Electrochemistry

Standard difficulty · 20 questions · 40 marks · Time: 40 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer 8 × 1 = 8 marks

1. In a galvanic cell, oxidation takes place at the:

(a) salt bridge **(b)** external wire **(c)** cathode **(d)** anode

2. The standard emf of the cell Fe | Fe^{2+} || Pb^{2+} | Pb is: ($E°$: Fe^{2+}/Fe = −0.44 V, Pb^{2+}/Pb = −0.13 V)

(a) 0.31 V **(b)** −0.57 V **(c)** −0.31 V **(d)** 0.62 V

3. A cell reaction involves 2 electrons and has $E°_{cell}$ = 0.11 V. Its standard Gibbs energy change is: (F = 96,500 C/mol)

(a) −21,230 kJ/mol **(b)** 21.23 kJ/mol **(c)** −10.62 kJ/mol **(d)** −21.23 kJ/mol

4. A current of 5 A is passed through a solution of a gold salt (gold ion charge 3+, molar mass 197 g/mol) for 3,860 s. The mass of gold deposited is: (F = 96,500 C/mol)

(a) 6.57 g **(b)** 39.4 g **(c)** 131.33 g **(d)** 13.13 g

5. A 0.11 M solution has conductivity 0.087 S cm^{-1}. Its molar conductivity is:

(a) 790.91 S cm^2 mol^{-1} **(b)** 9.57 S cm^2 mol^{-1}

(c) 79.09 S cm^2 mol^{-1} **(d)** 0.79 S cm^2 mol^{-1}

6. The electrode potential of Sn^{2+}/Sn when $[Sn^{2+}] = 10^{-3}$ M at 298 K is: ($E° = -0.14$ V; 2.303RT/F = 0.059 V)

(a) −0.0515 V **(b)** −0.2285 V **(c)** −0.317 V **(d)** −0.14 V

7. Using Kohlrausch's law, the limiting molar conductivity of HCl is: ($\lambda°$ in S cm^2 mol^{-1}: H^+ 349.6, Cl^- 76.3)

(a) 426.9 S cm^2 mol^{-1} **(b)** 851.8 S cm^2 mol^{-1}

(c) 212.95 S cm^2 mol^{-1} **(d)** 425.9 S cm^2 mol^{-1}

8. Assertion (A): In the cell made of Ni^{2+}/Ni ($E° = -0.25$ V) and Cu^{2+}/Cu ($E° = 0.34$ V), Ni is the anode.
Reason (R): A salt bridge keeps the two half-cells electrically neutral.

(a) Both A and R are true, and R is the correct explanation of A.

(b) Both A and R are true, but R is not the correct explanation of A.

(c) A is true, but R is false.

(d) A is false, but R is true.

Section B — Short answer 8 × 2 = 16 marks

9. What is the function of a salt bridge?

10. For the cell Mg | Mg^{2+} || Ni^{2+} | Ni, find E°cell and ΔG°, and say whether the reaction is spontaneous. (E°: Mg^{2+}/Mg = −2.37 V, Ni^{2+}/Ni = −0.25 V) (F = 96,500 C/mol)

11. How long must a current of 4 A flow to deposit 23.64 g of gold (ion charge 3+, M = 197 g/mol)? (F = 96,500 C/mol)

12. Find the emf at 298 K of the cell Pb | Pb^{2+} (10^{-1} M) || Cu^{2+} (10^{-2} M) | Cu. (E°: Pb^{2+}/Pb = −0.13 V, Cu^{2+}/Cu = 0.34 V; 2.303RT/F = 0.059 V)

13. The molar conductivity of 0.01 M acetic acid is 35.15 S cm^2 mol^{-1}. Find its degree of dissociation. (λ°: H^+ = 349.6, CH_3COO^- = 40.9 S cm^2 mol^{-1})

14. A cell reaction with n = 2 has E°cell = 0.8555 V at 298 K. Find its equilibrium constant. (2.303RT/F = 0.059 V)

15. How many faradays of charge are needed for the change of 4 mol of MnO_4^- to Mn^{2+}? How many coulombs is that? (F = 96,500 C/mol)

16. Find the limiting molar conductivity of K_2SO_4. (λ° in S cm^2 mol^{-1}: K^+ 73.5, SO_4^{2-} 160)

Section C — Word problems — 4 × 4 = 16 marks

17. Describe the Daniell cell: its set-up, electrode reactions and emf.

18. A galvanic cell is made from Pb^{2+}/Pb ($E° = -0.13$ V) and Cu^{2+}/Cu ($E° = 0.34$ V). Write the cell, name the anode and cathode, and find $E°_{cell}$ and $\Delta G°$. (F = 96,500 C/mol)

19. Two electrolytic cells containing nickel and zinc salts (ion charges 2+ and 2+) are joined in series. If 8.218 g of nickel is deposited, find the mass of zinc deposited, and the charge passed. (M: nickel 58.7, zinc 65.4 g/mol) (F = 96,500 C/mol)

20. A 0.01 M solution of acetic acid has conductivity 3.5145×10^{-4} S cm^{-1}. Find its molar conductivity, its degree of dissociation and its dissociation constant. ($\lambda°$: $H^+ = 349.6$, $CH_3COO^- = 40.9$ S cm^2 mol^{-1})

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Answer key

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Q	Answer	Working
1	**(d) anode**	—
2	**(a) 0.31 V**	$E°_{cell} = E°_{(cathode)} - E°_{(anode)}$
3	**(d) −21.23 kJ/mol**	$\Delta G° = -nFE° = -2 \times 96{,}500 \times 0.11$ J
4	**(d) 13.13 g**	$Q = It = 19{,}300$ C = 0.2 F; $m = M\,Q/(nF)$
5	**(a) 790.91 S cm^2 mol^{-1}**	$\Lambda m = \kappa \times 1000/c$
6	**(b) −0.2285 V**	$E = E° - (0.059/2)\log(1/[Sn^{2+}]) = -0.14 - 0.059 \times 3/2$
7	**(d) 425.9 S cm^2 mol^{-1}**	$\Lambda°m = \Sigma\, \nu\, \lambda°$
8	**(b) Both A and R are true, but R is not the correct explanation of A.**	A is true: Ni has the lower reduction potential, so it is oxidised. R is true but does not explain A.
9	**It completes the inner circuit by letting ions move between the half-cells, and it keeps each half-cell electrically neutral, so the cell keeps working.**	—
10	**$E° = 2.12$ V; $\Delta G° = -409.16$ kJ/mol; spontaneous**	$n = 2$; $\Delta G° = -nFE°$
11	**8,685 s**	charge = moles × n × F = 0.12 × 3 × 96,500
12	**0.4405 V**	$E = E° - (0.059/2)\log Q$, $\log Q = 1$; $E° = 0.47$ V
13	**α = 0.09**	$\Lambda°m = 390.5$; $\alpha = \Lambda m/\Lambda°m$
14	**$K = 10^{29}$**	$\log K = nE°/0.059 = 2 \times 0.8555/0.059 = 29$
15	**20 F; 1,930,000 C**	5 mol of electrons per mol
16	**307 S cm^2 mol^{-1}**	$2 \times 73.5 + 160$
17	**A zinc rod dips in $ZnSO_4$ solution and a copper rod in $CuSO_4$ solution; the solutions are joined by a salt bridge and the rods by a wire. Anode: $Zn \rightarrow Zn^{2+} + 2e^-$; cathode: $Cu^{2+} + 2e^- \rightarrow Cu$. Overall $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$. Standard emf = 0.34 − (−0.76) = 1.10 V.**	—
18	**Pb | Pb^{2+} || Cu^{2+} | Cu; anode Pb (oxidised), cathode Cu; $E° = 0.47$ V; $\Delta G° = -90.71$ kJ/mol (n = 2)**	the lower E° is the anode
19	**9.156 g; 27,020 C**	the same charge passes: 0.28 F
20	**$\Lambda m = 35.15$ S cm^2 mol^{-1}; $\alpha = 0.09$; $Ka = 8.90 \times 10^{-5}$**	$\Lambda m = 1000\kappa/c$; $\alpha = \Lambda m/\Lambda°m$; $Ka = c\alpha^2/(1-\alpha)$

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