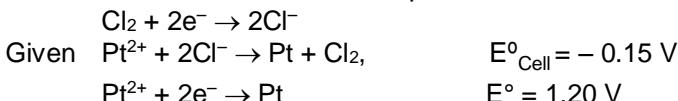


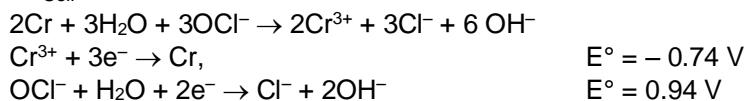


B-4. For the cell reaction $2\text{Ce}^{4+} + \text{Co} \rightarrow 2\text{Ce}^{3+} + \text{Co}^{2+}$, E°_{Cell} is 1.89 V. If $E^\circ_{\text{Co}^{2+}|\text{Co}}$ is -0.28 V, what is the value of $E^\circ_{\text{Ce}^{4+}|\text{Ce}^{3+}}$?

B-5. Determine the standard reduction potential for the half reaction :



B-6. What is E°_{Cell} if :



Section (C) : Concept of ΔG

Commit to memory :

E°_{cell} is an intensive property, so on multiplying or dividing electrode reaction, E°_{cell} remains same.
Calcualte E°_{cell} for 3rd reaction with the help of 1st and 2nd reaction using $\Delta G^\circ = -nF E^\circ_{\text{cell}}$.

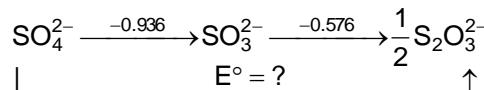
$$E^\circ_{\text{target}} = \frac{n_1 E_1 + n_2 E_2}{n_{\text{target}}} \quad \text{where } n_1 = \text{electrons participating in 1st reaction.}$$

$n_2 = \text{electrons participating in 2nd reaction.}$

$n_{\text{target}} = \text{electrons participating in target reaction.}$

C-1. If $E^\circ_{\text{Fe}^{2+}|\text{Fe}} = -0.44$ V, $E^\circ_{\text{Fe}^{3+}|\text{Fe}^{2+}} = 0.77$ V. Calculate $E^\circ_{\text{Fe}^{3+}|\text{Fe}}$

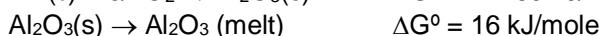
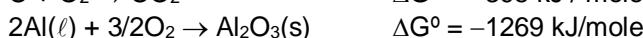
C-2. Consider the standard reduction potentials (in volts) as shown in Fig. Find E° .



C-3. The standard oxidation potentials for Mn^{3+} ion acid solution are $\text{Mn}^{2+} \xrightarrow{-1.5$ V} $\text{Mn}^{3+} \xrightarrow{-1.0$ V} MnO_2 .

Is the reaction $2\text{Mn}^{3+} + 2\text{H}_2\text{O} \rightarrow \text{Mn}^{2+} + \text{MnO}_2 + 4\text{H}^+$ spontaneous under conditions of unit activity ?
What is the change in free energy ?

C-4. Using the ΔG° for the reactions



Calculate the EMF for the cell reaction $2\text{Al}_2\text{O}_3 \text{ (melt)} + 3\text{C} \rightarrow 4\text{Al}(\ell) + 3\text{CO}_2(\text{g})$. The number of electrons involved in the reaction is 12.

Section (D) : Nernst equation & its Applications (including concentration cells)

Commit to memory :

$$\text{Nernst equation : } E_{\text{cell}} = E^\circ_{\text{cell}} \frac{RT}{nf} - \ln Q$$

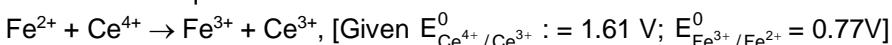
$$\text{At } 25^\circ\text{C, } E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0591}{n} \log Q$$

where, n = number of transferred electron, Q = reaction quotient.

For concentration cell $E^\circ_{\text{cell}} = 0$

D-1. Calculate the oxidation potential of a hydrogen electrode at $\text{pH} = 1$ ($T = 298$ K).

D-2. Calculate the equilibrium constant for the reaction :

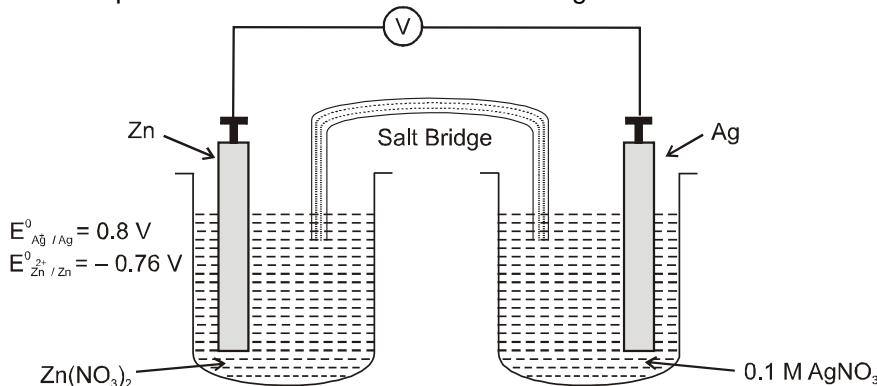


D-3. The standard reduction potential of $\text{Cu}^{2+} / \text{Cu}$ couple is 0.34 V at 25°C. Calculate the reduction potential at pH = 14 for this couple.
(Given : K_{sp} , $\text{Cu}(\text{OH})_2 = 1.0 \times 10^{-19}$).

D-4. The EMF of the cell $\text{M} | \text{M}^{n+} (0.02 \text{ M}) \parallel \text{H}^+ (1\text{M}) | \text{H}_2 (\text{g}) (1 \text{ atm}), \text{Pt}$ at 25°C is 0.81V. Calculate the valency of the metal if the standard oxidation potential of the metal is 0.76V.

D-5. Consider the following electrochemical cell :

- Write a balanced net ionic equation for the spontaneous reaction that take place in the cell.
- Calculte the standard cell potential E° for the cell reaction.
- If the cell emf is 1.6 V, what is the concentration of Zn^{2+} ?
- How will the cell potential be affected if KI is added to Ag^+ half-cell ?



D-6. $\text{NO}_3^- \rightarrow \text{NO}_2$ (acid medium), $E^{\circ} = 0.790 \text{ V}$

$\text{NO}_3^- \rightarrow \text{NH}_3\text{OH}^+$ (acid medium), $E^{\circ} = 0.731 \text{ V}$.

At what pH, the above two will have same E value? Assume the concentration of all other species NH_3OH^+ except $[\text{H}^+]$ to be unity.

D-7. The standard oxidation potential of Zn referred to SHE is 0.76V and that of Cu is -0.34V at 25°C. When excess of Zn is added to CuSO_4 , Zn displaces Cu^{2+} till equilibrium is reached. What is the approx value of $\log \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]}$ at equilibrium?

Section (E) : Electrolysis

Commit to memory :

Higher SOP means higher tendency of oxidation.

Higher SRP means higher tendency of reduction.

SOP order : $\text{SO}_4^{2-} < \text{NO}_3^- < \text{Cl}^- < \text{H}_2\text{O} < \text{Br}^- < \text{Ag} < \text{I}^- < \text{OH}^- < \text{Cu} \dots < \text{Li}$

SRP order : Follow ECS

E-1.

	ELECTROLYTE	ANODE Product	CATHODE Product
1	NaCl (Molten) with Pt electrode		
2	NaCl (aq) with Pt electrode		
3	Na_2SO_4 (aq) with Pt electrode		
4	NaNO_3 (aq) with Pt electrode		
5	AgNO_3 (aq) with Pt electrode		
6	CuSO_4 (aq) with Inert electrode		
7	CuSO_4 (aq) with Copper electrode		

Section (F) : Faraday laws & its Applications

Commit to memory :

Faraday's law of electrolysis :

Ist law $W = ZQ = \frac{EQ}{96500}$
 $Q = it$

$$\text{2nd law} \quad \frac{W_1}{W_2} = \frac{Z_1}{Z_2} = \frac{E_1}{E_2} \quad (Q = \text{same})$$

$$\text{Current efficiency } (\eta) = \frac{\text{actual amount of product}}{\text{theoretical amount of product}} \times 100$$

$$W_{\text{actual}} = \left(\frac{E \times Q}{96500} \right) \frac{\eta}{100}$$

F-1. Find the number of electrons involved in the electro-deposition of 63.5 g of copper from a solution of copper sulphate is :

F-2. A current 0.5 ampere when passed through AgNO_3 solution for 193 sec. deposited 0.108 g of Ag . Find the equivalent weight of Ag :

F-3. A certain metal salt solution is electrolysed in series with a silver coulometer. The weights of silver and the metal deposited are 0.5094 g and 0.2653g. Calculate the valency of the metal if its atomic weight is nearly that of silver.

F-4. 3A current was passed through an aqueous solution of an unknown salt of Pd for 1Hr. 2.977g of Pd^{+n} was deposited at cathode. Find n. (Given Atomic mass of Pd = 106.4)

F-5. How long a current of 2A has to be passed through a solution of AgNO_3 to coat a metal surface of 80cm^2 with $5\mu\text{m}$ thick layer? Density of silver = 10.8g/cm^3 .

F-6. A certain electricity deposited 0.54g of Ag from AgNO_3 Solution. What volume of hydrogen will the same quantity of electricity liberate at STP ($V_m = 22.4 \text{ L/mol}$).

F-7. A current of 3.7A is passed for 6hrs. between Ni electrodes in 0.5L of 2M solution of $\text{Ni}(\text{NO}_3)_2$. What will be the molarity of solution at the end of electrolysis?

F-8. Cd amalgam is prepared by electrolysis of a solution of CdCl_2 using a mercury cathode. How long should a current of 5A be passed in order to prepare 12% Cd-Hg amalgam when 2 g Hg is used as cathode (atomic weight of Cd = 112.4)

F-9. Electrolysis of a solution of HSO_4^- ions produces $\text{S}_2\text{O}_8^{2-}$. Assuming 75% current efficiency, what current should be employed to achieve a production rate of 1 mole of $\text{S}_2\text{O}_8^{2-}$ per hour ?

Section (G) : Commercial Cells & Corrosion

Commit to memory :

At STP, V_m (molar volume of the gas) = 22.4 L/mol

Volume of gas required at STP = moles of gas $\times 22.4$

G-1. A fuel cell uses $\text{CH}_4(\text{g})$ and forms CO_3^{2-} at the anode. It is used to power a car with 80 Amp. for 0.96 hr. How many litres of $\text{CH}_4(\text{g})$ (STP) would be required ? ($V_m = 22.4 \text{ L/mol}$) ($F = 96500$). Assume 100% efficiency.

G-2. Find E^0 of cell formed for rusting of iron ?

$$E_{\text{Fe}/\text{Fe}^{2+}}^0 = +0.44 \text{ V}$$

$$E_{\text{H}_2\text{O}/\text{O}_2/\text{H}^+}^0 = -1.23 \text{ V}$$

Section (H) : Electrical Conductance

Commit to memory :

$$\text{Conductivity } (\kappa) = C \times \frac{\ell}{A} = \frac{1}{R} \times \frac{\ell}{A}$$

where, $\frac{\ell}{A}$ = cell constant, C = conductance, R = resistance.

A = surface area of electrodes, ℓ = distance between electrodes.

$$\text{Molar conductance } (\Lambda_m) = \frac{\kappa \times 1000}{M} \text{ S cm}^2 \text{ mol}^{-1}$$

$$\text{Equivalent conductance } (\Lambda_{eq}) = \frac{\kappa \times 1000}{N} \text{ S cm}^2 \text{ eq}^{-1}$$

where, M = molarity, N = normality and N = M × valence factor

H-1. The resistance of a M/10 KCl solution is 245 ohms. Calculate the specific conductance and the molar conductance of the solution if the electrodes in the cell are 4 cm apart and each having an area of 7.0 sq. cm.

H-2. The equivalent conductance of 0.10 N solution of MgCl_2 is $97.1 \text{ mho cm}^2 \text{ eq}^{-1}$ at 25°C . A cell with electrodes that are 1.50 cm^2 in surface area and 0.50 cm apart is filled with 0.1N MgCl_2 solution. How much current will flow when the potential difference between the electrodes is 5 volts ?

H-3. The specific conductance of a N/10 KCl solution at 18°C is $1.12 \times 10^{-2} \text{ mho cm}^{-1}$. The resistance of the solution contained in the cell is found to be 65 ohms. Calculate the cell constant.

Section (I) : Kohlrausch law and its applications

Commit to memory :

Kohlrausch law : At infinite dilution, $\Lambda_{\text{m, electrolyte}}^0 = v_+ \Lambda_{\text{m}^+}^0 + v_- \Lambda_{\text{m}^-}^0$

where, v_+ = number of cations in one formula unit of electrolyte.

v_- = number of anions in one formula unit of electrolyte.

At infinite dilution equivalent conductance : $\Lambda_{\text{eq, electrolyte}}^0 = \Lambda_{\text{eq}^+}^0 + \Lambda_{\text{eq}^-}^0$

$$\text{Degree of dissociation (D.O.D.)} = \alpha = \frac{\Lambda_m}{\Lambda_m^0} = \frac{\Lambda_{\text{eq}}}{\Lambda_{\text{eq}}^0}$$

For weak electrolyte, dissociation constant (K_a) = $\frac{C\alpha^2}{1-\alpha}$, where, C = concentration of electrolyte.

$$\text{Solubility (s)} = \frac{\kappa \times 1000}{\Lambda_m^0} \text{ and } K_{\text{sp}} = S^2 \text{ for AB type salt.}$$

I-1. The molar conductance of an infinitely dilute solution of NH_4Cl is 150 and the ionic conductances of OH^- and Cl^- ions are 198 and 76 respectively. What will be the molar conductance of the solution of NH_4OH at infinite dilution. If the molar conductance of a 0.01 M solution NH_4OH is 9.6, what will be its degree of dissociation?

I-2. Given the molar conductance of sodium butyrate, sodium chloride and hydrogen chloride as 83, 127 and $426 \text{ mho cm}^2 \text{ mol}^{-1}$ at 25°C respectively. Calculate the molar conductance of butyric acid at infinite dilution.

I-3. Calculate K_a of acetic acid if its 0.05 N solution has equivalent conductance of 7.36 mho cm^2 at 25°C . ($\lambda_{\text{CH}_3\text{COOH}}^\infty = 390.7$).

I-4. The specific conductance of a saturated solution of AgCl at 25°C after subtracting the specific conductance of conductivity of water is $2.28 \times 10^{-6} \text{ mho cm}^{-1}$. Find the solubility product of AgCl at 25°C . ($\lambda_{\text{AgCl}}^\infty = 138.3 \text{ mho cm}^2$)

Section (J) : Conductometric Titration

Commit to memory :

H^+ and OH^- ions are highly conducting.

J-1. Draw approximate titration curve for following –

- (1) HCl(aq) is titrated with NaOH
- (2) $\text{CH}_3\text{COOH(aq)}$ is titrated with NaOH
- (3) Equimolar mixture of HCl and HCN titrated with NaOH
- (4) $\text{NH}_4\text{Cl(aq)}$ is titrated with NaOH

PART - II : ONLY ONE OPTION CORRECT TYPE

* Marked Questions are having more than one correct option.

Section (A) : Galvanic cell, its Representation & salt bridge

A-1. In a galvanic cell

(A) Chemical reaction produces electrical energy (B) electrical energy produces chemical reaction
(C) reduction occurs at anode (D) oxidation occurs at cathode

A-2. Which of the following is/are function(s) of salt-bridge ?

(A) It completes the electrical circuit with electrons flowing from one electrode to the other through external wires and a flow of ions between the two compartments through salt - bridge
(B) it minimises the liquid - liquid junction potential
(C) both correct
(D) none of these

A-3. Salt bridge contains :

(A) calomel (B) sugar (C) H_2O (D) agar-agar paste

A-4. The emf of the cell, $\text{Ni} | \text{Ni}^{2+} (1.0 \text{ M}) \parallel \text{Ag}^+ (1.0 \text{ M}) | \text{Ag}$ [E° for $\text{Ni}^{2+} / \text{Ni} = -0.25$ volt, E° for $\text{Ag}^+ / \text{Ag} = 0.80$ volt] is given by -

(A) $-0.25 + 0.80 = 0.55$ volt (B) $-0.25 - (+0.80) = -1.05$ volt
(C) $0 + 0.80 - (-0.25) = + 1.05$ volt (D) $-0.80 - (-0.25) = - 0.55$ volt

Section (B) : Electrochemical series & its Applications

B-1. E° for $\text{F}_2 + 2\text{e}^- \rightarrow 2\text{F}^-$ is 2.8 V, E° for $\frac{1}{2} \text{F}_2 + \text{e}^- \rightarrow \text{F}^-$ is

(A) 2.8 V (B) 1.4 V (C) - 2.8 V (D) - 1.4 V

B-2. Consider the cell potentials = $E^\circ_{\text{Mg}^{2+} | \text{Mg}} = -2.37$ V and $E^\circ_{\text{Fe}^{3+} | \text{Fe}} = -0.04$ V. The best reducing agent would be

(A) Mg^{2+} (B) Fe^{3+} (C) Mg (D) Fe

B-3. If a spoon of copper metal is placed in a solution of ferrous sulphate -

(A) Cu will precipitate out (B) iron will precipitate
(C) Cu and Fe will precipitate (D) no reaction will take place

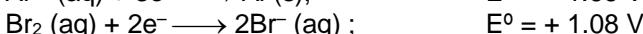
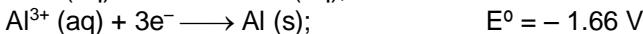
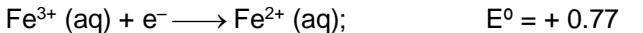
B-4. The position of some metals in the electrochemical series in decreasing electropositive character is given as $\text{Mg} > \text{Al} > \text{Zn} > \text{Cu} > \text{Ag}$. What will happen if a copper spoon is used to stir a solution of aluminium nitrate ?

(A) The spoon will get coated with aluminium (B) An alloy of aluminium and copper is formed
(C) The solution becomes blue (D) There is no reaction

B-5. For $\text{Zn}^{2+} / \text{Zn}$, $E^\circ = -0.76$ V, for Ag^+ / Ag $E^\circ = 0.799$ V. The correct statement is -

(A) the reaction Zn getting reduced Ag getting oxidized is spontaneous
(B) Zn undergoes reduction and Ag is oxidized
(C) Zn undergoes oxidation Ag⁺ gets reduced
(D) No suitable answer

B-6. Electrode potential data are given below.



Based one the data given above, reducing power of Fe^{2+} , Al and Br^- will increase in the order :

(A) $\text{Br}^- < \text{Fe}^{2+} < \text{Al}$ (B) $\text{Fe}^{2+} < \text{Al} < \text{Br}^-$ (C) $\text{Al} < \text{Br}^- < \text{Fe}^{2+}$ (D) $\text{Al} < \text{Fe}^{2+} < \text{Br}^-$

B-7. KCl can be used in salt bridge as electrolyte in which of the following cells?

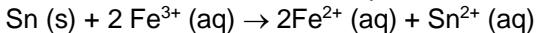
(A) $\text{Zn} | \text{ZnCl}_2 \parallel \text{AgNO}_3 | \text{Ag}$ (B) $\text{Pb} | \text{Pb}(\text{NO}_3)_2 \parallel \text{Cu}(\text{NO}_3)_2 | \text{Cu}$
(C) $\text{Cu} | \text{CuSO}_4 \parallel \text{AuCl}_3 | \text{Au}$ (D) $\text{Fe} | \text{FeSO}_4 \parallel \text{Pb}(\text{NO}_3)_2 | \text{Pb}$



B-8. Consider the following E° values :

$$E_{\text{Fe}^{3+}/\text{Fe}^{2+}}^\circ = +0.77 \text{ V} ; \quad E_{\text{Sn}^{2+}/\text{Sn}}^\circ = -0.14 \text{ V}$$

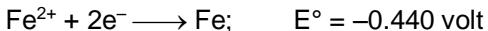
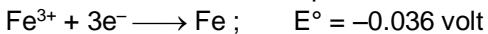
Under standard conditions the potential for the reaction is



(A) 1.68 V (B) 1.40 V (C) 0.91 V (D) 0.63 V

Section (C) : Concept of ΔG

C-1. Given standard electrode potentials :



The standard electrode potential E° for $\text{Fe}^{3+} + \text{e}^- \rightarrow \text{Fe}^{2+}$

(A) -0.476 volt (B) -0.404 volt (C) 0.440 volt (D) 0.772 volt

C-2. $\text{Cu}^+ + \text{e}^- \rightarrow \text{Cu}$, $E^\circ = x_1$ volt; $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$, $E^\circ = x_2$ volt, then for $\text{Cu}^{2+} + \text{e}^- \rightarrow \text{Cu}^+$, E° (volt) will be -

(A) $x_1 - 2x_2$ (B) $x_1 + 2x_2$ (C) $x_1 - x_2$ (D) $2x_2 - x_1$

C-3. Which of the following statements about the spontaneous reaction occurring in a galvanic cell is always true?

(A) $E_{\text{cell}}^\circ > 0$, $\Delta G^\circ < 0$, and $Q < K$ (B) $E_{\text{cell}}^\circ > 0$, $\Delta G^\circ < 0$, and $Q > K$

(C) $E_{\text{cell}}^\circ > 0$, $\Delta G^\circ > 0$, and $Q > K$ (D) $E_{\text{cell}} > 0$, $\Delta G < 0$, and $Q < K$

Section (D) : Nernst equation & its Applications (including concentration cells)

D-1. The standard emf for the cell reaction $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$ is 1.10 volt at 25°C. The emf for the cell reaction when 0.1 M Cu^{2+} and 0.1 M Zn^{2+} solutions are used at 25°C is

(A) 1.10 volt (B) 0.110 volt (C) -1.10 volt (D) -0.110 volt

D-2. Consider the cell $\text{H}_2(\text{Pt}) \left| \text{H}_3\text{O}^+(\text{aq}) \right| \text{Ag}^+ \text{Ag}$. The measured EMF of the cell is 1.0 V. What is the value of x ? $E_{\text{Ag}^+/\text{Ag}}^\circ = +0.8 \text{ V. [T = 25°C]}$; $E_{\text{Ag}^+/\text{Ag}}^\circ = +0.8 \text{ V. [T = 25°C]}$

(A) $2 \times 10^{-2} \text{ M}$ (B) $2 \times 10^{-3} \text{ M}$ (C) $1.5 \times 10^{-3} \text{ M}$ (D) $1.5 \times 10^{-2} \text{ M}$

D-3. $\text{Zn} | \text{Zn}^{2+}(\text{C}_1) || \text{Zn}^{2+}(\text{C}_2) | \text{Zn}$. for this cell ΔG is negative if -

(A) $\text{C}_1 = \text{C}_2$ (B) $\text{C}_1 > \text{C}_2$ (C) $\text{C}_2 > \text{C}_1$ (D) None

D-4. $\text{Pt} \left| \text{H}_2 \right| \text{H}^+ \left| \text{H}^+ \right| \text{H}_2 \left| \text{Pt} \right.$ (where p_1 and p_2 are pressures) cell reaction will be spontaneous if :

(A) $p_1 = p_2$ (B) $p_1 > p_2$ (C) $p_2 > p_1$ (D) $p_1 = 1 \text{ atm}$

D-5. $\text{Pt} | (\text{H}_2) | \text{pH} = 1 || \text{pH} = 2 | (\text{H}_2)\text{Pt}$
1 atm 1 atm

The cell reaction for the given cell is :

(A) spontaneous (B) non - spontaneous (C) equilibrium (D) none of these

D-6. The EMF of a concentration cell consisting of two zinc electrodes, one dipping into $\frac{M}{4}$ sol. of zinc sulphate & the other into $\frac{M}{16}$ sol. of the same salt at 25°C is

(A) 0.0125 V (B) 0.0250 V (C) 0.0178 V (D) 0.0356 V

Section (E) : Electrolysis

E-1. In an electrolytic cell of $\text{Ag}/\text{AgNO}_3/\text{Ag}$, when current is passed, the concentration of AgNO_3

(A) Increases (B) Decreases (C) Remains same (D) None of these

E-2. If 0.224 L of H_2 gas is formed at the cathode, the volume of O_2 gas formed at the anode under identical conditions, is
 (A) 0.224 L (B) 0.448 L (C) 0.112 L (D) 1.12 L

E-3. The two aqueous solutions, A ($AgNO_3$) and B ($LiCl$) were electrolysed using Pt. electrodes. The pH of the resulting solutions will
 (A) increase in A and decrease in B (B) decrease in both
 (C) increase in both (D) decrease in A and increase in B.

E-4. In the electrolysis of aqueous $CuBr_2$ using Pt electrodes :
 (A) Br_2 gas is not evolved at the anode
 (B) Cu (s) is deposited at the cathode
 (C) Br_2 gas is evolved at anode and H_2 gas at cathode
 (D) H_2 gas is evolved at anode.

E-5. During electrolysis of $CuSO_4$ using Pt-electrodes, the pH of solution
 (A) increases (B) decreases (C) remains unchanged (D) cannot be predicted

Section (F) : Faraday laws & its Applications

F-1. How many faradays are required to reduce one mol of MnO_4^- to Mn^{2+} -
 (A) 1 (B) 2 (C) 3 (D) 5

F-2. Three faradays of electricity was passed through an aqueous solution of iron (II) bromide. The mass of iron metal (at. mass 56) deposited at the cathode is -
 (A) 56 g (B) 84 g (C) 112 g (D) 168 g

F-3. A current of 2 A was passed for 1 h through a solution of $CuSO_4$ 0.237 g of Cu^{2+} ions were discharged at cathode. The current efficiency is
 (A) 42.2% (B) 26.1% (C) 10% (D) 40.01%

F-4. A current of 9.65 ampere is passed through the aqueous solution $NaCl$ using suitable electrodes for 1000 s. The amount of $NaOH$ formed during electrolysis is
 (A) 2.0 g (B) 4.0 g (C) 6.0 g (D) 8.0 g

F-5. Salts of A (atomic mass 15), B (atomic mass 27) and C (atomic mass 48) were electrolysed using same amount of charge. It was found that when 4.5 g of A was deposited, the mass of B and C deposited were 2.7g and 9.6 g. The valencies of A, B and C respectively.
 (A) 1, 3 and 2 (B) 3, 1 and 3 (C) 2, 6 and 3 (D) 3, 1 and 2

Section (G) : Commercial Cells & Corrosion

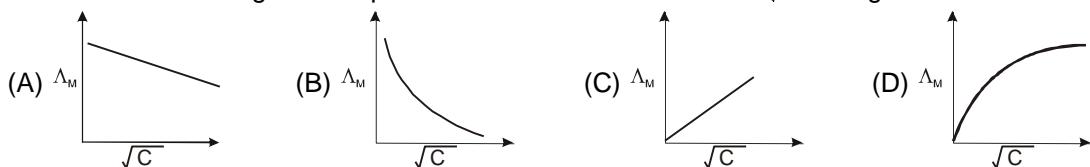
G-1. During discharge of a lead storage cell the density of sulphuric acid in the cell :
 (A) Increasing (B) decreasing
 (C) remains unchanged (D) initially increases but decrease subsequently

G-2. In H_2 - O_2 fuel cell the reaction occurring at cathode is :
 (A) $2 H_2O + O_2 + 4 e^- \longrightarrow 4 OH^-$ (B) $2H_2 + O_2 \longrightarrow 2H_2O$ (l)
 (C) $H^+ + OH^- \longrightarrow H_2O$ (D) $H^+ + e^- \longrightarrow \frac{1}{2} H_2$.

G-3. Which is not correct method for prevention of iron from Rusting -
 (A) Galvanisation (B) Connecting to sacrificial electrode of Mg
 (C) Making medium alkaline (D) Making medium acidic

Section (H) : Electrical Conductance

H-1. Which of the following curve represents the variation of Λ_M with \sqrt{C} for AgNO_3 ?



H-2. Which has maximum conductivity :

(A) $[\text{Cr}(\text{NH}_3)_3 \text{Cl}_3]$ (B) $[\text{Cr}(\text{NH}_3)_4 \text{Cl}_2]\text{Cl}$ (C) $[\text{Cr}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$ (D) $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$

H-3. Resistance of decimolar solution is 50 ohm. If electrodes of surface area 0.0004 m^2 each are placed at a distance of 0.02 m then conductivity of solution is :

(A) 1 s cm^{-1} (B) 0.01 s cm^{-1} (C) 0.001 s cm^{-1} (D) 10 s cm^{-1}

Section (I) : Kohlrausch law and its applications

I-1. The ionization constant of a weak electrolyte (HA) is 25×10^{-6} while the equivalent conductance of its 0.01 M solution is $19.6 \text{ S cm}^2 \text{ eq}^{-1}$. The equivalent conductance of the electrolyte at infinite dilution (in $\text{S cm}^2 \text{ eq}^{-1}$) will be

(A) 250 (B) 196 (C) 392 (D) 384

I-2. The conductivity of a saturated solution of BaSO_4 is $3.06 \times 10^{-6} \text{ ohm}^{-1} \text{ cm}^{-1}$ and its equivalent conductance is $1.53 \text{ ohm}^{-1} \text{ cm}^2 \text{ equiv}^{-1}$. The K_{sp} for BaSO_4 will be

(A) 4×10^{-12} (B) 2.5×10^{-13} (C) 25×10^{-9} (D) 10^{-6}

I-3. Molar conductance of 0.1 M acetic acid is $7 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$. If the molar cond. of acetic acid at infinite dilution is $380.8 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$, the value of dissociation constant will be :

(A) $226 \times 10^{-5} \text{ mol dm}^{-3}$ (B) $1.66 \times 10^{-3} \text{ mol dm}^{-1}$
 (C) $1.66 \times 10^{-2} \text{ mol dm}^{-3}$ (D) $3.442 \times 10^{-5} \text{ mol dm}^{-3}$

I-4. The conductivity of a solution of AgCl at 298 K is found to be $1.382 \times 10^{-6} \Omega^{-1} \text{ cm}^{-1}$. The ionic conductance of Ag^+ and Cl^- at infinite dilution are $61.9 \Omega^{-1} \text{ cm}^2 \text{ mol}^{-1}$ and $76.3 \Omega^{-1} \text{ cm}^2 \text{ mol}^{-1}$, respectively. The solubility of AgCl is

(A) $1.4 \times 10^{-5} \text{ mol L}^{-1}$ (B) $1 \times 10^{-2} \text{ mol L}^{-1}$ (C) $1 \times 10^{-5} \text{ mol L}^{-1}$ (D) $1.9 \times 10^{-5} \text{ mol L}^{-1}$

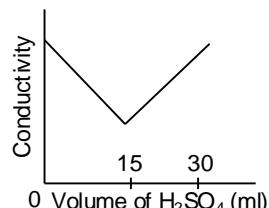
I-5. Molar conductances of BaCl_2 , H_2SO_4 and HCl at infinite dilutions are x_1 , x_2 and x_3 , respectively. Equivalent conductance of BaSO_4 at infinite dilution will be :

(A) $\frac{[x_1 + x_2 - x_3]}{2}$ (B) $\frac{[x_1 - x_2 - x_3]}{2}$ (C) $2(x_1 + x_2 - 2x_3)$ (D) $\frac{[x_1 + x_2 - 2x_3]}{2}$

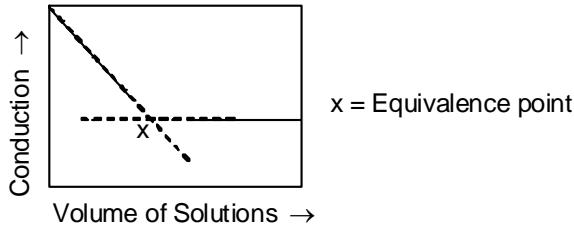
Section (J) : Conductometric Titration

J-1. 20 ml KOH solution was titrated with 0.2 mol/l H_2SO_4 solution in conductivity cell. Concentration of KOH solution was –

(A) 0.3 M
 (B) 0.15
 (C) 0.12
 (D) None of these



J-2. Following curve for conductometric titration is obtained when –



- (A) NaOH solution is added in to HCl solution
- (B) NaOH solution is added in to CH_3COOH solution
- (C) NH_4OH solution is added in to HCl solution
- (D) NH_4OH solution is added in to CH_3COOH solution

PART - III : MATCH THE COLUMN

1. Match the column

Nernst Equation Application			
Column I		Column II	
(A)	Zn Zn ²⁺ Mg ²⁺ Mg C ₁ C ₂ (C ₁ = C ₂)	(p)	E _{cell} = 0
(B)	Zn Zn ²⁺ Ag ⁺ Ag at. equilibrium	(q)	E ⁰ _{cell} = 0
(C)	Ag Ag ⁺ Ag ⁺ Ag C ₁ C ₂ (C ₁ = C ₂)	(r)	E ⁰ _{cell} = +ve
(D)	Fe Fe ²⁺ Ag Ag ⁺ C ₁ C ₂ (C ₁ = C ₂)	(s)	E ⁰ _{cell} = -ve

2.  Match Matrix ($E_{Ag^+/Ag}^0 = 0.8$).

Column I		Column II	
(A)	$\text{Pt} \text{H}_2 (0.1 \text{ bar}) \text{H}^+ (0.1 \text{ M}) \text{H}^+ (1 \text{ M}) \text{H}_2 (0.01 \text{ bar}) \text{Pt}$	(p)	Concentration cell
(B)	$\text{Ag} \text{Ag}^+ (10^{-9} \text{ M}) \text{Ag}^+ (10^{-2} \text{ M}) \text{Ag}$	(q)	$E_{\text{cell}} > 0$
(C)	$\text{Cu} \text{Cu}^{2+} (0.1 \text{ M}) \text{Cu}^{2+} (0.01 \text{ M}) \text{Cu}$	(r)	$E_{\text{cell}}^{\circ} = 0$ but cell is working.
(D)	$\text{Pt} \text{Cl}_2 (1\text{bar}) \text{HCl} (0.1 \text{ M}) \text{NaCl} (0.1\text{M}) \text{Cl}_2 \text{Pt} (1 \text{ bar})$	(s)	non working condition

Exercise-2

Marked Questions may have for Revision Questions.

PART - I : ONLY ONE OPTION CORRECT TYPE

2. Using the standard potential values given below, decide which of the statements I, II, III, IV are correct. Choose the right answer from (a), (b), (c) and (d)

$\text{Fe}^{2+} + 2\text{e}^- = \text{Fe}$, $E^\circ = -0.44 \text{ V}$
 $\text{Cu}^{2+} + 2\text{e}^- = \text{Cu}$, $E^\circ = +0.34 \text{ V}$
 $\text{Ag}^+ + \text{e}^- = \text{Ag}$, $E^\circ = +0.80 \text{ V}$

I. Copper can displace iron from FeSO_4 solution
 II. Iron can displace copper from CuSO_4 solution
 III. Silver can displace Cu from CuSO_4 solution
 IV. Iron can displace silver from AgNO_3 solution

(A) I and II (B) II and III (C) II and IV (D) I and IV

3. Red hot carbon will remove oxygen from the oxide AO and BO but not from MO, while B will remove oxygen from AO. The activity of metals A, B and M in decreasing order is

(A) $A > B > M$ (B) $B > A > M$ (C) $M > B > A$ (D) $M > A > B$

4. Which statement is correct.

(A) In SHE, the pressure of dihydrogen gas should be low and pH of solution should be zero.
 (B) In the reaction $\text{H}_2\text{O}_2 + \text{O}_3 \rightarrow 2\text{H}_2\text{O} + 2\text{O}_2$, H_2O_2 is oxidised to H_2O .
 (C) The absolute value of electrode potential cannot be determined.
 (D) According to IUPAC conventions, the standard electrode potential pertains to oxidation reactions only.

5. The electrode oxidation potential of electrode M(s) $\rightarrow \text{M}^{n+}(\text{aq})$ (2M) + $n\text{e}^-$ at 298 K is E_1 . When temperature (in $^\circ\text{C}$) is doubled and concentration is made half, then the electrode potential becomes E_2 . Which of the following represents the correct relationship between E_1 and E_2 ?

(A) $E_1 > E_2$ (B) $E_1 < E_2$ (C) $E_1 = E_2$ (D) Cannot be predicted

6. A galvanic cell is composed of two hydrogen electrodes, one of which is a standard one. In which of the following solutions should the other electrode be immersed to get maximum emf ?

$K_a(\text{CH}_3\text{COOH}) = 2 \times 10^{-5}$, $K_a(\text{H}_3\text{PO}_4) = 10^{-3}$.

(A) 0.1 M HCl (B) 0.1 M CH_3COOH (C) 0.1 M H_3PO_4 (D) 0.1 M H_2SO_4

7. Two weak acid solutions HA_1 and HA_2 each with the same concentration and having $\text{p}K_a$ values 3 and 5 are placed in contact with hydrogen electrode (1 atm, 25°C) and are interconnected through a salt bridge. The emf of the cell is :

(A) 0.21 V (B) 0.059 V (C) 0.018 V (D) 0.021 V

8. A hydrogen electrode placed in a buffer solution of CH_3COONa and CH_3COOH in the ratios of $x : y$ and $y : x$ has electrode potential values E_1 volts and E_2 volts, respectively at 25°C . The $\text{p}K_a$ values of acetic acid is (E_1 and E_2 are oxidation potentials)

(A) $\frac{E_1 + E_2}{0.118}$ (B) $\frac{E_2 - E_1}{0.118}$ (C) $-\frac{E_1 + E_2}{0.118}$ (D) $\frac{E_1 - E_2}{0.118}$

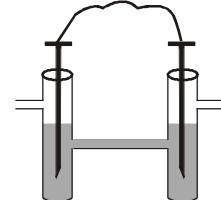
9. What is the emf at 25°C for the cell, $\text{Ag}, \left| \begin{array}{c} \text{AgBr} \text{ (s)}, \text{Br}^- \\ a = 0.34 \end{array} \right| \text{Fe}^{3+}, \text{Fe}^{2+} \right| \begin{array}{c} \text{Pt} \\ a = 0.1 \quad a = 0.02 \end{array} \right| \text{Pt}$

The standard reduction potentials for the half-reactions $\text{AgBr} + \text{e}^- \rightarrow \text{Ag} + \text{Br}^-$ and $\text{Fe}^{3+} + \text{e}^- \rightarrow \text{Fe}^{2+}$ are + 0.0713 V and + 0.770 V respectively.

(A) 0.474 volt (B) 0.529 volt (C) 0.356 volt (D) 0.713 volt

10. When the sample of copper with zinc impurity is to be purified by electrolysis, the appropriate electrode are

(A) pure zinc as cathode and pure copper as anode
 (B) impure sample as cathode and pure copper as anode
 (C) impure zinc as cathode and impure sample as anode
 (D) pure copper as cathode and impure sample as anode



PART - II : NUMERICAL VALUE QUESTIONS

1. $\text{H}_4\text{XeO}_6 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{XeO}_3 + 3\text{H}_2\text{O}$ $E^\circ = 3 \text{ V}$
 $\text{F}_2 + 2\text{e}^- \rightarrow 2\text{F}^-$ $E^\circ = 2.87 \text{ V}$
 $\text{O}_3 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{O}_2 + \text{H}_2\text{O}$ $E^\circ = 2.07 \text{ V}$
 $\text{Ce}^{4+} + \text{e}^- \rightarrow \text{Ce}^{3+}$ $E^\circ = 1.67 \text{ V}$
 $2\text{HClO} + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{Cl}_2 + 2\text{H}_2\text{O}$ $E^\circ = 1.63 \text{ V}$
 $\text{ClO}_4^- + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{ClO}_3^- + \text{H}_2\text{O}$ $E^\circ = 1.23 \text{ V}$
 $\text{ClO}^- + \text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{Cl}^- + 2\text{OH}^-$ $E^\circ = 0.89 \text{ V}$
 $\text{BrO}^- + \text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{Br}^- + 2\text{OH}^-$ $E^\circ = 0.76 \text{ V}$
 $\text{ClO}_4^- + \text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{ClO}_3^- + 2\text{OH}^-$ $E^\circ = 0.36 \text{ V}$
 $[\text{Fe}(\text{CN})_6]^{3-} + \text{e}^- \rightarrow [\text{Fe}(\text{CN})_6]^{4-}$ $E^\circ = 0.36 \text{ V}$

Based on the above data, how many of the following statements are correct ?

(A) F_2 is better oxidizing agent than H_4XeO_6 .
(B) Ozone can oxidize Cl_2
(C) ClO_4^- is better oxidizing agent in basic medium than in acidic medium
(D) Ferrocyanide ion can be easily oxidized by ClO^- , Ce^{4+} , Li^+ , BrO^-
(E) ClO^- can oxidize Br^- and ClO_3^- in basic medium
(F) Ce^{4+} can oxidize Cl_2 in acidic medium under standard conditions.

2. A hydrogen gas electrode is made by dipping platinum wire in a solution of NaOH of $\text{pH} = 10$ and by passing hydrogen gas around the platinum wire at one atm pressure. The oxidation potential of electrode is $10x$ milivolt. Find x ? (Take $\frac{2.303}{F} \frac{RT}{F} = 0.059$)

3. Estimate the cell potential of a Daniel cell having 1.0M Zn^{2+} and originally having 1.0M Cu^{2+} after sufficient NH_3 has been added to the cathode compartment to make NH_3 concentration 2.0M at equilibrium. Given K_f for $[\text{Cu}(\text{NH}_3)_4]^{2+} = 1 \times 10^{12}$, E° for the reaction, $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$ 1.1V .
(Take $\frac{2.303}{F} \frac{RT}{F} = 0.06$, $\log 6.25 = 0.8$) Respond as $10 \times$ your answer.

4. Molar conductivity of 0.04 $MgCl_2$ solution at 298 K is $200 \text{ Scm}^2 \text{ mole}^{-1}$. A conductivity cell which is filled with $MgCl_2$ have area of cross-section of electrode 4 cm^2 & distance between electrode is 8 cm. If potential difference between electrode is 10V then find current flow in milliampere.

5. The conductivity of a solution which is 0.1 M in $Ba(NO_3)_2$ and 0.2 M in $AgNO_3$ is 5.3 Sm^{-1} . If $\lambda_{(Ag^+)}^0 = 6 \times 10^{-3} \text{ Sm}^2 \text{ mol}^{-1}$ & $\lambda_{(Ba^{2+})}^0 = 13 \times 10^{-3} \text{ Sm}^2 \text{ mol}^{-1}$, determine $\lambda_{(NO_3^-)}^0$ in same unit. Report your answer after multiplying by 1000.

6. Λ_m^∞ (weak mono basic HA acid) = $390.7 \text{ S cm}^2 \text{ mol}^{-1}$
 Λ_m of HA at 0.01 M is $3.907 \text{ S cm}^2 \text{ mol}^{-1}$
 Find pH of 0.01 M HA ?

7. For a saturated solution of $AgCl$ at $25^\circ C$, $\kappa = 3.4 \times 10^{-6} \text{ ohm}^{-1} \text{ cm}^{-1}$ and that of $H_2O(\ell)$ used is $2.02 \times 10^{-6} \text{ ohm}^{-1} \text{ cm}^{-1}$. Λ_m^∞ for $AgCl$ is $138 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$ then the solubility of $AgCl$ in mili moles per m^3 will be :

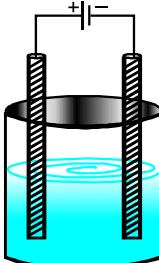
8. At 298 K, the conductivity of pure water is $5.5 \times 10^{-6} \text{ S m}^{-1}$. Calculate the ionic product of water using the following data :
 λ_m^0 values (in $\text{S m}^2 \text{ mol}^{-1}$) : $Ba(OH)_2 = 5.3 \times 10^{-2}$, $HCl = 4.25 \times 10^{-2}$, $BaCl_2 = 2.8 \times 10^{-2}$.
 Does your answer match with experimental value. Write 20 for yes & 40 for No.

9. How many of the following comparisons are correct with respect to their Λ_m^∞ ?
 (A) $K^+ > Na^+$ (B) $K^+ > H_3O^+$ (C) $Ca^{2+} > Na^+$ (D) $Mg^{2+} > NH_4^+$
 (E) $H_3O^+ > Mg^{2+}$ (F) $K^+ > Mg^{2+}$

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. Given $E_{Ag^+/Ag}^\circ = 0.80V$, $E_{Mg^{2+}/Mg}^\circ = -2.37V$, $E_{Cu^{2+}/Cu}^\circ = 0.34V$, $E_{Hg^{2+}/Hg}^\circ = 0.79 V$.
 Which of the following statements is/are correct
 (A) $AgNO_3$ can be stored in copper vessel (B) $Mg(NO_3)_2$ can be stored in copper vessel
 (C) $CuCl_2$ can be stored in silver vessel (D) $HgCl_2$ can be stored in copper vessel

2. Any redox reaction would occur spontaneously, if :
 (A) the free energy change (ΔG) is negative (B) the ΔG° is positive
 (C) the cell e.m.f. (E°) is negative (D) the cell e.m.f. is positive

3. Consider an electrolytic cell E being powered by a galvanic cell G, as shown in the figure. Then :


(A) Anode of E is connected to cathode of G (B) Anode of E is connected to anode of G
 (C) Cathode of E is connected to anode of G (D) Cathode of E is connected to cathode of G

4. On electrolysis, in which of the following, O_2 would be liberated at the anode ?
 (A) dilute H_2SO_4 with Pt electrodes (B) aqueous $AgNO_3$ solution with Pt electrodes
 (C) dilute H_2SO_4 with Cu electrodes (D) aqueous $NaOH$ with a Fe cathode & a Pt anode

5. A current of 2.68 A is passed for one hour through an aqueous solution of CuSO_4 using copper electrodes. Select the correct statement(s) from the following :

(A) increase in mass of cathode = 3.174 g
 (B) decrease in mass of anode = 3.174 g
 (C) no change in masses of electrodes
 (D) the ratio between the change of masses of cathode and anode is 1 : 2.

6. Three moles of electrons are passed through three solutions in succession containing AgNO_3 , CuSO_4 and AuCl_3 , respectively. The molar ratio of amounts of cations reduced at cathode will be

(A) 1 : 2 : 3 (B) $\frac{1}{1} : \frac{1}{2} : \frac{1}{3}$ (C) 3 : 2 : 1 (D) 6 : 3 : 2

7. If same quantity of electricity is passed through three electrolytic cells containing FeSO_4 , $\text{Fe}_2(\text{SO}_4)_3$ and $\text{Fe}(\text{NO}_3)_3$, then

(A) the amount of iron deposited in FeSO_4 and $\text{Fe}_2(\text{SO}_4)_3$ are equal
 (B) the amount of iron deposited in FeSO_4 is 1.5 times of the amount of iron deposited in $\text{Fe}(\text{NO}_3)_3$.
 (C) the amount of iron deposited in $\text{Fe}_2(\text{SO}_4)_3$ and $\text{Fe}(\text{NO}_3)_3$ are equal
 (D) the same amount of gas is evolved in all three cases at the anode.

8. When a lead storage battery is discharged then :

(A) SO_2 is evolved (B) lead sulphate is produced at both electrodes
 (C) sulphuric acid is consumed (D) water is formed

9. Mark out the correct statement(s) regarding electrolytic molar conductivity.

(A) It increase as temperature increases.
 (B) It experiences resistance due to vibration of ion at the mean position.
 (C) Increase in concentration decreases the electrolytic molar conductivity of both the strong as well as the weak electrolyte.
 (D) Greater the polarity of solvent, greater is the electrolytic molar conduction.

10. On increasing dilution following will increase :

(A) Equivalent conductivity (B) Conductivity
 (C) Molar conductivity (D) All of these

11. The resistances of following solutions of KCl were measured using conductivity cells of different cell constants, at same temperature. (Consider that at concentration less than 0.1 M, the specific conductivity of solution is directly proportional to the concentration of solution.)

	Concentration of Solution	Cell Constant
1.	0.1 M	1 cm^{-1}
2.	0.01 M	10 cm^{-1}
3.	0.005 M	5 cm^{-1}
4.	0.0025 M	25 cm^{-1}

Which of the following comparisons between their conductances (G) is/are correct ?

(A) G_1 is maximum (B) G_4 is minimum (C) $G_3 >> G_2$ (D) G_4 is maximum

12. Identify correct statements :

(A) Kohlraush law is applicable only on weak electrolyte.
 (B) On increasing dilution conductance, molar conductivity, equivalent conductivity increases but conductivity decreases.
 (C) $\Lambda_m = \frac{K}{C}$ following formula has units $\Lambda_m \rightarrow \Omega^{-} \text{ dm}^2/\text{mol}$, $K \rightarrow \Omega^{-} \text{ dm}^{-1}$, $C \rightarrow \text{mol}/\ell$.
 (D) Equation $\Lambda_m = \Lambda_m^{\infty} - b\sqrt{C}$ is applicable on weak as well as strong electrolyte.

13. Select the correct option(s):

(A) $\frac{\lambda_{\text{eq}}^{\circ} (\text{Al}^{3+})}{3} = \lambda_m^{\circ} (\text{Al}^{3+}) \text{ & } \frac{\lambda_{\text{eq}}^{\circ} (\text{SO}_4^{2-})}{2} = \lambda_m^{\circ} (\text{SO}_4^{2-})$

(B) $\lambda_{\text{eq}}^{\circ} (\text{Al}^{3+}) = \frac{\lambda_m^{\circ} (\text{Al}^{3+})}{3} \text{ & } \lambda_{\text{eq}}^{\circ} (\text{SO}_4^{2-}) = \frac{\lambda_m^{\circ} (\text{SO}_4^{2-})}{2}$

(C) $\lambda_{\text{eq}}^{\circ} (\text{Al}_2(\text{SO}_4)_3) = \frac{\lambda_m^{\circ} (\text{Al}^{3+})}{3} + \frac{\lambda_m^{\circ} (\text{SO}_4^{2-})}{2}$

(D) $\lambda_m^{\circ} (\text{Al}_2(\text{SO}_4)_3) = 6 \times \lambda_{\text{eq}}^{\circ} (\text{Al}_2(\text{SO}_4)_3)$

14. Which of the following order is correct related to their mobility in solution:

(A) $\text{Cs}_{\text{aq}}^+ > \text{Rb}_{\text{aq}}^+ > \text{K}_{\text{aq}}^+ > \text{Na}_{\text{aq}}^+ > \text{Li}_{\text{aq}}^+$ (B) $\text{Be}_{\text{aq}}^{+2} > \text{Li}_{\text{aq}}^+ > \text{Cs}_{\text{aq}}^+$

(C) $\text{H}_{\text{aq}}^+ > \text{Li}_{\text{aq}}^+ > \text{Be}_{\text{aq}}^{+2} > \text{Na}_{\text{aq}}^+ > \text{Mg}_{\text{aq}}^{+2}$ (D) $\text{H}_{\text{aq}}^+ > \text{Na}_{\text{aq}}^+ > \text{Li}_{\text{aq}}^+ > \text{Be}_{\text{aq}}^{+2}$

15. For strong electrolyte Λ_M increases slow with dilution and can be represented by the equation

$$\Lambda_M = \Lambda_M^0 - AC^{\frac{1}{2}}$$

Select correct statement

(A) Plot of Λ_M against $C^{\frac{1}{2}}$ is obtain a straight line with intercept Λ_M^0 & and slope ' $-A$ '

(B) Value of A depends upon temperature solvent and nature of electrolyte.

(C) NaCl and KCl have different value of constant ' A '

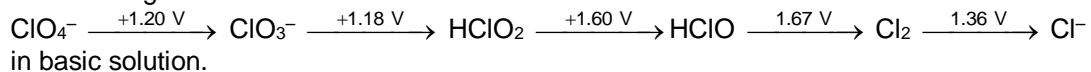
(D) NaCl and MgSO₄ have different value of constant ' A '

PART - IV : COMPREHENSION

Read the following passage carefully and answer the questions.

Comprehension # 1

If an element can exist in several oxidation states, it is convenient to display the reduction potentials corresponding to the various half reactions in diagrammatic form, known as Latimer diagram. The Latimer diagram for chlorine in acid solution is



The standard potentials for two nonadjacent species can also be calculated by using the concept that ΔG° as an additive property but potential is not an additive property and $\Delta G^\circ = -nFx^\circ$. If a given oxidation state is a stronger oxidising agent than in the next higher oxidation state, disproportionation can occur. The reverse of disproportionation is called comproportionation. The relative stabilities of the oxidation state can also be understood by drawing a graph of $\Delta G^\circ/F$ against oxidation state, known as Frost diagram, choosing the stability of zero oxidation state arbitrarily as zero. The most stable oxidation state of a species lies lowest in the diagram. Disproportionation is spontaneous if the species lies above a straight line joining its two product species.

1. Which of the following couple have same value of potential at pH = 0 and pH = 14?

(A) $\frac{\text{ClO}_4^-}{\text{ClO}_3^-}$

(B) $\frac{\text{ClO}_2^-}{\text{Cl}_2}$

(C) $\frac{\text{ClO}^-}{\text{Cl}_2}$

(D) $\frac{\text{Cl}_2}{\text{Cl}^-}$

2. What is the potential of couple $\frac{\text{ClO}^-}{\text{Cl}^-}$ at pH = 14?

(A) 1.78 V

(B) - 0.94 V

(C) 0.89 V

(D) - 0.89 V

3. Which of the following statement is correct?

(A) Cl_2 undergoes disproportionation into Cl^- and ClO^- both at pH = 0 and pH = 14.

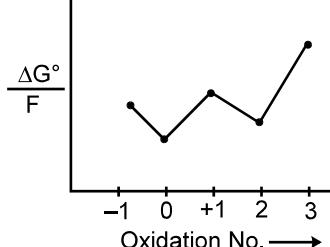
(B) Cl_2 undergoes disproportionation into Cl^- and ClO^- at pH = 14 but not at pH = 0.

(C) Cl_2 undergoes disproportionation into Cl^- and ClO^- at pH = 0 but not at pH = 14.

(D) None of these



4. For a hypothetical element, the Frost diagram is shown in figure?



Which of the following oxidation state is least stable?

5. Which of the following statement is correct ? According to Q.4

- (A) A^{+1} undergoes disproportionation into A and A^{2+} .
- (B) A^{2+} undergoes disproportionation in A and A^{3+} .
- (C) A undergoes comporportionation in A^{+1} and A^{-1} .
- (D) All of the above.

Comprehension # 2

The molar conductance of NaCl varies with the concentration as shown in the following table and all values follows the equation

$$\lambda_m^C = \lambda_m^\infty - b \sqrt{C}$$

Where λ_m^C = molar specific conductance

λ_m^∞ = molar specific conductance at infinite dilution

C = molar concentration

Molar Concentration of NaCl	Molar Conductance in $\text{ohm}^{-1} \text{ cm}^2 \text{ mole}^{-1}$
4×10^{-4}	107
9×10^{-4}	97
16×10^{-4}	87

When a certain conductivity cell (C) was filled with 25×10^{-4} (M) NaCl solution. The resistance of the cell was found to be 1000 ohm. At Infinite dilution, conductance of Cl^- and SO_4^{2-} are $80 \text{ ohm}^{-1} \text{ cm}^2 \text{ mole}^{-1}$ and $160 \text{ ohm}^{-1} \text{ cm}^2 \text{ mole}^{-1}$ respectively.

6. What is the molar conductance of NaCl at infinite dilution ?
(A) $147 \text{ ohm}^{-1} \text{ cm}^2 \text{ mole}^{-1}$ (B) $107 \text{ ohm}^{-1} \text{ cm}^2 \text{ s mole}^{-1}$
(C) $127 \text{ ohm}^{-1} \text{ cm}^2 \text{ mole}^{-1}$ (D) $157 \text{ ohm}^{-1} \text{ cm}^2 \text{ mole}^{-1}$

7. What is the cell constant of the conductivity cell (C)
(A) 0.385 cm^{-1} (B) 3.85 cm^{-1} (C) 38.5 cm^{-1} (D) 0.1925 cm^{-1}

8. If the cell (C) is filled with $5 \times 10^{-3} \text{ (N)}$ Na₂SO₄ the observed resistance was 400 ohm. What is the molar conductance of Na₂SO₄.
(A) $19.25 \text{ ohm}^{-1} \text{ cm}^2 \text{ mole}^{-1}$ (B) $96.25 \text{ ohm}^{-1} \text{ cm}^2 \text{ mole}^{-1}$
(C) $385 \text{ ohm}^{-1} \text{ cm}^2 \text{ mole}^{-1}$ (D) $192.5 \text{ ohm}^{-1} \text{ cm}^2 \text{ s mole}^{-1}$

9. If a 100 mL solution of 0.1M HBr is titrated using a very concentrated solution of NaOH, then the conductivity (specific conductance) of this solution at the equivalence point will be (assume volume change is negligible due to addition of NaOH). Report your answer after multiplying it with 10 in Sm⁻¹.
[Given $\lambda_{(\text{Na}^+)}^0 = 8 \times 10^{-3} \text{ Sm}^2 \text{ mol}^{-1}$, $\lambda_{(\text{Br}^-)}^0 = 4 \times 10^{-3} \text{ S m}^2 \text{ mol}^{-1}$]
(A) 6 (B) 12 (C) 15 (D) 24

Comprehension # 3

Answer 10, Q.11 and Q.12 by appropriately matching the information given in the three columns of the following table.

The curves in Column 1 shows the variation of conductivity during different titrations. The analyte and titrants has been listed in Column 2 & Column 3 respectively.

Column-1	Column-2 (Titrate)	Column-3 (Titrant)
(I) Conductivity decreases initially then increases slowly then increases rapidly	(i) $(C_2H_5)_2NH$	(P) HCl
(II) Conductivity decreases initially then increases	(ii) CH_3COOH	(Q) NaOH
(III) Conductivity decreases initially then remains approximately same	(iii) HBr	(R) CH_3COOH
(IV) Conductivity increases initially then remains approximately same	(iv) NaOH	(S) NH_4OH

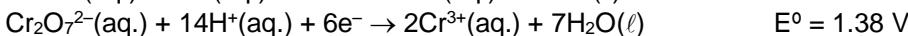
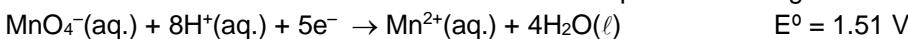
- Which of the following is an incorrect combination of curves in Column 1.
(A) (II) (iii) (Q) (B) (I) (i) (P) (C) (I) (iii) (S) (D) (I) (ii) (Q)
- The correct combination for a titration in which conductance at equivalent point is lower than initial
(A) (I) (ii) (Q) (B) (I) (iii) (S) (C) (III) (iv) (R) (D) (IV) (ii) (S)
- Select the correct combination
(A) (I) (iii) (Q) (B) (IV) (ii) (S) (C) (I) (iii) (S) (D) (I) (iv) (R)

Exercise-3

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

* Marked Questions are having one or more than one correct options.

- Standard electrode potential data are useful for understanding the suitability of an oxidant in a redox titration. Some half cell reactions and their standard potentials are given below : [JEE 2002, 3/84]



Identify the only INCORRECT statement regarding the quantitative estimation of aqueous $Fe(NO_3)_2$:

(A) MnO_4^- can be used in aqueous HCl. (B) $Cr_2O_7^{2-}$ can be used in aqueous HCl.
(C) MnO_4^- can be used in aqueous H_2SO_4 . (D) $Cr_2O_7^{2-}$ can be used in aqueous H_2SO_4 .

- Two students use the same stock solution of $ZnSO_4$ and different solutions of $CuSO_4$ to make Daniel cell. The emf of one cell is 0.03 V higher than the other. The concentration of $CuSO_4$ solution in the cell with higher emf value is 0.5 M. Find out the concentration of $CuSO_4$ solution in the other cell.

$$\left(\text{Given : } \frac{2.303}{F} \frac{RT}{F} = 0.06 \right) . \quad [\text{JEE 2003, 2/60}]$$

- The emf of the cell, $Zn | Zn^{2+}(0.01 \text{ M}) || Fe^{2+}(0.001 \text{ M}) | Fe$ at 298 K is 0.2905 V. Then the value of equilibrium constant for the cell reaction is : [JEE 2004, 3/84]

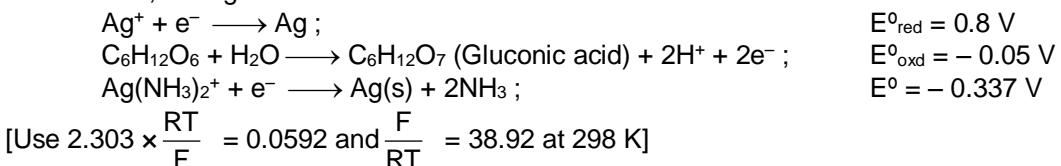
$$(A) e^{\frac{0.32}{0.0295}} \quad (B) 10^{\frac{0.32}{0.0295}} \quad (C) 10^{\frac{0.26}{0.0295}} \quad (D) 10^{\frac{0.32}{0.059}}$$

4. Find the equilibrium constant at 298 K for the reaction : [JEE 2004, 4/60]
 $\text{Cu}^{2+}(\text{aq}) + \text{In}^{2+}(\text{aq}) \rightleftharpoons \text{Cu}^+(\text{aq}) + \text{In}^{3+}(\text{aq})$
 Given that $E^0_{\text{Cu}^{2+}/\text{Cu}^+} = 0.15 \text{ V}$, $E^0_{\text{In}^{3+}/\text{In}^+} = -0.42 \text{ V}$, $E^0_{\text{In}^{2+}/\text{In}^+} = -0.40 \text{ V}$.

5. The half cell reactions for rusting of iron are :
 $2\text{H}^+ + \frac{1}{2}\text{O}_2 + 2\text{e}^- \longrightarrow \text{H}_2\text{O}; E^0 = +1.23 \text{ V}$ & $\text{Fe}^{2+} + 2\text{e}^- \longrightarrow \text{Fe}; E^0 = -0.44 \text{ V}$
 ΔG^0 (in kJ/mol) for the overall reaction is : [JEE 2005, 3/84]
 (A) -76 (B) -322 (C) -122 (D) -176

Comprehension # 1

Tollen's reagent is used for the detection of aldehyde. When a solution of AgNO_3 is added to glucose with NH_4OH , then gluconic acid is formed.



Now answer the following three questions :

6. $2\text{Ag}^+ + \text{C}_6\text{H}_{12}\text{O}_6 + \text{H}_2\text{O} \longrightarrow 2\text{Ag}(\text{s}) + \text{C}_6\text{H}_{12}\text{O}_7 + 2\text{H}^+$ [JEE 2006, 5/184]
 Find $\ln K$ of this reaction :
 $2\text{Ag}^+ + \text{C}_6\text{H}_{12}\text{O}_6 + \text{H}_2\text{O} \longrightarrow 2\text{Ag}(\text{s}) + \text{C}_6\text{H}_{12}\text{O}_7 + 2\text{H}^+$
 (A) 66.13 (B) 58.38 (C) 28.30 (D) 46.29

7. When ammonia is added to the solution, pH is raised to 11. Which half-cell reaction is affected by pH and by how much : [JEE 2006, 5/184]
 (A) E_{oxd} will increase by a factor of 0.65 for E^0_{oxd} (B) E_{oxd} will decrease by a factor of 0.65 for E^0_{oxd}
 (C) E_{red} will increase by a factor of 0.65 for E^0_{red} (D) E_{red} will decrease by a factor of 0.65 for E^0_{red}

8. Ammonia is always added in this reaction. Which of the following must be INCORRECT :
 (A) NH_3 combines with Ag^+ to form a complex. [JEE 2006, 5/184]
 (B) $\text{Ag}(\text{NH}_3)_2^+$ is a weaker oxidising reagent than Ag^+ .
 (C) In absence of NH_3 , silver salt of gluconic acid is formed.
 (D) NH_3 has affected the standard reduction potential of glucose/gluconic acid electrode.

9. We have taken a saturated solution of AgBr . K_{sp} of AgBr is 12×10^{-14} . If 10^{-7} mole of AgNO_3 are added to 1 litre of this solution, find conductivity (specific conductance) of this solution in terms of 10^{-7} Sm^{-1} .
 Given : $\Lambda^0_{(\text{Ag}^+)} = 6 \times 10^{-3} \text{ Sm}^2\text{mol}^{-1}$, $\Lambda^0_{(\text{Br}^-)} = 8 \times 10^{-3} \text{ Sm}^2\text{mol}^{-1}$, $\Lambda^0_{(\text{NO}_3^-)} = 7 \times 10^{-3} \text{ Sm}^2\text{mol}^{-1}$ [JEE 2006, 6/184]

Comprehension # 2

Chemical reactions involve interaction of atoms and molecules. A large number of atoms/molecules (approximately 6.023×10^{23}) are present in a few grams of any chemical compound varying with its atomic/molecular masses. To handle such large number conveniently, the mole concept was introduced. This concept has implications in diverse areas such as analytical chemistry, biochemistry, electrochemistry and radiochemistry. The following example illustrates a typical case, involving chemical/electrochemical reaction, which requires a clear understanding of the mole concept.

A 4.0 molar aqueous solution of NaCl is prepared and 500 mL of this solution is electrolysed. This leads to the evolution of chlorine gas at one of the electrodes.

(Given : Atomic masses : $\text{Na} = 23$, $\text{Hg} = 200$; 1 Faraday = 96500 coulombs)

Now answer the following three questions :

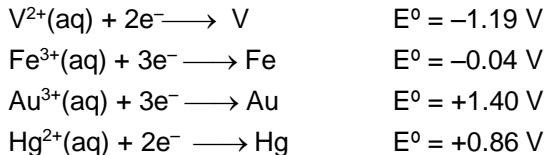
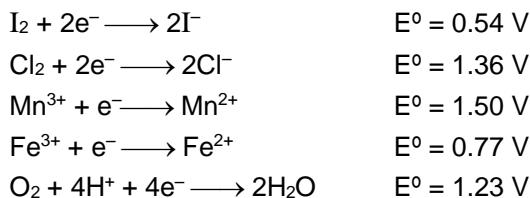
10. The total number of moles of chlorine gas evolved is : [JEE 2007, 4/162]
 (A) 0.5 (B) 1.0 (C) 2.0 (D) 3.0

11. If the cathode is Hg electrode, the maximum weight (in g) of amalgam formed from this solution is : [JEE 2007, 4/162]
 (A) 200 (B) 225 (C) 400 (D) 446

12. The total charge (in coulombs) required for complete electrolysis is : [JEE 2007, 4/162]
 (A) 24125 (B) 48250 (C) 96500 (D) 193000

Comprehension # 3

Redox reactions play a pivoted role in chemistry and biology. The values of standard redox potential (E°) of two half-cell reactions decide which way the reaction is expected to proceed. A simple example is a Daniel cell in which zinc goes into solution and copper gets deposited. Given below is a set of half-cell reactions (acidic medium) along with their E° values with respect to normal hydrogen electrode. Using this data, obtain the correct explanations to questions 13 - 14.

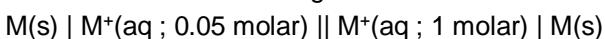


The pair(s) of metals that is(are) oxidized by NO_3^- in aqueous solution is(are) : **[JEE 2009, 4/160]**

(A) V and Hg (B) Hg and Fe (C) Fe and Au (D) Fe and V

Comprehension # 4

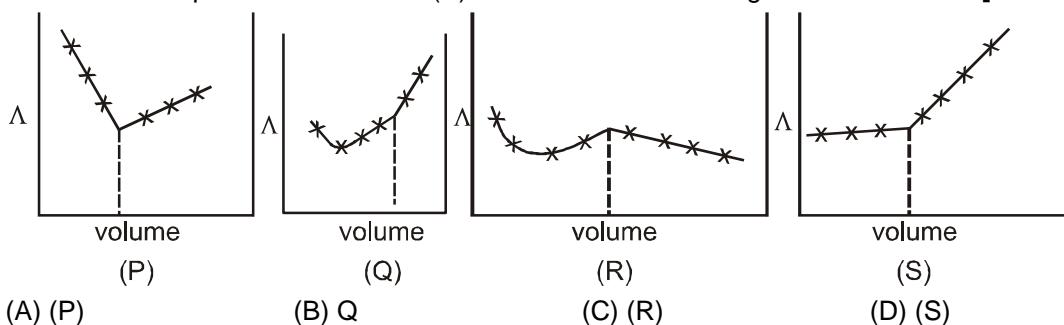
The concentration of potassium ions inside a biological cell is at least twenty times higher than the outside. The resulting potential difference across the cell is important in several processes such as transmission of nerve impulses and maintaining the ion balance. A simple model for such a concentration cell involving a metal M is :



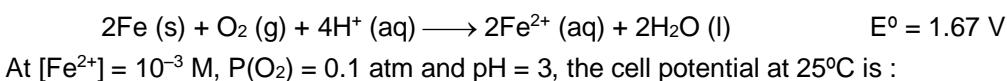
For the above electrolytic cell, the magnitude of the cell potential is $|E_{cell}| = 70 \text{ mV}$.

Now answer the following two questions :

19. $\text{AgNO}_3(\text{aq.})$ was added to an aqueous KCl solution gradually and the conductivity of the solution was measured. The plot of conductance (Λ) versus the volume of AgNO_3 is : [JEE 2011, 3/180]



20. Consider the following cell reaction :



$$(\text{Take } \frac{2.303 R (298)}{F} = 0.06)$$

(A) 1.47 V (B) 1.77 V (C) 1.87 V (D) 1.57 V

Comprehension # 5

The electrochemical cell shown below is a concentration cell.



The emf of the cell depends on the difference in concentration of M^{2+} ions at the two electrodes. The emf of the cell at 298 is 0.059 V.

21. The solubility product (K_{sp} ; in $\text{mol}^3 \text{ dm}^{-9}$) of MX_2 at 298 K based on the information available in the given concentration cell is : (Take $2.303 \times R \times 298/F = 0.059 \text{ V}$) [IIT-JEE 2012, 3/66]

(A) 1×10^{-15} (B) 4×10^{-15} (C) 1×10^{-12} (D) 4×10^{-12}

22. The value of ΔG (in kJ mol^{-1}) for the given cell is : (Take $1F = 96500 \text{ C mol}^{-1}$) [IIT-JEE 2012, 3/136]

(A) -5.7 (B) 5.7 (C) 11.4 (D) -11.4

23. An aqueous solution of X is added slowly to an aqueous solution of Y as shown in list I. The variation in conductivity of these reactions is given in List II. Match List I with List II and select the correct answer using the code given below the lists : [JEE(Advanced) 2013, 3/120]

	List I		List II
P.	$(\text{C}_2\text{H}_5)_3\text{N} + \text{CH}_3\text{COOH}$ X Y	1.	Conductivity decreases and then increases
Q.	$\text{KI} (0.1\text{M}) + \text{AgNO}_3 (0.01\text{M})$ X Y	2.	Conductivity decreases and then does not change much
R.	$\text{CH}_3\text{COOH} + \text{KOH}$ X Y	3.	Conductivity increases and then does not change much
S.	$\text{NaOH} + \text{HI}$ X Y	4.	Conductivity does not change much and then increases

Codes :

P	Q	R	S	P	Q	R	S
(A) 3	4	2	1	(B) 4	3	2	1
(C) 2	3	4	1	(D) 1	4	3	2

24. The standard reduction potential data at 25°C is given below. [JEE(Advanced) 2013, 3/120]

$$\begin{array}{ll}
 E^\circ(Fe^{3+}.Fe^{2+}) = +0.77 \text{ V}; & E^\circ(Fe^{2+}.Fe) = -0.44 \text{ V}; \\
 E^\circ(Cu^{2+}.Cu) = +0.34 \text{ V}; & E^\circ(Cu^{+}.Cu) = +0.52 \text{ V}; \\
 E^\circ(O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O) = +1.23 \text{ V}; & E^\circ(O_2(g) + 2H_2O + 4e^- \rightarrow 4OH^-) = +0.40 \text{ V} \\
 E^\circ(Cr^{3+}.Cr) = -0.74 \text{ V}; & E^\circ(Cr^{2+}.Cr) = -0.91 \text{ V}
 \end{array}$$

Match E° of the rebox pair in List I with the values given in List II and select the correct answer using the code given below the lists :

	List I		List II
P.	$E^\circ(Fe^{3+}.Fe)$	1.	-0.36 V
Q.	$E^\circ(4H_2O \rightleftharpoons 4H^+ + 4OH^-)$	2.	-0.4 V
R.	$E^\circ(Cu^{2+} + Cu \rightarrow 2Cu^+)$	3.	-0.04 V
S.	$E^\circ(Cr^{3+}, Cr^{2+})$	4.	-0.83 V

Codes :

	P	Q	R	S	P	Q	R	S
(A)	4	1	2	3	(B)	2	3	4
(C)	1	2	3	4	(D)	3	4	1

25. In a galvanic cell, the salt bridge

[JEE(Advanced) 2014, 3/120]

- (A) does not participate chemically in the cell reaction.
- (B) stops the diffusion of ions from one electrode to another.
- (C) is necessary for the occurrence of the cell reaction.
- (D) ensures mixing of the two electrolytic solutions.

26. All the energy released from the reaction $X \rightarrow Y$, $\Delta_r G^\circ = -193 \text{ kJ mol}^{-1}$ is used for oxidizing M^+ as $M^+ \rightarrow M^{3+} + 2e^-$, $E^\circ = -0.25 \text{ V}$. Under standard conditions, the number of moles of M^+ oxidized when one mole of X is converted to Y is : $[F = 96500 \text{ C mol}^{-1}]$ [JEE(Advanced) 2015, 4/168]

27. The molar conductivity of a solution of a weak acid HX (0.01 M) is 10 times smaller than the molar conductivity of a solution of a weak acid HY (0.10 M). If $\lambda_{X^-}^0 \approx \lambda_{Y^-}^0$, the difference in their pK_a values, $pK_a(HX) - pK_a(HY)$, is (consider degree of ionization of both acids to be $<<1$)

[JEE(Advanced) 2015, 4/168]

28. For the following electrochemical cell at 298 K,

$$\text{Pt(s) | H}_2(\text{g}, 1 \text{ bar}) \mid \text{H}^+(\text{aq}, 1 \text{ M}) \parallel \text{M}^{4+}(\text{aq}) \mid \text{M}^{2+}(\text{aq}) \mid \text{Pt(s)}, E_{\text{cell}} = 0.092 \text{ V when } \frac{[\text{M}^{2+}(\text{aq})]}{[\text{M}^{4+}(\text{aq})]} = 10^x.$$

$$\text{Given : } E_{M^{4+}/M^{2+}}^\circ = 0.151 \text{ V}; 2.303 \frac{RT}{F} = 0.059 \text{ V}$$

The value of x is :

(A) -2 (B) -1 (C) 1 (D) 2

[JEE(Advanced) 2016, 3/124]

29. The conductance of a 0.0015 M aqueous solution of a weak monobasic acid was determined by using a conductivity cell consisting of platinized Pt electrodes. The distance between the electrodes is 120 cm with an area of cross section of 1 cm^2 . The conductance of this solution was found to be $5 \times 10^{-7} \text{ S}$. The pH of the solution is 4. The value of limiting molar conductivity (Λ°_m) of this weak monobasic acid in aqueous solution is $Z \times 10^2 \text{ S cm}^{-1} \text{ mol}^{-1}$. The value of Z is [JEE(Advanced) 2017, 3/122]

30. For the following cell, $\text{Zn(s) | ZnSO}_4(\text{aq}) \parallel \text{CuSO}_4(\text{aq}) \mid \text{Cu(s)}$ when the concentration of Zn^{2+} is 10 times the concentration of Cu^{2+} , the expression for ΔG (in J mol^{-1}) is : [JEE(Advanced) 2017, 3/122]
 $[F$ is Faraday constant; R is gas constant; T is temperature; $E^\circ(\text{cell}) = 1.1 \text{ V}]$
 (A) $2.303 RT + 1.1 F$ (B) $1.1 F$ (C) $2.303 RT - 2.2 F$ (D) $-2.2 F$

31. For the electrochemical cell, $\text{Mg(s) | Mg}^{2+}(\text{aq}, 1 \text{ M}) \parallel \text{Cu}^{2+}(\text{aq}, 1 \text{ M}) \mid \text{Cu(s)}$ the standard emf of the cell is 2.70 V at 300 K. When the concentration of Mg^{2+} is changed to $x \text{ M}$, the cell potential changes to 2.67 V at 300 K. The value of x is _____. (Given, $\frac{F}{R} = 11500 \text{ K V}^{-1}$, where F is the Faraday constant and R is the gas constant, $\ln(10) = 2.30$) [JEE(Advanced) 2018, 3/120]

32. Consider an electrochemical cell : $\text{A(s) | A}^{n+}(\text{aq}, 2 \text{ M}) \parallel \text{B}^{2n+}(\text{aq}, 1 \text{ M}) \mid \text{B(s)}$. The value of ΔH° for the cell reaction is twice that of ΔG° at 300 K. If the emf of the cell is zero, the ΔS° (in $\text{J K}^{-1} \text{ mol}^{-1}$) of the cell reaction per mole of B formed at 300 K is _____. (Given : $\ln(2) = 0.7$, R (universal gas constant) = $8.3 \text{ J K}^{-1} \text{ mol}^{-1}$. H, S and G are enthalpy, entropy and Gibbs energy, respectively.) [JEE(Advanced) 2018, 3/120]



PART - II : JEE (MAIN) ONLINE PROBLEMS (PREVIOUS YEARS)

1. The standard electrode potentials ($E_{M^+/M}^\circ$) of four metals A, B, C and D are -1.2 V, 0.6 V, 0.85 V and -0.76 V, respectively. The sequence of deposition of metals on applying potential is :
[JEE(Main) 2014 Online (09-04-14), 4/120]
 (1) A, C, B, D (2) B, D, C, A (3) C, B, D, A (4) D, A, B, C

2. A current of 10.0 A flows for 2.00 h through an electrolytic cell containing a molten salt of metal X. This results in the decomposition of 0.250 mol of metal X at the cathode. The oxidation state of X in the molten salt is : ($F = 96,500$ C)
[JEE(Main) 2014 Online (09-04-14), 4/120]
 (1) $1 +$ (2) $2 +$ (3) $3 +$ (4) $4 +$

3. Given : $Fe^{3+} (aq) + e^- \rightarrow Fe^{2+} (aq); E^\circ = +0.77$ V
 $Al^{3+} (aq) + 3e^- \rightarrow Al(s); E^\circ = -1.66$ V
 $Br_2 (aq) + 2e^- \rightarrow 2Br^-; E^\circ = +1.09$ V
 Considering the electrode potentials, which of the following represents the correct order of reducing power?
[JEE(Main) 2014 Online (11-04-14), 4/120]
 (1) $Fe^{2+} < Al < Br^-$ (2) $Br^- < Fe^{2+} < Al$ (3) $Al < Br^- < Fe^{2+}$ (4) $Al < Fe^{2+} < Br^-$

4. How many electrons would be required to deposit 6.35 g of copper at the cathode during the electrolysis of an aqueous solution of copper sulphate ? (Atomic mass of copper = 63.5 u, N_A = Avogadro's constant).
[JEE(Main) 2014 Online (12-04-14), 4/120]
 (1) $\frac{N_A}{20}$ (2) $\frac{N_A}{10}$ (3) $\frac{N_A}{5}$ (4) $\frac{N_A}{2}$

5. A variable, opposite external potential (E_{ext}) is applied to the cell $Zn|Zn^{2+}$ (1 M) || Cu^{2+} (1 M) | Cu , of potential 1.1 V. When $E_{ext} < 1.1$ V and $E_{ext} > 1.1$ V respectively electrons flow from :
[JEE(Main) 2015 Online (10-04-15), 4/120]
 (1) Cathode to anode in both cases (2) cathode to anode and anode to cathode
 (3) anode to cathode and cathode to anode (4) anode to cathode in both cases

6. At 298 K, the standard reduction potentials are 1.51 V for $MnO_4^-|Mn^{2+}$, 1.36 V for $Cl_2|Cl^-$, 1.07 V for $Br_2|Br$, and 0.54 V for $I_2|I^-$. At $pH = 3$, permanganate is expected to oxidize : $\left(\frac{RT}{F} = 0.059\text{ V} \right)$
[JEE(Main) 2015 Online (11-04-15), 4/120]
 (1) Cl^- , Br^- and I^- (2) Br^- and I^- (3) Cl^- and Br^- (4) I^- only

7. What will occur if a block of copper metal is dropped into a beaker containing a solution of 1M $ZnSO_4$?
[JEE(Main) 2016 Online (09-04-16), 4/120]
 (1) The copper metal will dissolve and zinc metal will be deposited.
 (2) The copper metal will dissolve with evolution of oxygen gas.
 (3) The copper metal will dissolve with evolution of hydrogen gas.
 (4) No reaction will occur.

8. Identify the correct statement:
[JEE(Main) 2016 Online (10-04-16), 4/120]
 (1) Corrosion of iron can be minimized by forming an impermeable barrier at its surface.
 (2) Iron corrodes in oxygen-free water.
 (3) Iron corrodes more rapidly in salt water because its electrochemical potential is higher.
 (4) Corrosion of iron can be minimized by forming a contact with another metal with a higher reduction potential.

9. What is the standard reduction potential (E°) for $Fe^{3+} \rightarrow Fe$?
 Given that :
[JEE(Main) 2017 Online (08-04-17), 4/120]
 $Fe^{2+} + 2e^- \rightarrow Fe; E_{Fe^{2+}/Fe}^\circ = -0.47$ V
 $Fe^{3+} + e^- \rightarrow Fe^{2+}; E_{Fe^{2+}/Fe}^\circ = +0.77$ V
 (1) $+0.30$ V (2) -0.057 V (3) $+0.057$ V (4) -0.30 V

10. Consider the following standard electrode potentials (E° in volts) in aqueous solution :

Element	M^{3+} / M	M^+ / M
Al	-1.66	+ 0.55
Tl	+1.26	- 0.34

[JEE(Main) 2017 Online (08-04-17), 4/120]

Based on these data, which of the following statements is **correct** ?

(1) Al^+ is more stable than Al^{3+} (2) Tl^{3+} is more stable than Al^{3+}
 (3) Tl^+ is more stable than Al^{3+} (4) Tl^+ is more stable than Al^+

11. Which of the following ions does not liberate hydrogen gas on reaction with dilute acids ?

[JEE(Main) 2017 Online (09-04-17), 4/120]

(1) Mn^{2+} (2) Ti^{2+} (3) V^{2+} (4) Cr^{2+}

12. To find the standard potential of M^{3+}/M electrode, the following cell is constituted : Pt / M / M^{3+} (0.001 mol L⁻¹) / Ag^+ (0.01 mol L⁻¹) / Ag

The emf of the cell is found to be 0.421 volt at 298 K. The standard potential of half reaction $M^{3+} + 3e^- \rightarrow M$ at 298 K will be : [JEE(Main) 2017 Online (09-04-17), 4/120]

(Given $E_{Ag^+/Ag}^-$ at 298 K = 0.80 volt)

(1) 0.32 Volt (2) 0.66 Volt (3) 0.38 Volt (4) 1.28 Volt

13. When an electric current is passed through acidified water, 112 mL of hydrogen gas at N.T.P was collected at the cathode in 965 seconds. The current passed, in ampere, is :

[JEE(Main) 2018 Online (15-04-2018), 4/120]

(1) 2.0 (2) 0.1 (3) 0.5 (4) 1.0

14. When 9.65 ampere current was passed for 1.0 hour into nitrobenzene in acidic medium, the amount of p-aminophenol produced is : [JEE(Main) 2018 Online (16-04-2018), 4/120]

Note : Nitrobenzene actually convert into aniline in reduction in acidic medium.

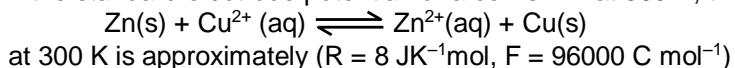
(1) 109.0 g (2) 98.1 g (3) 9.81 g (4) 10.9 g

15. The anodic half-cell of lead-acid battery is recharged using electricity of 0.05 Faraday. The amount of $PbSO_4$ electrolyzed in g during the process is : (Molar mass of $PbSO_4$ = 303 g mol⁻¹)

[JEE(Main) 2019 Online (09-01-2019), 4/120]

(1) 15.2 (2) 22.8 (3) 7.6 (4) 11.6

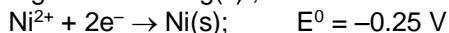
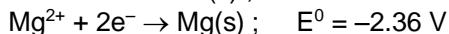
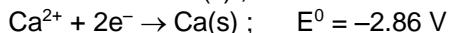
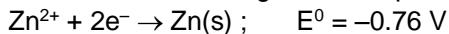
16. If the standard electrode potential for a cell is 2 V at 300 K, the equilibrium constant (K) for the reaction



[JEE(Main) 2019 Online (09-01-2019), 4/120]

(1) e^{320} (2) e^{-80} (3) e^{160} (4) e^{-160}

17. Consider the following reduction processes :



The reducing power of the metals increases in the order: [JEE(Main) 2019 Online (10-01-2019), 4/120]

(1) Ca < Mg < Zn < Ni (2) Ni < Zn < Mg < Ca (3) Ca < Zn < Mg < Ni (4) Zn < Mg < Ni < Ca

18. In the cell, Pt(s) | $H_2(g, 1\text{bar})$ | $HCl(aq)$ | $AgCl(s)$ | $Ag(s)$ | Pt(s)

The cell potential is 0.92 V when a 10^{-6} molal HCl solution is used. The standard electrode potential of

($AgCl / Ag$, Cl^-) electrode is : $\left\{ \text{Given, } \frac{2.303RT}{F} = 0.06 \text{ V at } 298\text{K} \right\}$

[JEE(Main) 2019 Online (10-01-2019), 4/120]

(1) 0.76 V (2) 0.20 V (3) 0.94 V (4) 0.40 V

19. The electrolytes usually used in the electroplating of gold and silver, respectively, are:

[JEE(Main) 2019 Online (10-01-2019), 4/120]

(1) $[Au(CN)_2]^-$ and $[AgCl_2]^-$ (2) $[Au(NH_3)_2]^+$ and $[Ag(CN)_2]^-$
 (3) $[Au(CN)_2]^-$ and $[Ag(CN)_2]^-$ (4) $[Au(OH)_4]^-$ and $[Ag(OH)_2]^-$

20. For the cell $Zn(s) | Zn^{2+}(aq) || M^{x+}(aq) | M(s)$, different half cells and their standard electrode potentials are given below :

$M^{x+}(aq)/M(s)$	$Au^{3+}(aq)/Au(s)$	$Ag^{+}(aq)/Ag(s)$	$Fe^{3+}(aq)/Fe^{2+}(aq)$	$Fe^{2+}(aq)/Fe(s)$
$E^\ominus_{M^{x+}/M(V)}$	1.40	0.80	0.77	-0.44

If $E^\ominus_{Zn^{2+}/Zn} = -0.76$ V, which cathode will give a maximum value of E^\ominus_{cell} per electron transferred ?

[JEE(Main) 2019 Online (11-01-2019), 4/120]

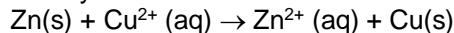
(1) Au^{3+}/Au (2) Fe^{3+}/Fe^{2+} (3) Fe^{2+}/Fe (4) Ag^{+}/Ag

21. Given the equilibrium constant : K_c of the reaction $Cu(s) + 2Ag^{+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$ is 10×10^{15} , calculate the E^\ominus_{cell} of this reaction at 298 K :
$$2.303 \frac{RT}{F} \text{ at } 298K = 0.059 \text{ V}$$

[JEE(Main) 2019 Online (11-01-2019), 4/120]

(1) 0.4736 mV (2) 0.04736 V (3) 0.4736 V (4) 0.04736 mV

22. The standard electrode potential E^\ominus and its temperature coefficient $\left(\frac{dE^\ominus}{dT}\right)$ for a cell are 2 V and $-5 \times 10^{-4} \text{ VK}^{-1}$ at 300 K respectively. The cell reaction is



The standard reaction enthalpy (Δ_rH^\ominus) at 300 K in kJ mol^{-1} is :

(Use $R = 8\text{J K}^{-1} \text{ mol}^{-1}$ and $F = 96,000 \text{ C mol}^{-1}$) [JEE(Main) 2019 Online (12-01-2019), 4/120]

(1) 206.4 (2) -384.0 (3) 192.0 (4) -412.8

23. Λ_m^0 for NaCl, HCl and NaA are 126.4, 425.9 and 100.5 $\text{S cm}^2 \text{ mol}^{-1}$, respectively. If the conductivity of 0.001 M HA is $5 \times 10^{-5} \text{ S cm}^{-1}$, degree of dissociation of HA is:

[JEE(Main) 2019 Online (12-01-2019), 4/120]

(1) 0.125 (2) 0.50 (3) 0.75 (4) 0.25

24. Given that, $E^\ominus_{O_2/H_2O} = +1.23 \text{ V}$

$$E^\ominus_{S_2O_8^{2-}/SO_4^{2-}} = 2.05 \text{ V}$$

$$E^\ominus_{Br_2/Br^-} = +1.09 \text{ V};$$

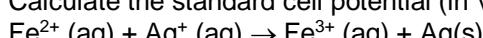
$$E^\ominus_{Au^{3+}/Au} = +1.4 \text{ V}$$

The strongest oxidizing agent is :

(1) O_2 (2) Br_2 (3) Au^{3+} (4) $S_2O_8^{2-}$

[JEE(Main) 2019 Online (08-04-19)S1, 4/120]

25. Calculate the standard cell potential (in V) of the cell in which following reaction takes place :



Given that

$$E^\ominus_{Ag^{+}/Ag} = x \text{ V}$$

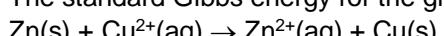
$$E^\ominus_{Fe^{2+}/Fe} = y \text{ V}$$

$$E^\ominus_{Fe^{3+}/Fe} = z \text{ V}$$

(1) $x - z$ (2) $x - y$ (3) $x + y - z$ (4) $x + 2y - .3z$

[JEE(Main) 2019 Online (08-04-19)S2, 4/120]

26. The standard Gibbs energy for the given cell reaction in kJ mol^{-1} at 298 K is :



$E^\ominus = 2 \text{ V}$ at 298 K

(Faraday's constant, $F = 96000 \text{ C mol}^{-1}$)

[JEE(Main) 2019 Online (09-04-19)S1, 4/120]

27. A solution of $Ni(NO_3)_2$ is electrolyzed between platinum electrodes using 0.1 Faraday electricity. How many mole of Ni will be deposited at the cathode?

[JEE(Main) 2019 Online (09-04-19)S2, 4/120]

(1) 0.20 (2) 0.15 (3) 0.10 (4) 0.05



28. Consider the statements Statement-1 and Statement-2 :

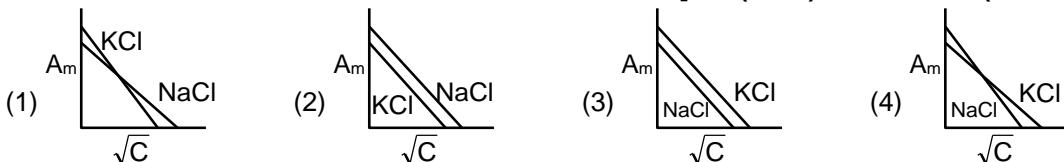
Statement-1 : Conductivity always increases with decrease in the concentration of electrolyte.
Statement-2 : Molar conductivity always increase with decrease in the concentration of electrolyte.
 The correct option among the following is :

[JEE(Main) 2019 Online (10-04-19)S1, 4/120]

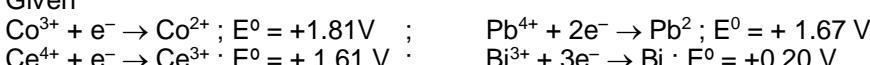
- Both Statement-1 and Statement-2 are correct
- Both Statement-1 and Statement-2 are wrong
- Statement-1 is wrong and Statement-2 is correct
- Statement-1 is correct and Statement-2 is wrong

29. Which one of the following graphs between molar conductivity (Λ_m) versus \sqrt{C} is correct?

[JEE(Main) 2019 Online (10-04-19)S2, 4/120]



30. Given



Oxidizing power of the species will increase in the order : [JEE(Main) 2019 Online (12-04-19)S1, 4/120]

- $\text{Ce}^{4+} < \text{Pb}^{4+} < \text{Bi}^{3+} < \text{Co}^{3+}$
- $\text{Bi}^{3+} < \text{Ce}^{4+} < \text{Pb}^{4+} < \text{Co}^{3+}$
- $\text{Co}^{3+} < \text{Pb}^{4+} < \text{Ce}^{4+} < \text{Bi}^{3+}$
- $\text{Co}^{3+} < \text{Ce}^{4+} < \text{Bi}^{3+} < \text{Pb}^{4+}$

31. The decreasing order of electrical conductivity of the following aqueous solution is :

[JEE(Main) 2019 Online (12-04-19)S2, 4/120]

0.1 M Formic acid (A) ; 0.1 M Acetic acid (B) ; 0.1 M Benzoic acid (C)

- $A > B > C$
- $A > C > B$
- $C > A > B$
- $C > B > A$

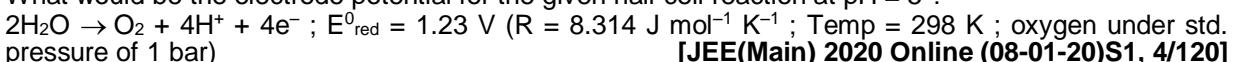
32. Given that the standard potentials (E°) of Cu^{2+}/Cu and Cu^+/Cu are 0.34 V and 0.522 V respectively, the E° of $\text{Cu}^{2+}/\text{Cu}^+$ is:

- +0.158 V
- 0.182 V
- 0.182 V
- 0.158 V

33. The equation that is incorrect is:

- $(\Lambda_m^0)_{\text{NaBr}} - (\Lambda_m^0)_{\text{NaI}} = (\Lambda_m^0)_{\text{KBr}} - (\Lambda_m^0)_{\text{NaBr}}$
- $(\Lambda_m^0)_{\text{H}_2\text{O}} = (\Lambda_m^0)_{\text{HCl}} + (\Lambda_m^0)_{\text{NaOH}} - (\Lambda_m^0)_{\text{NaCl}}$
- $(\Lambda_m^0)_{\text{KCl}} - (\Lambda_m^0)_{\text{NaCl}} = (\Lambda_m^0)_{\text{KBr}} - (\Lambda_m^0)_{\text{NaBr}}$
- $(\Lambda_m^0)_{\text{NaBr}} - (\Lambda_m^0)_{\text{NaCl}} = (\Lambda_m^0)_{\text{KBr}} - (\Lambda_m^0)_{\text{KCl}}$

34. What would be the electrode potential for the given half cell reaction at $\text{pH} = 5$?



[JEE(Main) 2020 Online (08-01-20)S1, 4/120]

35. For an electrochemical cell

[JEE(Main) 2020 Online (08-01-20)S2, 4/120]

$\text{Sn(s)} | \text{Sn}^{2+}(\text{aq}, 1\text{M}) || \text{Pb}^{2+}(\text{aq}, 1\text{M}) | \text{Pb(s)}$ the ratio $\frac{[\text{Sn}^{2+}]}{[\text{Pb}^{2+}]}$ when this cell attains equilibrium is _____

$$\left(\text{Given: } E^\circ_{\text{Sn}^{2+}|\text{Sn}} = -0.14 \text{ V}, E^\circ_{\text{Pb}^{2+}|\text{Pb}} = -0.13 \text{ V}, \frac{2.303 \text{ RT}}{F} = 0.06 \right)$$

36. 108 g of silver (molar mass 108 g mol⁻¹) is deposited at cathode from $\text{AgNO}_3(\text{aq})$ solution by a certain quantity of electricity. The volume (in L) of oxygen gas produced at 273 K and 1 bar pressure from water by the same quantity of electricity is _____

[JEE(Main) 2020 Online (09-01-20)S1, 4/120]

37. Amongst the following, the form of water with the lowest ionic conductance at 298 K is:

[JEE(Main) 2020 Online (09-01-20)S2, 4/120]

- distilled water
- sea water
- water from a well
- saline water used for intravenous injection



Answers**EXERCISE - 1****PART - I**

A-1. (a) Cu (b) Ag (c) oxidation (d) reduction
 (e) Cu (f) Ag (g) anode-Cu \longrightarrow Cu²⁺ + 2e⁻; cathode-Ag⁺ + e⁻ \longrightarrow Ag
 (h) Cu + 2Ag⁺ \longrightarrow Cu²⁺ + 2Ag (i) Cu (j) Cu
 (k) to complete circuit and maintain electrical neutrality in solution

A-2. (a) 2Ag⁺ + Cu \longrightarrow 2Ag + Cu²⁺ (b) 8H⁺ + MnO₄⁻ \longrightarrow 5Fe³⁺ + Mn²⁺ + 4H₂O
 (c) 2Ag⁺ + 2Cl⁻ \longrightarrow 2Ag + Cl₂ (d) Cd + 2H⁺ \longrightarrow Cd²⁺ + H₂

A-3. (a) Zn | Zn²⁺ || H⁺ | H₂ | Pt (b) Pt | Sn²⁺, Sn⁴⁺ || Fe³⁺, Fe²⁺ | Pt (c) Pb | Pb²⁺ || Br⁻ | Br₂ | Pt

B-1. Mg **B-2.** Y > Z > X

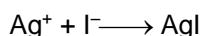
B-3. (i) CuO : Cu is below hydrogen in series, so it can reduce from CuO to Cu.
 (ii) Ag₂O: Lower in series stability of oxide become lesser.
 (iii) Lower S.R.P. metal can displace higher S.R.P. metals ions from solution.

B-4. 1.61 V **B-5.** 1.35 V **B-6.** 1.68 V **C-1.** - 0.036 V

C-2. -0.756 V **C-3.** Spontaneous, -48250 J **C-4.** -1.14 volt

D-1. 0.059 volt **D-2.** 10¹⁴ **D-3.** - 0.2214 V **D-4.** n = 2

D-5. (a) The spontaneous cell reaction: Zn + 2Ag⁺ (aq) \rightleftharpoons Zn²⁺ (aq) + 2Ag (s)
 (b) 1.56 V (c) [Zn²⁺] = 4 × 10⁻⁴ M
 (d) As we add KI to cathode chamber, some Ag⁺ will precipitate out as:



The above reaction reducing [Ag⁺] from cathode chamber. This will reduce E_{cell} according to Nernst's equation.

D-6. pH = 1.5. **D-7.** log [Zn²⁺]/[Cu²⁺] = 37.22

E-1.

	ELECTROLYTE	ANODE Product	CATHODE Product
1	NaCl (Molten) with Pt electrode	Cl ₂ (g)	Na
2	NaCl (aq) with Pt electrode	Cl ₂ (g)	H ₂ (g)
3	Na ₂ SO ₄ (aq) with Pt electrode	O ₂ (g)	H ₂ (g)
4	NaNO ₃ (aq) with Pt electrode	O ₂ (g)	H ₂ (g)
5	AgNO ₃ (aq) with Pt electrode	O ₂ (g)	Ag
6	CuSO ₄ (aq) with Inert electrode	O ₂ (g)	Cu
7	CuSO ₄ (aq) with Copper electrode	Cu dissolve	Cu



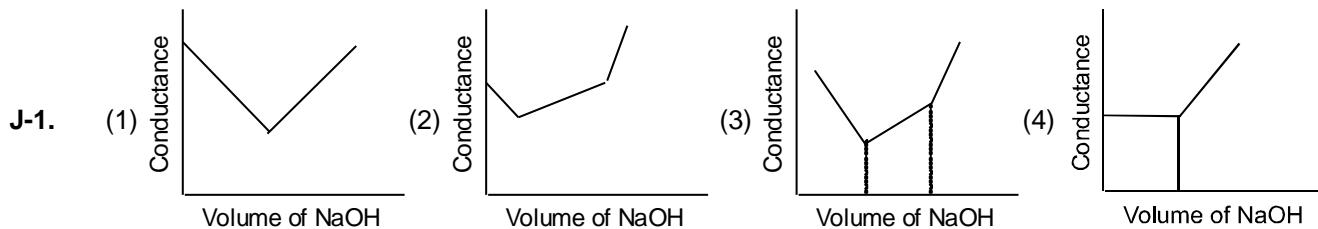
F-1. 12.04×10^{23} F-2. 108. F-3. 2 F-4. $n = 4$ F-5. $t = 193$ sec.

F-6. $V_{(H_2)} = 56.0$ mL. F-7. $Ni^{2+} = 2M$ F-8. $t = 93.65$ sec. F-9. +71.5 amp

G-1. 8 G-2. 1.67 V H-1. 2.332×10^{-3} mho cm^{-1} , 23.32 mho $cm^2 mol^{-1}$.

H-2. 0.1456 amp H-3. $0.728 cm^{-1}$. I-1. 272, 0.0353 I-2. 382 mho $cm^2 mol^{-1}$.

I-3. 1.76×10^{-5} mole/litre. I-4. 2.70×10^{-10} (mole/litre) 2 .



PART - II

A-1. (A)	A-2. (C)	A-3. (D)	A-4. (C)	B-1. (A)
B-2. (C)	B-3. (D)	B-4. (D)	B-5. (C)	B-6. (A)
B-7. (C)	B-8. (C)	C-1. (D)	C-2. (D)	C-3. (D)
D-1. (A)	D-2. (A)	D-3. (C)	D-4. (B)	D-5. (B)
D-6. (C)	E-1. (C)	E-2. (C)	E-3. (D)	E-4. (B)
E-5. (B)	F-1. (D)	F-2. (B)	F-3. (C)	F-4. (B)
F-5. (C)	G-1. (B)	G-2. (A)	G-3. (D)	H-1. (A)
H-2. (D)	H-3. (B)	I-1. (C)	I-2. (D)	I-3. (D)
I-4. (C)	I-5. (D)	J-1. (A)	J-2. (C)	

PART - III

1. (A - s) ; (B - p,r) ; (C - p,q) ; (D - r) 2. (A - p, q, r) ; (B - p, q, r) ; (C - p, s) ; (D - p, s)

EXERCISE - 2

PART - I

1. (A)	2. (C)	3. (C)	4. (C)	5. (B)
6. (B)	7. (B)	8. (A)	9. (D)	10. (D)
11. (C)	12. (B)	13. (B)	14. (D)	15. (B)

PART - II

1. 3 (B, E & F) 2. 59 3. $E^\circ = 7 \text{ V.}$ 4. 40

5. $\lambda_{(\text{NO}_3^-)}^\circ = 7 \text{ Sm}^2 \text{ mol}^{-1}$ 6. 4 7. 10 8. 20 9. 4

PART - III

1. (BC) 2. (AD) 3. (AC) 4. (ABD) 5. (AB)

6. (BD) 7. (BCD) 8. (BCD) 9. (ACD) 10. (AC)

11. (AB) 12. (BC) 13. (BCD) 14. (A) 15. (ABD)

PART - IV

1. (D) 2. (C) 3. (B) 4. (D) 5. (A)

6. (C) 7. (D) 8. (D) 9. (B) 10. (C)

11. (C) 12. (B)

EXERCISE – 3**PART - I**

1. (A) 2. 0.05 M 3. (B) 4. $K_c = 10^{10}$ 5. (B)

6. (B) 7. (A) 8. (D) 9. 55 S m^{-1} 10. (B)

11. (D) 12. (D) 13. (C) 14. (D) 15. (B)

16. (ABD) 17. (B) 18. (C) 19. (D) 20. (D)

21. (B) 22. (D) 23. (A) 24. (D) 25. (A)

26. 4 27. 3 28. (D) 29. 6 30. (C)

31. 10 32. $-11.62 \text{ JK}^{-1}\text{mol}^{-1}$

PART - II

1. (3) 2. (3) 3. (2) 4. (3) 5. (4)

6. (2) 7. (4) 8. (1) 9. (2) 10. (4)

11. (1) 12. (1) 13. (4) 14. (3) 15. (3)

16. (3) 17. (2) 18. (2) 19. (3) 20. (1)

21. (3) 22. (4) 23. (1) 24. (4) 25. (4)

26. (2) 27. (4) 28. (3) 29. (3) 30. (2)

31. (2) 32. (1) 33. (1) 34. $-0.93 \text{ to } -0.94$

35. 2.13 to 2.17 36. 5.66 to 5.68 37. (1)