CHUKA  **UNIVERSITY**

UNIVERSITY EXAMINATIONS

EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE (CHEMISTRY)

CHIN 428: INDUSTRIAL ELECTROCHEMISTRY AND CORROSION

STREAMS: **TIME:2 HOURS**

DAY/DATE: THURSDAY 20/04/2023 **2.30 P.M. –4.30 P.M.**

INSTRUCTIONS

Answer question **one** and any other **two.**

Useful data are provided.

General data and fundamental constants

Quantity	Symbol	Value	Power of ten	Units
Speed of light	c	2.997 925 58*	10^{8}	$m\ s^{-1}$
Elementary charge	e	1.602 176	10^{-19}	C
Faraday's constant	$F = N_A e$	9.648 53	10^{4}	$C\ mol^{-1}$
Boltzmann's constant	k	1.380 65	10^{-23}	$J\ K^{-1}$
Gas constant	$R = N_A k$	8.314 47		$J\ K^{-1}\ mol^{-1}$
		8.314 47	10^{-2}	$dm^3\ bar\ K^{-1}\ mol^{-1}$
		8.205 74	10^{-2}	$dm^3\ atm\ K^{-1}\ mol^{-1}$
		6.236 37	10	$dm^3\ Torr\ K^{-1}\ mol^{-1}$
Planck's constant	h	6.626 08	10^{-34}	J s
	$\hbar = h/2\pi$	1.054 57	10^{-34}	J s
Avogadro's constant	N_A	6.022 14	10^{23}	mol^{-1}
Atomic mass constant	m_u	1.660 54	10^{-27}	kg
Mass				
electron	m_e	9.109 38	10^{-31}	kg
proton	m_p	1.672 62	10^{-27}	kg
neutron	m_n	1.674 93	10^{-27}	kg
Vacuum permittivity	$\varepsilon_0 = 1/c^2\mu_0$	8.854 19	10^{-12}	$J^{-1}\ C^2\ m^{-1}$
	$4\pi\varepsilon_0$	1.112 65	10^{-10}	$J^{-1}\ C^2\ m^{-1}$
Vacuum permeability	μ_0	4π	10^{-7}	$J\ s^2\ C^{-2}\ m^{-1}\ (= T^2\ J^{-1}\ m^3)$
Magneton				
Bohr	$\mu_B = e\hbar/2m_e$	9.274 01	10^{-24}	$J\ T^{-1}$
nuclear	$\mu_N = e\hbar/2m_p$	5.050 78	10^{-27}	$J\ T^{-1}$
g value	g_e	2.002 32		
Bohr radius	$a_0 = 4\pi\varepsilon_0\hbar^2/m_e e^2$	5.291 77	10^{-11}	m
Fine-structure constant	$\alpha = \mu_0 e^2 c/2h$	7.297 35	10^{-3}	
	α^{-1}	1.370 36	10^{2}	
Second radiation constant	$c_2 = hc/k$	1.438 78	10^{-2}	m K
Stefan–Boltzmann constant	$\sigma = 2\pi^5 k^4/15h^3c^2$	5.670 51	10^{-8}	$W\ m^{-2}\ K^{-4}$
Rydberg constant	$R = m_e e^4/8h^3 c\varepsilon_0^2$	1.097 37	10^{5}	cm^{-1}
Standard acceleration of free fall	g	9.806 65*		$m\ s^{-2}$
Gravitational constant	G	6.673	10^{-11}	$N\ m^2\ kg^{-2}$

Exact value

QUESTION ONE (30 MARKS)

a) Briefly describe the following types of corrosion

(I)Crevice corrosion (3 marks)

(II) Pitting corrosion (3 marks)

b) (i)Outline the advantages and limitations of E-pH diagram. (3 marks)

(ii) Predict whether or not Sn will dissolve spontaneously in hydrochloric acid.

$$Sn + 2HCl \rightarrow SnCl_2 + H_2 \quad E_{cell} = 0.138\,V$$

(2 marks)

(iii) Calculate the tendency for corrosion to occur in the following metal electrolyte systems:

(a) Silver in cupric acid and (1 mark)

(b) Nickel in silver nitrate. (1 mark)

(iv) Tin is immersed in a solution of $CuCl_2$ with activity of Cu^{2+}=0.2. Determine the concentration of Sn^{2+} at which the corrosion will stop. (2 marks)

c) (i) What is the selectivity coefficient? Discuss its significance and how you would determine its value. (2 marks)

(ii) Describe the different types of ion-selective electrodes. Include in your discussion the construction of the electrodes, differences in membranes, and their usefulness. (3 marks)

(iii) A potassium ion-selective electrode is used to measure the concentration of potassium ion in a solution that contains $6.0 \times 10^{-3} M$ cesium (activity). From Table 13.3, the electrode responds equally to either ion ($K_{KCs} = 1$). If the potential versus a reference electrode is −18.3mV for a 5.0 × 10−3 *M* KCl solution and +20.9 mV in the sample solution, what is the activity of K^+ in the sample? Assume Nernstian response. (2 marks)

Table 13.3

Typical Properties of Some Commercial Ion-Selective Electrodes

Electrode	Concentration Range (*M*)	Principal Interferences[a]
Liquid–liquid ion exchange electrodes		
Ca^{2+}	10^0–10^{-5}	Zn^{2+}(3); Fe^{2+}(0.8); Pb^{2+}(0.6); Mg^{2+}(0.1); Na^+(0.003)
Cl^-	10^{-1}–10^{-5}	I^-(17); NO_3^-(4); Br^-(2); HCO_3^-(0.2); SO_4^{2-}, F^-(0.1)
Divalent cation	10^0–10^{-8}	Fe^{2+}, Zn^{2+}(3.5); Cu^{2+}(3.1); Ni^{2+}(1.3); Ca^{2+}, Mg^{2+}(1); Ba^{2+}(0.94); Sr^{2+}(0.54); Na^+(0.015)
BF_4^-	10^{-1}–10^{-5}	NO_3^-(0.1); Br^-(0.04); OAc^-, HCO_3^-(0.004); Cl^-(0.001)
NO_3^-	10^{-1}–10^{-5}	ClO_4^-(1000); I^-(20); Br^-(0.1); NO_2^-(0.04); Cl^-(0.004); CO_3^{2-}(0.0002); F^-(0.00006); SO_4^{2-}(0.00003)
ClO_4^-	10^{-1}–10^{-5}	I^-(0.01); NO_3^-, OH^-(0.0015); Br^-(0.0006); F^-, Cl^-(0.0002)
K^+	10^0–10^{-5}	Cs^+(1); NH_4^+(0.03); H^+(0.01); Na^+(0.002); Ag^+, Li^+(0.001)
Solid-state electrodes[b]		
F^-	10^0 – 10^{-6}	Maximum OH^- < 0.1 F^-
Ag^+ or S^{2-}	10^0–10^{-7}	$Hg^{2+} < 10^{-7} M$

d) (i) The sulfide content in a pulp plant effluent is determined with a sulfide ion-selective electrode using the method of standard additions for calibration. A 10.0-mL sample is diluted to 25.0 mL with water and gives a potential reading of −216.4 mV. A similar 10.0-mL sample plus 1.00 mL of 0.030 *M* sulfide standard diluted to 25.0 mL gives a reading of −224.0 mV. Calculate the concentration of sulfide in the sample. (3 marks)

(ii) The limiting current of lead in an unknown solution is 5.60 μA. One milliliter of a 1.00×10^{-3} M lead solution is added to 10.0 mL of the unknown solution and the limiting current of the lead is increased to 12.2 μA. What is the concentration of lead in the unknown solution?

(2 marks)

e) Distinguish between

(i) Faradaic impedance and double-layer capacitance, (1 mark)

(ii) A limiting current and a diffusion current, (1 mark)

(iii) Laminar flow and turbulent flow (1 mark)

QUESTION TWO (20 MARKS)

a)(i)

Determine the corrosion potential, the corrosion rate, and the protective current of zinc in 1 N hydrochloric acid. Assume that the entire zinc surface acts as a cathode, Tafel slopes are $b_a = 0.1$ V/decade and $b_c = -0.1$ V/decade, and the exchange current densities for zinc dissolution and for hydrogen evolution on zinc are 10^{-5} and 10^{-8} A/cm^2, respectively.

Additional information:

$$e^{o}_{Zn^{2+}|Zn} = -0.762\,\text{V vs. SHE} \quad e^{o}_{H^{+}|H_2} = 0.00\,\text{V vs. SHE}$$

$$i^{o}_{Zn} = 10^{-5}\,\text{A/cm}^2 \quad i^{o}_{H_2} = 10^{-8}\,\text{A/cm}^2$$

(3 marks)

(ii)Explain how galvanic corrosion can be minimized. (3 marks)

b)(i)Discuss amperometric sensors with reference to oxygen sensor. (3 marks)

(ii)Outline the advantages and limitations of electrochemical sensors. (4 marks)

(iii) . Iron(III) is polarographically reduced to iron(II) at potentials more negative than about +0.4 V versus SCE and is further reduced to iron(0) at −1.5 V versus SCE. Iron(II) is also reduced to the metal at −1.5 V. A polarogram is run (using a DME) on a solution containing Fe^{3+} and/or Fe^{2+} .A current is recorded at zero applied volts, and its magnitude is 12.5 μA. A wave is also recorded with $E_{1/2}$ equal to −1.5 V versus SCE, and its height is 30.0 μA. Identify the iron species in solution (3+ and/or 2+) and calculate the relative concentration of each. (2 marks)

c) A solution containing Cd^{2+} was analyzed voltammetrically using the standard addition method. Twenty-five milliliters of the deaerated solution, which was 1M in $HN0_3$, produced a net limiting current of 1.78 μA at a rotating mercury film working electrode at a potential of -0.85 V (versus SCE). Following addition of 5.00 mL of a 2.25 x 10-3 M standard Cd^{2+} solution, the resulting solution produced a current of 4.48 μA. Calculate the concentration of Cd^{2+} in the sample. (2 marks)

d) (i) What arc the advantages of performing voltammetry with microelectrodes? (1.5 marks)

(ii) Is it possible for an electrode to be too small'? Explain your answer. (1.5 marks)

QUESTION THREE (20 MARKS)

a) Describe and explain the shape of the voltammogram given below

(i)

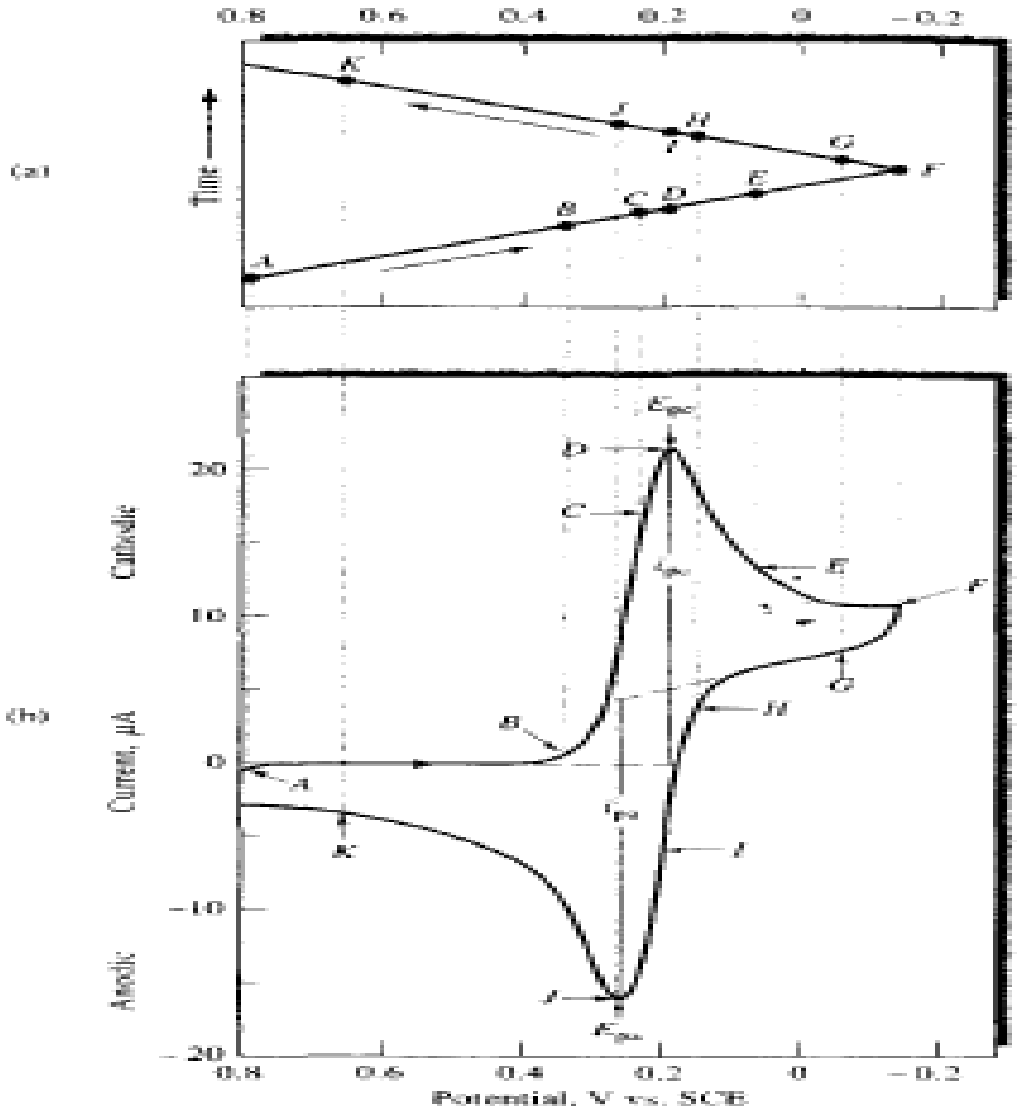


FIGURE 25-24 (a) Potential versus time waveform and (b) cyclic voltammogram for a solution that is 6.0 mM in $K_3Fe(CN)_6$ and 1.0 M in KNO_3. (From P. T. Kissinger and W. H. Heineman, *J. Chem. Educ.*, **1983**, 60, 702. Copyright 1983; Division of Chemical Education, Inc.)

3 marks)

(ii)

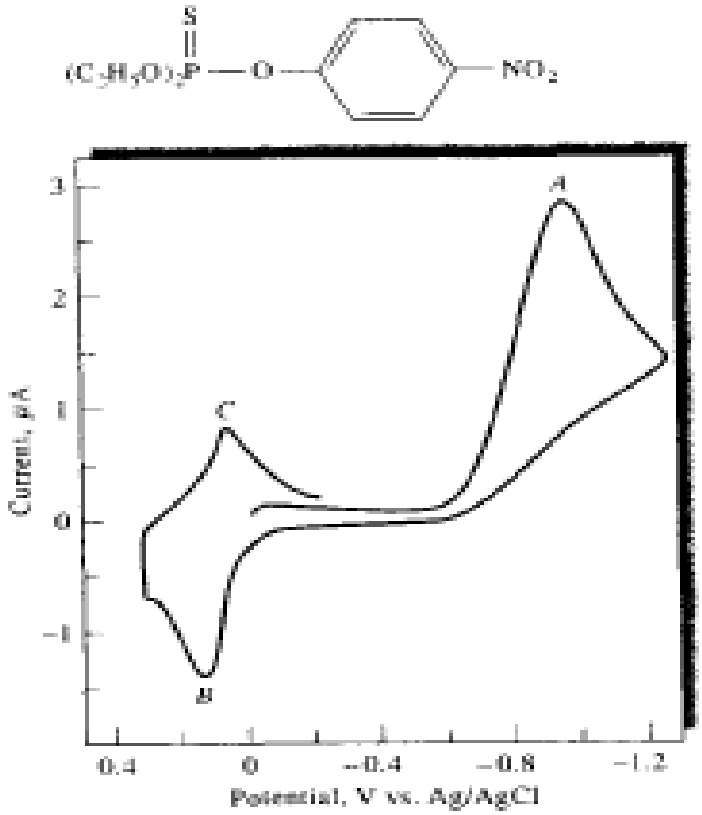


FIGURE 25-25 Cyclic voltammogram of the insecticide parathion in 0.5 *M* pH 5 sodium acetate buffer in 50% ethanol. Hanging mercury drop electrode. Scan rate: 200 mV/s. (From W. R. Heineman and P. T. Kissinger, *Amer. Lab.*, **1982**, no. 11, 34. Copyright 1982 by International Scientific Communications, Inc.)

(2 marks)

b) The working curve for the determination of dopamine at a nanoneedle electrode by differential-pulse voltammetry (Figure 25-38) was constructed from the following table of data.

Concentration Dopamine, mM	Peak Current, nA
0.093	0.66
0.194	1.31
0.400	2.64
0.596	4.51
0.991	5.97

(i)Use the least-squares analysis of the data to determine the slope, intercept, and regression statistics, including the standard deviation about regression. (3 marks)

(ii) Use your results to find the concentration of dopamine in a sample solution that produced a peak current of 3.62 nA. This value is the average of duplicate experiments. (1 mark)

(iii) Calculate the standard deviation of the unknown concentration and its 95% confidence interval assuming that each of the data in the table was obtained in a single experiment.(2 marks)

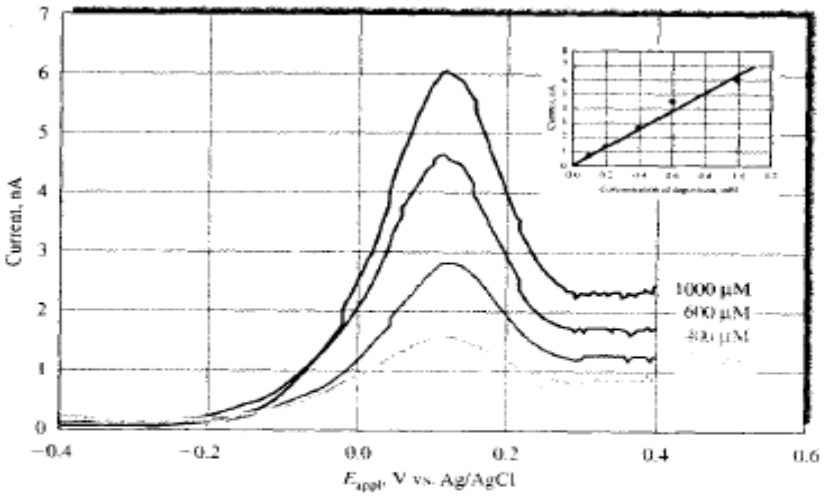


FIGURE 25-38 Detection of dopamine at a multiwall carbon nanotube-based nanoneedle electrode. Differential-pulse voltammograms of dopamine at the nanoneedle electrode in various concentrations from 100 to 1000 μM. Inset is the calibration curve. (From H. Boo et al., *Anal. Chem.*, **2006**, *78*, 617. With permission. Copyright 2006 American Chemical Society.)

c) Account for the following features of cyclic voltammograms:

(i) Why is it expected that peak current is proportional to the square root of scan rate? (2 marks)

(ii) Why is the peak current less in the limit of slow electrode kinetics? (2 marks)

(iii) Why does altering the diffusion coefficient of the product (D_B) for a given diffusion coefficient of the reactant (D_A) affect the forward peak potential but not the forward peak current? (2 marks)

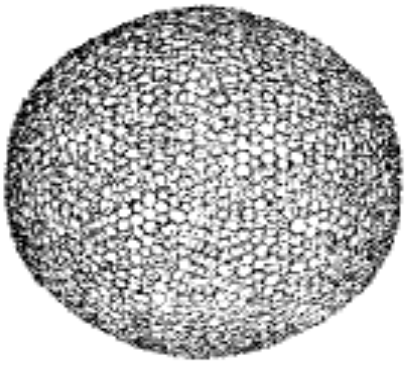
(iv) Why, in practice, does a plot of I_{pf} vs. $c*$ often not go through the origin? (3 marks)

QUESTION FOUR (20 MARKS)

a) (i)Briefly discuss electrochemical impedance spectroscopy. (5 marks)

(ii)

Suppose that a spherical electrode can be fabricated from a single nano onion, C_{60}–C_{240}–C_{540}–C_{960}–C_{1500}–C_{2160}–C_{2940}–C_{3840}–C_{4860}, shown here. Nano onions comprise concentric fullerenes of increasingly larger size as indicated in the formula. Assume that the nano onion has been synthesized with a carbon nanotube tail of sufficient size and strength that it can be electrically connected to a 0.1 μm tungsten needle and that the needle and nanotube tail can be properly insulated so that only the surface of the nano onion is exposed.



(a) Given that the radius of the nano onion is 3.17 nm, find the surface area in cm^2, neglecting the area of the nanotube attachment.
(b) If the diffusion coefficient of analyte A is 8×10^{-10} m^2/s, calculate the concentration gradient and the current for A at a concentration of 1.00 mM at the following times after the application of a voltage at which A is reduced: 1×10^{-8} s, 1×10^{-7} s, 1×10^{-6} s, 1×10^{-5} s, 1×10^{-4} s, 1×10^{-3} s, 1×10^{-2} s, 1×10^{-1} s, 1 s, and 10 s.
(c) Find the steady-state current.
(d) Find the time required for the electrode to achieve steady-state current following the application of the voltage step.
(e) Repeat these calculations for a 3-μm spherical platinum electrode and for a spherical iridium electrode with a surface area of 0.785 mm^2.
(f) Compare the results for the three electrodes, and discuss any differences that you find.

a)6 marks ,b) 1 mark ,c) 1 mark d) 1 mark e) 1 mark, f) 1 mark

c) Suggest how Equation 25-13 could be used to detcrmine the number of electrons n involved in a reversible reaction at an electrode. (1 mark)

$$E_{appl} = E_{1/2} - \frac{0.0592}{n} \log \frac{i}{i_l - i} \qquad (25\text{-}13)$$

c)State and explain the advantages of microelectrodes. (3 marks)

PERIODIC TABLE OF THE ELEMENTS

Metals
Nonmetals
Metalloids

	IA 1	IIA 2	IIIB 3	IVB 4	VB 5	VIB 6	VIIB 7	VIIIB 8	VIIIB 9	VIIIB 10	IB 11	IIB 12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	0 18
1	1 H 1.008																1 H 1.008	2 He 4.0026
2	3 Li 6.941	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.9984	10 Ne 20.1797
3	11 Na 22.9898	12 Mg 24.3050											13 Al 26.9815	14 Si 28.085	15 P 30.9738	16 S 32.06	17 Cl 35.453	18 Ar 39.948
4	19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.9380	26 Fe 55.845	27 Co 58.9332	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.63	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.798
5	37 Rb 85.4678	38 Sr 87.62	39 Y 88.9058	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.9055	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.9045	54 Xe 131.293
6	55 Cs 132.9055	56 Ba 137.327	57 La 138.9055 *	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.084	79 Au 196.9666	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.9804	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac (227) **	104 Rf (265)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)

*Lanthanide Series

58 Ce 140.116	59 Pr 140.9076	60 Nd 144.242	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.9254	66 Dy 162.500	67 Ho 164.9303	68 Er 167.259	69 Tm 168.9342	70 Yb 173.054	71 Lu 174.9668

** Actinide Series

90 Th 232.0381	91 Pa 231.0359	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Note: Atomic masses are 2009 IUPAC values (up to four decimal places). More accurate values for some elements are given in the table inside the back cover.

Table 2.2 Standard Electrode Potentials at 25 °C and Their Isothermal Temperature Coefficients [12]

	Electrode Reaction	e° (*V* vs. SHE)	$\left(\frac{dE^\circ}{dT}\right) \times 10^3 \left(\frac{V}{^\circ C}\right)$
$Li^+ \mid Li$	$Li^+ + e^- = Li$	−3.045	−0.534
$Rb^+ \mid Rb$	$Rb^+ + e^- = Rb$	−2.925	−1.245
$Cs^+ \mid Cs$	$Cs^+ + e^- = Cs$	−2.923	−1.197
$K^+ \mid K$	$K^+ + e^- = K$	−2.925	−1.080
$Ra^{2+} \mid Ra$	$Ra^{2+} + 2e^- = Ra$	−2.916	−0.59
$Ba^{2+} \mid Ba$	$Ba^{2+} + 2e^- = Ba$	−2.906	−0.395
$Ca^{2+} \mid Ca$	$Ca^{2+} + 2e^- = Ca$	−2.866	−0.175
$Na^+ \mid Na$	$Na^+ + e^- = Na$	−2.714	−0.772
$La^{3+} \mid La$	$La^{3+} + 3e^- = La$	−2.522	+0.085
$Mg^{2+} \mid Mg$	$Mg^{2+} + 2e^- = Mg$	−2.363	+0.103
$Be^{2+} \mid Be$	$Be^{2+} + 2e^- = Be$	−1.847	+0.565
$Al^{3+} \mid Al$	$Al^{3+} + 3e^- = Al$	−1.662	+0.504
$Ti^{2+} \mid Ti$	$Ti^{2+} + 2e^- = Ti$	−1.628	-
$Zr^{4+} \mid Zr$	$Zr^{4+} + 4e^- = Zr$	−1.529	-
$V^{2+} \mid V$	$V^{2+} + 2e^- = V$	−1.186	-
$Mn^{2+} \mid Mn$	$Mn^{2+} + 2e^- = Mn$	−1.180	−0.08
$Zn^{2+} \mid Zn$	$Zn^{2+} + 2e^- = Zn$	−0.762	+0.09
$Cr^{3+} \mid Cr$	$Cr^{3+} + 3e^- = Cr$	−0.744	+0.468
$SbO_2^- \mid Sb$	$SbO_2^- + 2H_2O + 3e^- = Sb + 4OH^-$	−0.670	-
$Ga^{3+} \mid Ga$	$Ga^{3+} + 3e^- = Ga$	−0.529	+0.67
$S^{2-} \mid S$	$S + 2e^- = S^{2-}$	−0.510	-
$Fe^{2+} \mid Fe$	$Fe^{2+} + 2e^- = Fe$	−0.440	+0.052
$Cr^{3+}, Cr^{2+} \mid Pt$	$Cr^{3+} + e^- = Cr^{2+}$	−0.408	-
$Cd^{2+} \mid Cd$	$Cd^{2+} + 2e^- = Cd$	−0.402	−0.093
$Ti^{3+}, Ti^{2+} \mid Pt$	$Ti^{3+} + e^- = Ti^{2+}$	−0.369	-
$Tl^+ \mid Tl$	$Tl^+ + e^- = Tl$	−0.336	−1.327
$Co^{2+} \mid Co$	$Co^{2+} + 2e^- = Co$	−0.277	+0.06
$Ni^{2+} \mid Ni$	$Ni^{2+} + 2e^- = Ni$	−0.250	+0.06
$Mo^{3+} \mid Mo$	$Mo^{3+} + 3e^- = Mo$	−0.20	-
$Sn^{2+} \mid Sn$	$Sn^{2+} + 2e^- = Sn$	−0.138	−0.282
$Pb^{2+} \mid Pb$	$Pb^{2+} + 2e^- = Pb$	−0.126	−0.451
$Ti^{4+}, Ti^{3+} \mid Pt$	$Ti^{4+} + e^- = Ti^{3+}$	−0.040	-
$H^+, H_2 \mid Pt$	$H^+ + e^- = ½\ H_2$	±0.000	±0.000 (+0.871)*
$Sn^{4+}, Sn^{2+} \mid Pt$	$Sn^{4+} + 2e^- = Sn^{2+}$	+ 0.015	-
$Cu^{2+}, Cu^+ \mid Pt$	$Cu^{2+} + e^- = Cu^+$	+ 0.153	+0.073
$Cu^{2+} \mid Cu$	$Cu^{2+} + 2e^- = Cu$	+0.337	+0.008
$Fe(CN)_6^{3-}$, $Fe(CN)_6^{4-} \mid Pt$	$Fe(CN)_6^{3-} + e^- = Fe(CN)_6^{4-}$	+0.360	-
$OH^-, O_2 \mid Pt$	$½\ O_2 + H_2O + 2e^- = 2OH^-$	+0.401	−0.440
$Cu^+ \mid Cu$	$Cu^+ + e^- = Cu$	+0.521	−0.058
$I^- \mid I_2, Pt$	$I_2 + 2e^- = 2I^-$	+0.535	−0.148
MnO_4^-, $MnO_4^{2-} \mid Pt$	$MnO_4^- + e^- = MnO_4^{2-}$	+0.564	-

Continued

Table 2.2 Standard Electrode Potentials at 25 °C and Their Isothermal Temperature Coefficients [12]—cont'd

	Electrode Reaction	e° (*V* vs. SHE)	$\left(\frac{dE^\circ}{dT}\right) \times 10^3 \left(\frac{V}{^\circ C}\right)$
$Fe^{3+}, Fe^{2+} \mid Pt$	$Fe^{3+} + e^- = Fe^{2+}$	+0.771	+ 1.188
$Hg_2^{2+} \mid Hg$	$Hg_2^{2+} + 2e^- = 2Hg$	+0.788	-
$Ag^+ \mid Ag$	$Ag^+ + e^- = Ag$	+0.799	−1.000
$Hg^{2+} \mid Hg$	$Hg^{2+} + 2e^- = Hg$	+0.854	-
$Hg^{2+}, Hg^+ \mid Pt$	$Hg^{2+} + e^- = Hg^+$	+0.910	-
$Pd^{2+} \mid Pd$	$Pd^{2+} + 2e^- = Pd$	+0.987	-
$Br^- \mid Br_2$, Pt	$Br_2 + 2e^- = 2Br^-$	+1.065	−0.629
$Pt^{2+} \mid Pt$	$Pt^{2+} + 2e^- = Pt$	+1.200	-
$Mn^{2+}, H^+ \mid MnO_2$, Pt	$MnO_2 + 4H^+ + 2e^- = Mn^{2+} + 2H_2O$	+1.230	−0.661
$Cr^{3+}, Cr_2O_7^{2-}, H^+ \mid Pt$	$Cr_2O_7^{2-} + 14H^+ + 6e^- = 2Cr^{3+} + 7H_2O$	+1.330	−1.263
$Cl^- \mid Cl_2$, Pt	$Cl_2 + 2e^- = 2Cl^-$	+1.359	−1.260
$Pb^{2+}, H^+ \mid PbO_2$, Pt	$PbO_2 + 4H^+ + 2e^- = Pb^{2+} + 2H_2O$	+1.455	−0.238
$Au^{3+} \mid Au$	$Au^{3+} + 3e^- = Au$	+1.498	-
$MnO_4^-, H^+ \mid MnO_2$, Pt	$MnO_4^- + 4H^+ + 3e^- = MnO_2 + 2H_2O$	+1.695	−0.666
$Ce^{4+}, Ce^{3+} \mid Pt$	$Ce^{4+} + e^- = Ce^{3+}$	+1.610	-
$SO_4^{2-}, H^+ \mid PbSO_4, PbO_2$, Pb	$PbO_2 + SO_4^{2-} + 4H^+ + 2e^- = PbSO_4 + 2H_2O$	+1.682	+0.326
$Au^+ \mid Au$	$Au^+ + e^- = Au$	+1.691	-