_T = E^0_{298} + (T-298.15)\cdot\left(\frac{dE^0}{dT}\right)_{298} + 0.5(T-298.15)^2\cdot\left(\frac{d^2E^0}{dT^2}\right)_{298}, \qquad (27)$$

where $(d^2E^0/dT^2)_{298}$ is the second temperature coefficient of the standard electrode potential. According to Salvi and de Bethune $(d^2E^0/dT^2)_{298}$ may be calculated from ΔC_P^0 by the expression

$$\left(\frac{d^2E^0}{dT^2}\right)_{298} = \Delta C_P^0/(298.15nF). \quad (28)$$

Second temperature coefficients may be conveniently expressed in microvolts per Kelvin squared, $\mu V/K^2$.

For the reaction described by Eq. (5) $(d^2E^0/dT^2)_{298}$ may be evaluated from heat capacity data[6,7] as $3.4\,\mu V/K^2$. In accord with Eq.(27), this changes E^0_{373} from 2.212 V [Eq. (6)] to 2.222 V. For many half-reactions and complete cell reactions, the typical effect of the second temperature coefficient on E^0 in going from 298.15 to 373.15 K is only ~5–10 mV, which is often less than 10% of the effect of dE^0/dT on E^0 over the same temperature range, and smaller than the uncertainties associated with many E^0 values at 298.15 K.

Second temperature coefficients of standard electrode potentials involving ions in water are given in Table 3, as calculated from the heat capacities selected by NBS.[6,7] It appears that heat capacity changes involving aquo-ions have generally not been well determined. The values which can be derived from Refs. 3 and 8(b) show poor agreement with those selected by NBS,[6,7] differing occasionally even in algebraic sign. On the other hand, the heat capacities of many crystalline oxides and hydroxides are accurately known,[6,7] but display such regularity that it is more efficient to summarize d^2E^0/dT^2 values for half-reactions involving these substances in terms of equations (*vide infra*) than it is to tabulate the individual values.

Table 3. Second Temperature Coefficients at 298.15 K[a, b]

Half-Reaction	d^2E^0/dT^2 ($\mu V/K^2$)	Half-Reaction	d^2E^0/dT^2 ($\mu V/K^2$)
H^+ / H_2 (g)	0.0000	Yb^{3+} / Yb (c)	-0.5
H_2O (liq) / H_2 (g), OH^-	-7.78	Lu^{3+} / Lu (c)	-0.5
Li^+ / Li (c)	-2.02	$MnO_4^-, H^+ / Mn^{2+}$	2.5
Na^+ / Na (c)	-1.13	Mn^{2+} / Mn (c)	-0.9
K^+ / K (c)	-0.23	$ReO_4^-, H^+ / Re$ (c)	1.19
Cs^+ / Cs (c)	0.98	Ag^+ / Ag (c)	-0.38
La^{3+} / La (c)	0.0	Zn^{2+} / Zn (c)	-0.9
Pr^{3+} / Pr (c)	0.2	$NO_3^-, H^+ / N_2$ (g)	1.77
Nd^{3+} / Nd (c)	0.1	N_2 (g), H^+ / NH_4^+	0.26
Sm^{3+} / Sm (c)	0.1	O_2 (g), H^+ / H_2O (liq)	0.5525
Eu^{3+} / Eu (c)	-0.3	O_2 (g) / OH^-	7.23
Gd^{3+} / Gd (c)	-0.2	$SO_4^{2-}, H^+ / S_8$ (c)	3.1
Tb^{3+} / Tb (c)	-0.4	F_2 (g) / F^-	-4.75
Dy^{3+} / Dy (c)	-0.4	Cl_2 (g) / Cl^-	-5.83
Ho^{3+} / Ho (c)	-0.4	Br_2 (g) / Br^-	-6.06
Er^{3+} / Er (c)	-0.4	Br_2 (liq) / Br^-	-6.75
Tm^{3+} / Tm (c)	-0.5	I_2 (c) / I^-	-6.39

Notes to Table 3:

[a]References 6 and 7

[b]See also Eqs. (31), (34) and (36).

9. Estimated Values

The tabulation of estimated thermodynamic quantities fulfills three very important functions. First, for a known chemical species, an estimated value offers a temporary semiquantitative means of predicting chemical reactivity, e.g., an E^0 value in an activity series. Second, the tabulation of estimated thermodynamic quantities for a known species emphasizes the gaps in our knowledge (provided that one clearly labels such values as estimates), and can serve as the incentive for new research. (It is worth noting here that ~30% of the frequently quoted dE^0/dT values listed by de Bethune *et al.*[2–4] have been derived from *estimated* standard entropies given by Latimer,[1] but have not been identified as estimates.) Third, for an unknown species, an estimated standard Gibbs energy of formation based on a reasonable method of prediction can provide insight as to why the species might be unknown. In this report, estimated values have been enclosed in parentheses to clearly distinguish them from experimentally based data. The author accepts full responsibility for all estimated values in this report.

There are occasions where ΔH^0 for a half-reaction is experimentally known but both ΔG^0 and ΔS^0 are estimated. As a result, both E^0 and dE^0/dT for the half-reaction are estimated quantities and are listed in Table 1 with parentheses. However, it is noted in Table 1 that E^0 and dE^0/dT for the half-reaction correspond to an experimental ΔH^0.

The following list of general methods for the estimation of thermodynamic quantities, while not exhaustive, is indicative of the logic involved.

One general method of thermodynamic prediction involves the fitting of ion hydration and lattice thermodynamics of chemically similar species to simple ionic charge-size functions. Examples of this method may be found in Refs. 11–13.

Latimer[1] has provided equations for the estimation of standard entropies of solids and aqueous molecules and ions. The reliability of Latimer's equations can be increased by restricting comparisons to chemically similar species and correcting for differences in atomic or ionic size and mass (e.g., the estimation of the standard entropy of FeO_4^{2-} by comparison with CrO_4^{2-} and MnO_4^{2-}). Theoretical corrections can also be made for magnetic effects due to the presence of unpaired electrons.[11–13]

Baes and Mesmer[8] have shown that useful empirical relationships exist among the thermodynamics of hydrolytic processes, such as in the solubility products of oxides and hydroxides and their acid–base behavior in terms of aquo-species such as M^{z+} and $MO_a(OH)_b^{(z-2a-b)+}$. Useful relationships also exist among these processes and such parameters as ionic charge, radius and electron configuration, and location in the Periodic Table.[8] The latter can also be used as a guide in predicting trends in E^0 values (e.g., for Po, At, and Rn species by extrapolation from their lighter congeners).

Latimer[1] has illustrated a procedure by which one may assign upper and lower limits to a standard electrode potential on the basis of observed (or expected) chemical behavior. This method by itself is not always sufficient to assign a

specific numerical value to a half-reaction, but it serves as a useful guide when combined with other methods. In the present work, the necessary descriptive chemistry for this procedure has been taken from Latimer,[1] Baes and Mesmer,[8(a)] Bard *et al.*[9] and especially Cotton and Wilkinson.[10]

The following specific examples of estimated values are worthy of mention.

H^-: Estimated by assuming that the thermodynamics of dissolution of the alkali hydrides lie between those of the alkali fluorides and chlorides,[6,7] and may be interpolated on the basis of the relative internuclear distances in MF, MH, and MCl. Other assumptions lead to similar results.[1,9]

Fr and Ra species: Estimated from thermochemical cycles extrapolated from the lighter alkali and alkaline earth metals, by the methods described in Refs. 11–13.

Pr^{2+}, Nd^{2+}, Pm species, Dy^{2+}–Tm^{2+}, Pu^{2+}, Am^{2+}, Bk^{2+}, and Es–Lr species: Estimated from thermochemical cycles by the methods described in Refs. 11–13.

Ti^{2+}, Nb^{3+}, Ta^{3+}, Mo^{3+}, Re^{3+}, Ru^{3+}, Os^{3+}, Ir^{3+}, Ni^{3+}, Ag^{3+}, Au^{3+}, and Ge^{2+}: Estimated by assuming a periodic variation in the thermodynamics of dissolution of oxides, hydroxides and halides, fitting to known cases[6,7] for neighboring elements in the Periodic Table (e.g., Ti^{2+} by interpolation between Ca^{2+} and V^{2+}, Cr^{2+}).

Sc^{2+}, W^{3+}, Tc^{2+}, Tc^{3+}, Cu^{3+}, and Au^{2+}: Estimated by assuming a periodic variation in the thermodynamics of ion hydration, fitting to known or estimated cases for neighboring elements in the Periodic Table (e.g., Sc^{2+} by interpolation between Ca^{2+} and Ti^{2+}, V^{2+}).

AlH_4^-: Estimated by assuming that the thermodynamics of dissolution of $MAlH_4$ (M = Li, Na, K) are similar to those of MBH_4.[6,7]

OH: Estimated by assuming that the thermodynamics of dissolution of OH(g) are the same as those of HF(g).[6,7] Other assumptions lead to similar results.[1,9]

O_3^-: Estimated by noting that ΔG^0 for the reaction $O_2(g) + O^- \rightarrow O_3^-$ is near zero.[9]

A number of estimated half-reactions in Table 1 involve doubtful chemical species of three main types:

(1) Species which are known in certain nonaqueous environments but which have only a transient existence in water. Examples include Tm^{2+}, AlH_4^-, and SiO(c).

(2) Species which have been claimed to exist or form in aqueous media but which have been improperly characterized and require further investigation. Examples include RhO_4^{2-}, NiO_2(c), and XeO.

(3) Species which are essentially nonexistent in chemical environments but which have been included in Table 1 to illustrate probable periodic trends. Examples include Sc^{2+}, UO_2OH(c), and Au^{2+}.

It is worth noting that the distinction among the three different types of doubtful chemical species is not always clear-cut. Half-reactions involving doubtful species have been noted as such in Table 1.

Iron may be used as an example of the details involved in the thermodynamic calculations for an element. All thermodynamic data for Fe(c,α), $Fe_{0.947}O$(c), $Fe(OH)_2$ (c), Fe_3O_4(c), Fe_2O_3(c,α) and $Fe(OH)_3$(pt), $\Delta_f H^0$ for Fe^{2+}, FeOOH(c), Fe^{3+}, $FeOH^{2+}$, and $Fe_2(OH)_2^{4+}$, and $\Delta_f G^0$ for $Fe(OH)_4^{2-}$ have been taken from Refs. 6 and 7. $\Delta_f G^0$ for Fe^{2+} and Fe^{3+} have been taken from the recommended E^0 values in Ref. 9 (which also discusses the problems associated with the reproducibility of iron electrodes). All thermodynamic data for $FeOH^+$, $FeOH^{2+}$, and $Fe_2(OH)_2^{4+}$, and $\Delta_f G^0$ for $Fe(OH)_2$(pt), $Fe(OH)_4^{2-}$, and $Fe(OH)_4^-$ have been deduced from the equilibrium data given in Ref. 8. $\Delta_f H^0$ for FeO_4^{2-} has been taken from Ref. 2. The following quantities have been estimated in this work: S^0 for $Fe(OH)_2$(pt), FeOOH(c), $Fe(OH)_4^-$, and FeO_4^{2-} (the latter three by comparison with AlOOH(c), $Al(OH)_4^-$ and CrO_4^{2-} and MnO_4^{2-}), and $\Delta_f G^0$ for $HFeO_4^-$ (by comparison with the acid dissociation constant for $HCrO_4^-$).

For half-reactions of the type: M^{z+}/M (free metal), the experimental E^0, dE^0/dT and d^2E^0/dT^2 values show interesting correlations with electronegativity (X),[15] ionic charge (z) and ionic radius (r, nm)[15]:

$$E^0_{298} + 4.5 = 3.4 \cdot X - \frac{0.4}{r + 0.138} \pm 0.4 \text{ V}, \tag{29}$$

$$\left(\frac{dE^0}{dT}\right)_{298} + 0.906 = \frac{0.484}{r + 0.138} - \frac{2.90}{1.5^z} \pm 0.09 \text{ mV/K}, \tag{30}$$

$$\left(\frac{d^2E^0}{dT^2}\right)_{298} = 27r - \frac{2.0}{1.5^z} - 2.4 \pm 0.2 \ \mu\text{V/K}^2. \tag{31}$$

The absolute potential and temperature coefficient of the SHE are 4.5 ± 0.1 V and 0.906 ± 0.015 mV/K, respectively,[9,12] while the radius of a water molecule is 0.138 nm.[15] The other parameters in Eqs. (29)–(31) have no physical significance.

For half-reactions of the type: Oxide (c), H^+/M (free metal), the corresponding equations are

$$E^0_{298} = 2.3X - \frac{0.8}{r + 0.140} - 0.6 \pm 0.4 \text{ V}, \tag{32}$$

$$\left(\frac{dE^0}{dT}\right)_{298} = -0.37 \pm 0.04 \text{ mV/K}, \tag{33}$$

$$\left(\frac{d^2E^0}{dT^2}\right)_{298} - 0.52 \pm 0.08 \ \mu\text{V/K}^2. \tag{34}$$

The radius of oxide ion is 0.140 nm.[15] The other parameters in Eqs. (32)–(34) have no physical significance.

For half-reactions of the type: Hydroxide (c), H^+/M (free metal), the equation for E^0_{298} is essentially the same as for oxides, i.e., Eq. (32). The equations for $(dE^0/dT)_{298}$ and $(d^2E^0/dT^2)_{298}$ are the following:

$$\left(\frac{dE^0}{dT}\right)_{298} = -0.17 \pm 0.05 \text{ mV/K}; \tag{35}$$

$$\left(\frac{d^2E^0}{dT^2}\right)_{298} = 1.29 \pm 0.09 \ \mu\text{V/K}^2. \tag{36}$$

The parameters in Eqs. (35) and (36) have no physical significance. At pH = 13.996, the E^0 values for Eq. (32) are 0.8280 V more negative, the dE^0/dT values for Eqs. (33) and (35) are 0.8360 mV/K more negative, and the d^2E^0/dT^2 values for Eqs. (34) and (36) are 7.78 μV/K^2 more negative.

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