APPENDIX

C

REFERENCE TABLES

TABLE C.1 Selected Standard Electrode Potentials in Aqueous Solutions at 25°C in V *vs.* NHE[a]

Reaction	Potential, V
$Ag^+ + e \rightleftarrows Ag$	0.7991
$AgBr + e \rightleftarrows Ag + Br^-$	0.0711
$AgCl + e \rightleftarrows Ag + Cl^-$	0.2223
$AgI + e \rightleftarrows Ag + I^-$	−0.1522
$Ag_2O + H_2O + 2e \rightleftarrows 2Ag + 2OH^-$	0.342
$Al^{3+} + 3e \rightleftarrows Al$	−1.676
$Au^+ + e \rightleftarrows Au$	1.83
$Au^{3+} + 2e \rightleftarrows Au^+$	1.36
p-benzoquinone $+ 2H^+ + 2e \rightleftarrows$ hydroquinone	0.6992
$Br_2(aq) + 2e \rightleftarrows 2Br^-$	1.0874
$Ca^{2+} + 2e \rightleftarrows Ca$	−2.84
$Cd^{2+} + 2e \rightleftarrows Cd$	−0.4025
$Cd^{2+} + 2e \rightleftarrows Cd(Hg)$	−0.3515
$Ce^{4+} + e \rightleftarrows Ce^{3+}$	1.72
$Cl_2(g) + 2e \rightleftarrows 2Cl^-$	1.3583
$HClO + H^+ + e \rightleftarrows \frac{1}{2}Cl_2 + H_2O$	1.630
$Co^{2+} + 2e \rightleftarrows Co$	−0.277
$Co^{3+} + e \rightleftarrows Co^{2+}$	1.92
$Cr^{2+} + 2e \rightleftarrows Cr$	−0.90
$Cr^{3+} + e \rightleftarrows Cr^{2+}$	−0.424
$Cr_2O_7^{2-} + 14H^+ + 6e \rightleftarrows 2Cr^{3+} + 7H_2O$	1.36
$Cu^+ + e \rightleftarrows Cu$	0.520
$Cu^{2+} + 2CN^- + e \rightleftarrows Cu(CN)_2^-$	1.12
$Cu^{2+} + e \rightleftarrows Cu^+$	0.159
$Cu^{2+} + 2e \rightleftarrows Cu$	0.340
$Cu^{2+} + 2e \rightleftarrows Cu(Hg)$	0.345
$Eu^{3+} + e \rightleftarrows Eu^{2+}$	−0.35
$1/2F_2 + H^+ + e \rightleftarrows HF$	3.053
$Fe^{2+} + 2e \rightleftarrows Fe$	−0.44
$Fe^{3+} + e \rightleftarrows Fe^{2+}$	0.771
$Fe(CN)_6^{3-} + e \rightleftarrows Fe(CN)_6^{4-}$	0.3610

(*continued*)

TABLE C.1 (*continued*)

Reaction	Potential, V
$2H^+ + 2e \rightleftarrows H_2$	0.0000
$2H_2O + 2e \rightleftarrows H_2 + 2OH^-$	−0.828
$H_2O_2 + 2H^+ + 2e \rightleftarrows 2H_2O$	1.763
$2Hg^{2+} + 2e \rightleftarrows Hg_2^{2+}$	0.9110
$Hg_2^{2+} + 2e \rightleftarrows 2Hg$	0.7960
$Hg_2Cl_2 + 2e \rightleftarrows 2Hg + 2Cl^-$	0.26816
$Hg_2Cl_2 + 2e \rightleftarrows 2Hg + 2Cl^-$ (sat'd. KCl)	0.2415
$HgO + H_2O + 2e \rightleftarrows Hg + 2OH^-$	0.0977
$Hg_2SO_4 + 2e \rightleftarrows 2Hg + SO_4^{2-}$	0.613
$I_2 + 2e \rightleftarrows 2I^-$	0.5355
$I_3^- + 2e \rightleftarrows 3I^-$	0.536
$K^+ + e \rightleftarrows K$	−2.925
$Li^+ + e \rightleftarrows Li$	−3.045
$Mg^{2+} + 2e \rightleftarrows Mg$	−2.356
$Mn^{2+} + 2e \rightleftarrows Mn$	−1.18
$Mn^{3+} + e \rightleftarrows Mn^{2+}$	1.5
$MnO_2 + 4H^+ + 2e \rightleftarrows Mn^{2+} + 2H_2O$	1.23
$MnO_4^- + 8H^+ + 5e \rightleftarrows Mn^{2+} + 4H_2O$	1.51
$Na^+ + e \rightleftarrows Na$	−2.714
$Ni^{2+} + 2e \rightleftarrows Ni$	−0.257
$Ni(OH)_2 + 2e \rightleftarrows Ni + 2OH^-$	−0.72
$O_2 + 2H^+ + 2e \rightleftarrows H_2O_2$	0.695
$O_2 + 4H^+ + 4e \rightleftarrows 2H_2O$	1.229
$O_2 + 2H_2O + 4e \rightleftarrows 4OH^-$	0.401
$O_3 + 2H^+ + 2e \rightleftarrows O_2 + H_2O$	2.075
$Pb^{2+} + 2e \rightleftarrows Pb$	−0.1251
$Pb^{2+} + 2e \rightleftarrows Pb(Hg)$	−0.1205
$PbO_2 + 4H^+ + 2e \rightleftarrows Pb^{2+} + 2H_2O$	1.468
$PbO_2 + SO_4^{2-} + 4H^+ + 2e \rightleftarrows PbSO_4 + 2H_2O$	1.698
$PbSO_4 + 2e \rightleftarrows Pb + SO_4^{2-}$	−0.3505
$Pd^{2+} + 2e \rightleftarrows Pd$	0.915
$Pt^{2+} + 2e \rightleftarrows Pt$	1.188
$PtCl_4^{2-} + 2e \rightleftarrows Pt + 4Cl^-$	0.758
$PtCl_6^{2-} + 2e \rightleftarrows PtCl_4^{2-} + 2Cl^-$	0.726
$Ru(NH_3)_6^{3+} + e \rightleftarrows Ru(NH_3)_6^{2+}$	0.10
$S + 2e \rightleftarrows S^{2-}$	−0.447
$Sn^{2+} + 2e \rightleftarrows Sn$	−0.1375
$Sn^{4+} + 2e \rightleftarrows Sn^{2+}$	0.15
$Tl^+ + e \rightleftarrows Tl$	−0.3363
$Tl^+ + e \rightleftarrows Tl(Hg)$	−0.3338
$Tl^{3+} + 2e \rightleftarrows Tl^+$	1.25
$U^{3+} + 3e \rightleftarrows U$	−1.66
$U^{4+} + e \rightleftarrows U^{3+}$	−0.52
$UO_2^+ + 4H^+ + e \rightleftarrows U^{4+} + 2H_2O$	0.273
$UO_2^{2+} + e \rightleftarrows UO_2^+$	0.163

(*continued*)

TABLE C.1 *(continued)*

Reaction	Potential, V
$V^{2+} + 2e \rightleftarrows V$	−1.13
$V^{3+} + e \rightleftarrows V^{2+}$	−0.255
$VO^{2+} + 2H^+ + e \rightleftarrows V^{3+} + H_2O$	0.337
$VO_2^+ + 2H^+ + e \rightleftarrows VO^{2+} + H_2O$	1.00
$Zn^{2+} + 2e \rightleftarrows Zn$	−0.7626
$ZnO_2^{2-} + 2H_2O + 2e \rightleftarrows Zn + 4OH^-$	−1.285

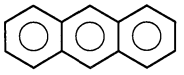
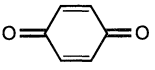
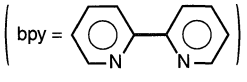
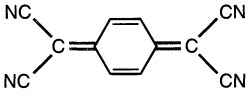
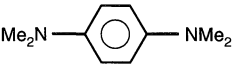
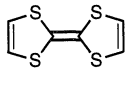
[a] The data in this table are mainly taken from A. J. Bard, J. Jordan, and R. Parsons, Eds., "Standard Potentials in Aqueous Solutions," Marcel Dekker, New York, 1985 (prepared under the auspices of the Electrochemistry and Electroanalytical Chemistry Commissions of IUPAC). Other sources of standard potentials and thermodynamic data include: (1) A. J. Bard and H. Lund, Eds., "The Encyclopedia of the Electrochemistry of the Elements," Marcel Dekker, New York, 1973–1986. (2) G. Milazzo and S. Caroli, "Tables of Standard Electrode Potentials," Wiley-Interscience, New York, 1977. The data here are referred to the NHE based on a 1-atm standard state for H_2. See the footnote in Section 2.1.5 concerning the recent change in standard state.

Table C.2 Selected Formal Potentials in Aqueous Solution at 25°C in V *vs.* NHE[a]

Reaction	Conditions	Potential, V
Cu(II) + $e \rightleftarrows$ Cu	1 *M* NH_3 + 1 *M* NH_4^+	0.01
	1 *M* KBr	0.52
Ce(IV) + $e \rightleftarrows$ Ce(III)	1 *M* HNO_3	1.61
	1 *M* HCl	1.28
	1 *M* $HClO_4$	1.70
	1 *M* H_2SO_4	1.44
Fe(III) + $e \rightleftarrows$ Fe(II)	1 *M* HCl	0.70
	10 *M* HCl	0.53
	1 *M* $HClO_4$	0.735
	1 *M* H_2SO_4	0.68
	2 *M* H_3PO_4	0.46
$Fe(CN)_6^{3-} + e \rightleftarrows Fe(CN)_6^{4-}$	0.1 *M* HCl	0.56
	1 *M* HCl	0.71
	1 *M* $HClO_4$	0.72
Sn(IV) + $2e \rightleftarrows$ Sn(II)	1 *M* HCl	0.14

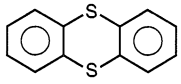
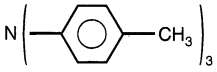
[a] The data in this table are taken mainly from G. Charlot, "Oxidation-Reduction Potentials," Pergamon, London, 1958. Additional values are found in J. J. Lingane, "Electroanalytical Chemistry," Interscience, New York, 1958, and L. Meites, Ed., "Handbook of Analytical Chemistry," McGraw-Hill, New York, 1963.

TABLE C.3 Estimated Standard Potentials in Aprotic Solvents, in V *vs.* aq SCE[a,b]

Substance	Reaction	Conditions[c]	Potential, V
Anthracene (An) 	$An + e \rightleftarrows An^{\cdot-}$	DMF, 0.1 *M* TBAI	−1.92
	$An^{\cdot-} + e \rightleftarrows An^{2-}$	DMF, 0.1 *M* TBAI	−2.5
	$An^{\cdot+} + e \rightleftarrows An$	MeCN, 0.1 *M* TBAP	+1.3
Azobenzene (AB) Ph—N=N—Ph	$AB + e \rightleftarrows AB^{\cdot-}$	DMF, 0.1 *M* TBAP	−1.36
	$AB^{\cdot-} + e \rightleftarrows AB^{2-}$	DMF, 0.1 *M* TBAP	−2.0
	$AB + e \rightleftarrows AB^{\cdot-}$	MeCN, 0.1 *M* TEAP	−1.40
	$AB + e \rightleftarrows AB^{\cdot-}$	PC, 0.1 *M* TBAP	−1.40
Benzophenone (BP) 	$BP + e \rightleftarrows BP^{\cdot-}$	MeCN, 0.1 *M* TBAP	−1.88
	$BP + e \rightleftarrows BP^{\cdot-}$	THF, 0.1 *M* TBAP	−2.06
	$BP + e \rightleftarrows BP^{\cdot-}$	NH_3, 0.1 *M* KI	−1.23[d]
	$BP^{\cdot-} + e \rightleftarrows BP^{2-}$	NH_3, 0.1 *M* KI	−1.76[d]
1,4 Benzoquinone (BQ) 	$BQ + e \rightleftarrows BQ^{\cdot-}$	MeCN, 0.1 *M* TEAP	−0.54
	$BQ^{\cdot-} + e \rightleftarrows BQ^{2-}$	MeCN, 0.1 *M* TEAP	−1.4
Ferrocene (Cp_2Fe)	$Cp_2Fe^{+} + e \rightleftarrows Cp_2Fe$	MeCN, 0.2 *M* $LiClO_4$	+0.31
Nitrobenzene (NB) Ph—NO_2	$NB + e \rightleftarrows NB^{\cdot-}$	MeCN, 0.1 *M* TEAP	−1.15
	$NB + e \rightleftarrows NB^{\cdot-}$	DMF, 0.1 *M* $NaClO_4$	−1.01
	$NB + e \rightleftarrows NB^{\cdot-}$	NH_3, 0.1 *M* KI	−0.42[d]
	$NB^{\cdot-} + e \rightleftarrows NB^{2-}$	NH_3, 0.1 *M* KI	−1.241[d]
Oxygen	$O_2 + e \rightleftarrows O_2^{\cdot-}$	DMF, 0.2 *M* TBAP	−0.87
	$O_2 + e \rightleftarrows O_2^{\cdot-}$	MeCN, 0.2 *M* TBAP	−0.82
	$O_2 + e \rightleftarrows O_2^{\cdot-}$	DMSO, 0.1 *M* TBAP	−0.73
$Ru(bpy)_3^{n+}(RuL_3^{n+})$ 	$RuL_3^{3+} + e \rightleftarrows RuL_3^{2+}$	MeCN, 0.1 *M* $TBABF_4$	+1.32
	$RuL_3^{2+} + e \rightleftarrows RuL_3^{+}$	MeCN, 0.1 *M* $TBABF_4$	−1.30
	$RuL_3^{+} + e \rightleftarrows RuL_3^{0}$	MeCN, 0.1 *M* $TBABF_4$	−1.49
	$RuL_3^{0} + e \rightleftarrows RuL_3^{-}$	MeCN, 0.1 *M* $TBABF_4$	−1.73
Tetracyanoquinodimethane (TCNQ)	$TCNQ + e \rightleftarrows TCNQ^{\cdot-}$	MeCN, 0.1 *M* $LiClO_4$	+0.13
	$TCNQ^{\cdot-} + e \rightleftarrows TCNQ^{2-}$	MeCN, 0.1 *M* $LiClO_4$	−0.29
N,N,N′,N′-Tetramethyl-*p*-phenylenediamine (TMPD)	$TMPD^{\cdot+} + e \rightleftarrows TMPD$	DMF, 0.1 *M* TBAP	+0.21
			
Tetrathiafulvalene (TTF)	$TTF^{\cdot+} + e \rightleftarrows TTF$	MeCN, 0.1 *M* TEAP	+0.30
	$TTF^{2+} + e \rightleftarrows TTF^{\cdot+}$	MeCN, 0.1 *M* TEAP	+0.66

(*continued*)

TABLE C.3 Estimated Standard Potentials in Aprotic Solvents, in V *vs.* aq SCE[a,b]

Substance	Reaction	Conditions[c]	Potential, V
Thianthrene (TH) 	$TH^{+\cdot} + e \rightleftarrows TH$	MeCN, 0.1 *M* $TBABF_4$	+1.23
	$TH^{2+} + e \rightleftarrows TH^{+\cdot}$	MeCN, 0.1 *M* $TBABF_4$	+1.74
	$TH^{+\cdot} + e \rightleftarrows TH$	SO_2, 0.1 *M* TBAP	+0.30[e]
	$TH^{2+} + e \rightleftarrows TH^{+\cdot}$	SO_2, 0.1 *M* TBAP	+0.88[e]
Tri-*N*-*p*-tolylamine (TPTA) 	$TPTA^{+\cdot} + e \rightleftarrows TPTA$	THF, 0.2 *M* TBAP	+0.98

[a]See footnote in Table C.1.

[b]Problems arise in reporting potentials in nonaqueous solvents. The practice of using an aqueous SCE as a reference electrode introduces an unknown and sometimes irreproducible liquid junction potential. Sometimes reference electrodes made up in the solvent of interest (e.g., $Ag/AgClO_4$) or QREs are employed. Results here are reported *vs.* an aqueous SCE unless noted otherwise. While there has not yet been an adopted convention for reporting potentials in nonaqueous solvents, a frequent practice is to reference these to the potential of a particular reversible couple in the same solvent. This couple (sometimes called the "reference redox system") is usually chosen on the basis of the extrathermodynamic assumption that the redox potential of this system is only slightly affected by the solvent system. Suggested reference redox systems include ferrocene/ferrocenium, Rb/Rb^+, $Fe(bpy)_3^{2+}/Fe(bpy)_3^{2+}$ (bpy = 2,2′-bipyridine), and aromatic hydrocarbon/radical cation. For further information concerning these problems, the following references can be consulted: (1) O. Popovych, *Crit. Rev. Anal. Chem.*, **1**, 73 (1970); (2) D. Bauer and M. Breant, *Electroanal. Chem.*, **8**, 282 (1975); (3) A. J. Parker, *Electrochim. Acta*, **21**, 671 (1976).

[c]See Standard Abbreviations.

[d]*vs.* Ag/Ag^+ (0.01 *M*) in NH_3 at −50°C.

[e]*vs.* $Ag/AgNO_3$ (sat'd) in SO_2 at −40°C.