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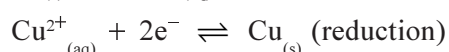
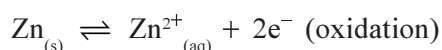
Redox Reactions and Electro Chemistry

Electrochemical cell (Galvanic cell) : An apparatus which converts chemical energy into electrical energy is called electrochemical cell.

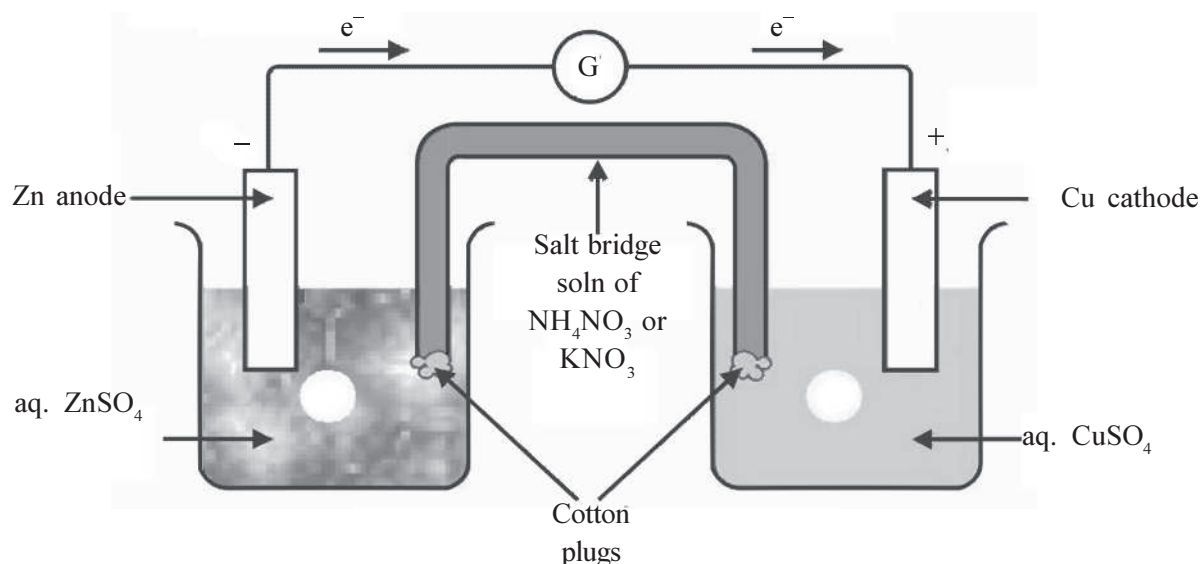
Principle of electrochemical cell : Conversion of chemical energy into electrical energy.

A redox reaction takes place in electro chemical cell. For example, following redox reaction takes place when metallic strip of zinc is dipped in aqueous solution of copper sulphate.

$\text{Zn}_{(s)} + \text{Cu}^{2+}_{(aq)} \rightleftharpoons \text{Zn}^{2+}_{(aq)} + \text{Cu}_{(s)}$ In reality this reaction is the sum of following two half reactions.



Above both reactions occur in a same container. But these reactions can be made to occur in two different containers as follows.



Metallic strips dipped in solution are called electrodes.

The strip on which oxidation takes place is called anode and that on which reduction takes place is called cathode.

On connecting both the electrodes by copper wire electrons flow from anode (Zn) to cathode (Cu) in external circuit.

The conduction of electricity in solution is by ions and that in external circuit is by electrons.

The flow of electric current in external circuit is from cathode (Cu) to anode (Zn).

Salt-bridge : The U shaped glass tube connecting two solutions of electrochemical cell and filled with proper electrolytic solution (NH_4NO_3) is called salt-bridge.

Function of salt bridge : It connects two solutions of electrochemical cell and maintains its electrical neutrality. Besides this, it completes the electrical circuit of the cell.

Types of electrodes :

The three main types of electrodes are as follows :

- (1) Active metal electrodes : eg. Zn, Ag, Cu, Al etc.
- (2) Inert electrodes of metal or non-metals eg. Pt (metal), steel (alloy), graphite (non-metal) etc.
- (3) Gas electrodes : eg. H_2 , Cl_2 etc.

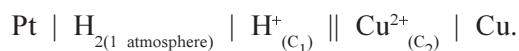
Half-cell : An electrode and a solution in which it is dipped are collectively known as half-cell.

Standard half-cell : If concentration of a solution of half cell is 1 M or the pressure of a gas is 1 atmosphere and temperature is $25^\circ C$, then such a half-cell is termed as **standard half cell**.

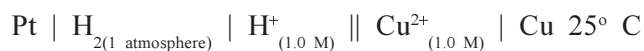
Standard cell : A standard cell is formed by connecting two standard half-cells.

Symbolic representation of electrochemical cell : Anode is shown at left hand side and cathode is shown at right hand side.

For example, $Zn | Zn^{2+}_{(C_1)} || Cu^{2+}_{(C_2)} | Cu$ For standard cell, $Zn | Zn^{2+}_{(1.0\ M)} || Cu^{2+}_{(1.0M)} | Cu$ $25^\circ C$
Similarly, symbollic representation involving gas electrode as one of the half-cell is :



For the same cell under standard state,



Cell potential : In electrochemical cell, when two electrodes are joined the electrons flow from anode to cathode in external circuit due to electrical pressure produced from chemical reaction. This electrical pressure is called cell potential. (E_{cell})

If cell is in standard condition then it is called **standard cell potential (E^0_{cell})**.

Voltmeter does not measure the true potential of cell therefore potentiometer is used to measure the true cell potential.

In reality, the cell potential is a measure of difference of intensities of tendencies of two electrodes to release (or gain) electrons.

The absolute value of intensity of tendency of an electrode to release electrons cannot be measured. Because a single half-cell cannot produce electric current and it cannot complete a redox reaction.

E.M.F. Series : A cell potential measured with respect to standard hydrogen electrode is called electromotive force (E.M.F.) of the electrode joined with standard hydrogen electrode.

When different electrodes are arranged in decreasing order of their standard reduction potentials, the resulting series is called emf series.

Following informations are obtained from emf series.

- (1) The tendency to undergo oxidation, to release electrons and strength to act as reducing agent increases moving down the series.
- (2) The tendency to undergo reduction, to accept electrons and strength to act as oxidizing agent decreases moving down the series.
- (3) The standard cell potential of a cell constructed by joining any two half cells can be calculated from this series.
- (4) Which electrode would act as cathode and which would act as anode can be predicted.

The cell potential of electrochemical cell depends on nature of electrode, temperature of cell and concentration of solution.

- When copper strip is dipped in aqueous solution of silver nitrate,
 (A) solution becomes colourless. (B) intensity of blue colour increases.
 (C) intensity of blue colour decreases. (D) chemical reaction does not take place.
- What is observed when zinc strip is dipped in aq. solution of CuSO_4 ?
 (Atomic mass of Zn is more than that of Cu).
 (A) The intensity of blue colour of solution decreases. (B) The mass of zinc strip increases.
 (C) The intensity of blue colour of solution increases. (D) None of the given.
- What is not observed when zinc strip is placed in aq. solution of CuSO_4 ?
 (Atomic mass of Zn is more than Cu)
 (A) The colour of surface of zinc strip is changed.
 (B) The mass of zinc strip decreases.
 (C) The mass of zinc strip increases
 (D) The intensity of blue colour of solution decreases
- What is the observation when Zn-rod is dipped in aq. CuSO_4 ?
 (Atomic mass of Zn is more than Cu)
 (A) The intensity of blue colour of solution decreases.
 (B) The mass of zinc rod increases.
 (C) The concentration of SO_4^{2-} ions in solution increases.
 (D) The concentration of SO_4^{2-} ions in solution decreases.
- What is observed when copper rod is dipped in aq. AgNO_3 ?
 (Atomic mass of Ag is more than Cu) ?
 (A) The mass of copper rod does not change.
 (B) The mass of copper rod decreases.
 (C) Solution becomes blue gradually.
 (D) The colour of surface of copper rod does not change.
- What is not observed when Cu rod is dipped in aq. AgNO_3 ?
 (A) The mass of copper rod increases. (B) The mass of copper rod decreases.
 (C) Solution becomes blue gradually. (D) Ag deposits on surface of Cu.
- When Zn strip is dipped in $\text{Cu}(\text{NO}_3)_2$
 (A) Zn undergoes reduction. (B) Zn undergoes oxidation.
 (C) Cu undergoes reduction. (D) Cu undergoes oxidation.
- Zn rod is dipped in 1.5 L aqueous solution of 0.1M CuSO_4 . Choose correct option for following statements doing theoretical calculations.
 (Atomic mass : Zn = 65 gm mole⁻¹ and Cu = 63.5 gm mole⁻¹) T = True, F = False.
 (i) 13 gram Zn dissolves when its mass decrease by 0.3 gram.
 (ii) Concentration of Cu^{2+} becomes 0.08 M when 1.95 gram Zn dissolves.
 (iii) number of Zn^{2+} ions is 4.5165×10^{24} when molarities of Cu^{2+} and Zn^{2+} are equal in solution.
 (iv) The molarity of Zn^{2+} is 0.04 M when 3.6132×10^{22} Cu atoms deposit.

- (A) TTTF (B) FFFT (C) TTFT (D) FFTT

9. Which observations are true when Zn strip is dissolved in aq. $\text{Cu}(\text{NO}_3)_2$?

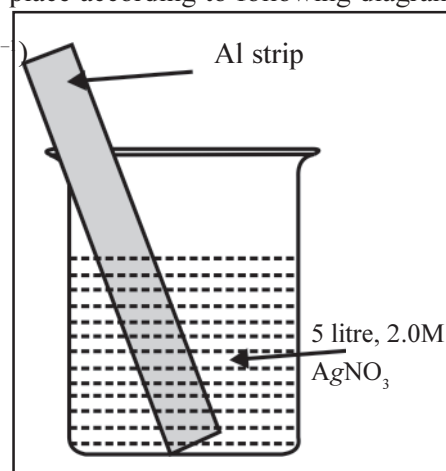
- (i) Blue colour of solution fades gradually.
 (ii) Concentration of NO_3^- ions in solution decrease gradually.
 (iii) Concentration of Zn^{2+} ions in solution increase gradually.
 (iv) $\text{Cu}^{2+}_{(\text{aq})}$ ions are displaced by $\text{Zn}^{2+}_{(\text{aq})}$ ions in solution.

- (A) (i), (ii) (B) (ii), (iii) (C) (i), (iii), (iv) (D) (i), (iv)

10. Which option is incorrect for a stoichiometric reaction taking place according to following diagram ?

(Atomic mass : Al = 27 gm mole⁻¹ and Ag = 108 gm mole⁻¹)

- (A) For reduction of all Ag^+ ions in solution, 90 gram Al is required.
 (B) 648 gram Ag^+ ions are reduced by 54 gram Al
 (C) If 81 gram Al is reduced, then 972 gram Ag^+ ions will be left unreacted in solution.
 (D) During oxidation of 2 mol Al, 3.6132×10^{24} Ag^+ ions will reduce.



11. Zn strip is dipped in 1.5 L aqueous solution of 0.1 M CuSO_4 . Choose correct option with reference to following statements. (Atomic mass : Zn = 65 gm mole⁻¹ and Cu = 63.5 gm mole⁻¹)

- (i) When 13 gram Zn dissolves 12.7 gram Cu deposits and there is increase of 0.3 gram in mass of strip.
 (ii) When there is decrease of 0.02 M in concentration of Cu^{2+} , 1.3 gram Zn dissolves.
 (iii) When molarities of Cu^{2+} and Zn^{2+} are equal, the number of Zn^{2+} ions is 3.011×10^{22} in solution.
 (iv) When 3.6132×10^{22} Cu atoms deposit, molarity of Zn^{2+} ions is 0.04 M.

- (A) (iv) (B) (ii) (C) (ii), (iv) (D) (i), (iv)

12. Which carbon having following oxidation number is not there in methyl acetate ($\text{CH}_3\text{COOCH}_3$ OR $\text{C}_3\text{H}_6\text{O}_2$) ?

- (A) +3 (B) -2 (C) +4 (D) -3

13. In which of the following compound oxidation number of oxygen is zero ?

- (A) HOCl (B) HOF (C) HOI (D) HOBr

14. In a compound containing Xe and F, xenon is 53.85% by mass. State the oxidation number of Xe in compound. (Atomic mass : Xe = 133, F = 19).

- (A) +2 (B) 0 (C) +4 (D) +6

15. How many moles of Ag_2S would have been consumed theoretically when 1.93×10^6 coulomb of electricity is associated with a redox reaction $\text{Ag}_2\text{S} + \text{CN}^- + \text{O}_2 \rightarrow \text{Ag}(\text{CN})_2^- + \text{S}$ in basic medium ?
(1 mole $e^- = 96500$ coulomb)
(A) 10 (B) 2 (C) 8 (D) 4
16. Choose correct option from following statements with reference to emf series.
(A) electron accepting tendency increases moving down.
(B) Strength to act as oxidizing agent decrease moving upward.
(C) Tendency of undergoing oxidation increase moving down.
(D) If rod of metal present downward is immersed in a solution of salt of metal present upward in a series, then it does not dissolve.
17. Which electrolyte cannot be used in salt bridge of an electrochemical cell : $\text{Fe} | \text{Fe}^{2+}_{(1.0\text{M})} || \text{Ag}^{+}_{(1.0\text{M})} | \text{Ag}$?
(A) KNO_3 (B) NaCl (C) NH_4NO_3 (D) NaNO_3
18. If standard reduction potentials of half cells : $\text{X}^{2+} | \text{X}$, $\text{Y}^{2+} | \text{Y}$, $\text{Z}^{2+} | \text{Z}$ and $\text{W}^{2+} | \text{W}$ are in increasing order then select correct option from following statements. (T = true statement, F = False Statement)
(i) rod of metal X dissolves in solution of Y^{2+} .
(ii) solution of X^{2+} cannot be filled in container of metal Z.
(iii) reaction $\text{W}_{(s)} + \text{Y}^{2+}_{(\text{aq } 1.0\text{ M})} \rightleftharpoons \text{W}^{2+}_{(\text{aq } 1.0\text{ M})} + \text{Y}_{(s)}$ is spontaneous in forward direction.
(iv) metal atoms Z cannot displace $\text{Y}^{2+}_{(\text{aq})}$ ions from solution of Y^{2+} ions.
(A) TFFT (B) FTTF (C) FTFT (D) TFTF
19. Aq. solution of a salt of metal Y can be filled up in a vessel of a metal X and aq. solution of a salt of metal Z can be filled up in a vessel of a metal Y. Which of the given decreasing order of X, Y and Z as reducing agent is correct ?
(A) $\text{X} > \text{Y} > \text{Z}$ (B) $\text{X} > \text{Z} > \text{Y}$ (C) $\text{Z} > \text{Y} > \text{X}$ (D) $\text{Z} > \text{X} > \text{Y}$
20. At 25°C under standard state conditions, (i) On dipping metallic rod of A in $\text{B}^{2+}_{(\text{aq})}$ metal A does not dissolve. (ii) aqueous solution ($\text{C}^{2+}_{(\text{aq})}$) of metallic salt of C, cannot be filled up in a vessel of metal A. (iii) on dipping a spoon of metal C in ($\text{D}^{2+}_{(\text{aq})}$) metal deposits on spoon. (iv) Give correct order of metals as reducing agents.
(A) $\text{A} > \text{B} > \text{C} > \text{D}$ (B) $\text{D} > \text{B} > \text{C} > \text{A}$ (C) $\text{D} > \text{C} > \text{A} > \text{B}$ (D) $\text{B} > \text{A} > \text{C} > \text{D}$
21. If standard oxidation potentials of $\text{M} | \text{M}^{2+}$, $\text{N} | \text{N}^{2+}$, $\text{Q} | \text{Q}^{2+}$ and $\text{R} | \text{R}^{2+}$ half cells are in increasing order then which of the given statement is correct ?
(A) Solution of a salt of M^{2+} can be stored in vessel of metal N.
(B) Solution of a salt of R^{2+} cannot be stored in vessel of metal Q.
(C) Solution of a salt of R^{2+} can be stored in vessel of metal N.
(D) All given three statements are wrong.
22. On what does cell potential of electrochemical cell not depend ?
(A) Concentration of solution associated with cell reaction.
(B) Substance present in salt bridge.
(C) temperature
(D) nature of electrode

23. When electrochemical cell $\text{Fe} \mid \text{Fe}^{2+}_{(C_1)} \parallel \text{Cu}^{2+}_{(C_2)} \mid \text{Cu}$ is operating, then
- (A) oxidation potentials of half cells at L.H.S. and R.H.S. increases gradually.
 (B) oxidation potential of half cells at L.H.S. and R.H.S. decreases gradually.
 (C) oxidation potential of half cell at L.H.S. decrease while that of at RHS increase gradually.
 (D) reduction potential of half cell at L.H.S. and oxidation potential of half cell at RHS decrease gradually.
24. Which instrument measures cell potential accurately ?
 (A) ameter (B) voltmeter (C) galvanometer (D) potentiometer
25. The potential of a cell constructed by joining a std. half-cell with S.H.E. by salt bridge is measured using potentiometer. If S.H.E. is cathode, then measured potential is equal to
 (A) E^0_{red} of another electrode (B) E^0_{ox} of another electrode
 (C) E_{ox} of another electrode (D) E_{red} of another electrode
26. Select true and false statements with respect to electrochemical cell.
 Where, T = True Statement and F = False statement
- (i) electricity is conducted from anode to cathode in external circuit.
 (ii) electricity is conducted by ions in solution.
 (iii) negative ions at anode move towards solution at cathode through salt bridge.
 (iv) electrons flow from cathode to anode in external circuit.
- (A) FFTF (B) FTFF (C) TFTF (D) FTTF

Answers : 1. (B), 2. (A), 3. (C), 4. (A), 5. (C), 6. (B), 7. (B), 8. (C), 9. (C), 10. (C), 11. (A), 12. (C), 13. (B), 14. (D), 15. (A), 16. (C), 17. (B), 18. (A), 19. (C), 20. (D), 21. (C), 22. (B), 23. (C), 24. (D), 25. (B), 26. (B)

Nernst equation : An equation showing relation between cell potential of non standard electrochemical cell and concentration of solution associated with cell reaction at definite temperature is called Nernst equation.

This equation can be derived on the basis of principles of thermodynamics.

$\Delta G = \Delta G^0 + RT \ln Q_c$ But $\Delta G = -nFE_{\text{cell}}$ and $\Delta G^0 = -nFE^0_{\text{cell}}$ Substituting these values in equation,

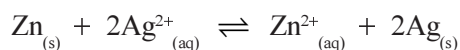
$$-nFE_{\text{cell}} = -nFE^0_{\text{cell}} + RT \ln Q_c \quad \text{So, } E_{\text{cell}} = E^0_{\text{cell}} - \frac{RT}{nF} \ln Q_c \quad \text{Therefore } E_{\text{cell}} = E^0_{\text{cell}} - \frac{2.303RT}{nF} \log Q_c$$

At 298 K, the value of $\frac{2.303RT}{F}$, $\frac{2.303 \times 8.314 \times 298}{96500} = 0.059 \text{ V}$.

$\therefore$ Nernst equation at 298 K $E_{\text{cell}} = E^0_{\text{cell}} - \frac{0.059}{n} \log Q_c$. Where, n = change in oxidation number in

cell reaction, $Q_c = \frac{\text{Product of concentration of products}}{\text{Product of concentration of reactants}}$

eg. For a cell, $\text{Zn} \mid \text{Zn}^{2+}_{(C_1)} \parallel \text{Ag}^+_{(C_2)} \mid \text{Ag}$, cell reaction is :



Nernst equation for above cell reaction is as follows :

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{2.303RT}{nF} \cdot \log \frac{[\text{Zn}^{2+}]}{[\text{Ag}^+]^2} \quad \text{Therefore at 298K temprature } E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{0.0592}{n} \cdot \log \frac{[\text{Zn}^{2+}]}{[\text{Ag}^+]^2}$$

where n = Change in oxidation numbner of rejaction in balanced equation of cell reaction or number of moles of

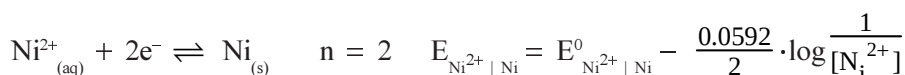
electrons associated with reaction. Here n = 2. $\therefore$ At 298 K temperature $E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{0.0592}{2} \cdot \log \frac{[\text{Zn}^{2+}]}{[\text{Ag}^+]^2}$

With the help of Nernst equation half cell potential of non standard half cell also can be calculated.

eg., oxidation potential of Ni | Ni²⁺ half cell is given by writing oxidation reaction.

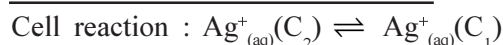
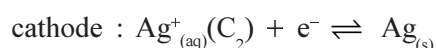
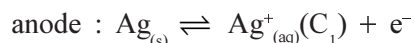


In order to determine reduction potential of Ni/Ni²⁺ half cell reduction half reaction is written as :



Concentration cell : An electrochemical cell made up of two same electrodes but having different concentrations of electrolytic solutions is called concentration cell.

eg. Ag | Ag⁺_(C₁) || Ag⁺_(C₂) | Ag (C₁ < C₂) In this cell, ions move from a solution containing higher concentration to a solution having lower concentration.



For this cell, n = 1 and E^o_{cell} = 0.0V

$$\therefore E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{0.059}{n} \cdot \log \frac{C_1}{C_2}$$

$$\therefore E_{\text{cell}} = 0 - \frac{0.059}{1} \cdot \log \frac{C_1}{C_2}$$

$$\therefore E_{\text{cell}} = 0.059 \cdot \log \frac{C_1}{C_2}$$

The potential of concentration cells are relatively low. Because E^o_{cell} = 0.0 V. When the cell is operating, ions of a concentrated solution move towards dilute solution and when concentrations of both the solution is equal E_{cell} = 0.0 V.

The equilibrium constant for concentration cell is “1”.

27. What is the value of a term $\frac{2.303RT}{F}$ in Nernst equation at 80° C ?
 (A) 0.007 V (B) 0.01587 V (C) 0.01857 V (D) 0.07 V
28. Give the unit of a value 0.059 obtained in Nernst equation at 25° C.
 (A) coulomb (B) volt (C) faraday (D) has no unit
29. Which equation is appropriate to find E_{cell}^0 ?
 (A) $E_{\text{cell}}^0 = E_{\text{red(anode)}}^0 + E_{\text{red(cathode)}}^0$ (B) $E_{\text{cell}}^0 = E_{\text{oxi(cathode)}}^0 + E_{\text{oxi(anode)}}^0$
 (C) $E_{\text{cell}}^0 = E_{\text{oxi(cathode)}}^0 - E_{\text{oxi(anode)}}^0$ (D) $E_{\text{cell}}^0 = E_{\text{red(anode)}}^0 + E_{\text{oxi(cathode)}}^0$
30. What is the value of Q if n = 3 taken for the cell : $\text{Al} \mid \text{Al}^{3+}_{(0.02\text{M})} \parallel \text{Pb}^{2+}_{(0.2\text{M})} \mid \text{Pb}$?
 (A) 0.05 M^{-1} (B) $0.2236 \text{ M}^{-\frac{1}{2}}$ (C) 0.01 M (D) $0.05 \text{ M}^{-\frac{1}{2}}$
31. Which Nernst equation is correct for a cell : $\text{Co} \mid \text{Co}^{2+}_{(C_1)} \parallel \text{Ag}^{1+}_{(C_2)} \mid \text{Ag}$?
 (A) $E_{\text{cell}}^0 = E_{\text{cell}} + \frac{RT}{2F} \cdot \ln \frac{[\text{Ag}^+]^2}{[\text{Co}^{2+}]}$ (B) $E_{\text{cell}}^0 = E_{\text{cell}} + \frac{RT}{F} \cdot \ln \frac{[\text{Co}^{2+}]^{\frac{1}{2}}}{[\text{Ag}^+]}$
 (C) $E_{\text{cell}}^0 = E_{\text{cell}} - \frac{RT}{2F} \cdot \ln \frac{[\text{Co}^{2+}]}{[\text{Ag}^+]^2}$ (D) $E_{\text{cell}}^0 = E_{\text{cell}} + \frac{RT}{F} \cdot \ln \frac{[\text{Co}^{2+}]}{[\text{Ag}^+]^2}$
32. Which Nernst equation is correct for finding oxidation potential of $\text{Ni} \mid \text{Ni}^{2+}$ half cell ?
 (A) $E_{\text{Ni} \mid \text{Ni}^{2+}}^0 = E_{\text{Ni} \mid \text{Ni}^{2+}} - \frac{RT}{2F} \cdot \ln [\text{Ni}^{2+}]$ (B) $E_{\text{Ni} \mid \text{Ni}^{2+}} = E_{\text{Ni} \mid \text{Ni}^{2+}}^0 + \frac{RT}{2F} \cdot \ln [\text{Ni}^{2+}]$
 (C) $E_{\text{Ni} \mid \text{Ni}^{2+}}^0 = E_{\text{Ni} \mid \text{Ni}^{2+}} + \frac{RT}{2F} \cdot \ln [\text{Ni}^{2+}]$ (D) $E_{\text{Ni} \mid \text{Ni}^{2+}}^0 - E_{\text{Ni} \mid \text{Ni}^{2+}} = \frac{RT}{2F} \cdot \ln \frac{1}{[\text{Ni}^{2+}]}$
33. Which option is proper for the value of Q for given value of n for the cell :
 $\text{Zn} \mid \text{Zn}^{2+}_{(0.005\text{M})} \parallel \text{Ag}^{+}_{(0.04\text{M})} \mid \text{Ag}$?
 (A) $n = 1, Q = 3.125 \text{ M}^{-\frac{1}{2}}$ (B) $n = 2, Q = 1.7677 \text{ M}$
 (C) $n = 3, Q = 5.5243 \text{ M}^{-\frac{3}{2}}$ (D) $n = 4, Q = 0.156 \text{ M}^{-2}$
34. Which option is true for the values of n and Q for the cell : $\text{Pt} \mid \text{Br}_{2(l)} \mid \text{Br}^{-}_{(C_1)} \parallel \text{Au}^{3+}_{(C_2)} \mid \text{Au}$?
 (A) $n = 3, Q = [\text{Au}^{3+}][\text{Br}^{-}]^3$ (B) $n = 6, Q = [\text{Au}^{3+}]^2 [\text{Br}^{-}]^6$
 (C) $n = 6, Q = \frac{[\text{Au}^{3+}]^2 [\text{Br}^{-}]^6}{1}$ (D) $n = 3, Q = \frac{1}{[\text{Au}^{3+}][\text{Br}^{-}]^3}$

35. If $Q_c = 20 \text{ M}^{-4}$ for the cell; $\text{Pt} \mid \text{Cl}_{2(\text{g}, 1.0\text{bar})} \mid \text{Cl}^-_{(0.5\text{M})} \parallel \text{Au}^{3+}_{(0.4\text{M})} \mid \text{Au}$ then
 (A) $n = 6$ (B) $n = 2$ (C) $n = 3$ (D) $n = 4$
36. Give the oxidation potential of a half cell : $\text{Pt} \mid \text{H}_{2(\text{g}, 1.0\text{bar})} \mid \text{H}^+_{(\text{pOH} = 11)}$ at 25°C .
 (A) 0.177 V (B) 0.0282 V (C) 0.616 V (D) 0.649 V
37. If $E_{\text{Zn}^{2+}(\text{XM})|\text{Zn}} < E^\circ_{\text{Zn}^{2+}|\text{Zn}}$ what is the possible value of x ?
 (A) 1.2 M (B) 0.2 M (C) 1.0 M (D) cannot be determined
38. The actual potential of a cell $\text{Fe} \mid \text{Fe}^{2+}_{(\text{xM})} \parallel \text{Ag}^+_{(\text{yM})} \mid \text{Ag}$ is 1.295 V at 25°C . If potential of $\text{Fe}^{2+}_{(\text{xM})} \mid \text{Fe}$ is 0.455 V at 25°C , what will be the potential of $\text{Ag}^+_{(\text{yM})} \mid \text{Ag}$ half cell at the same temperature ?
 (A) 0.84 V (B) -2.135 V (C) 3.125 V (D) -0.84 V
39. For a reaction $\text{Co}_{(\text{s})} + 2\text{Ag}^+_{(\text{aq})} \rightleftharpoons \text{Co}^{2+}_{(\text{aq})} + 2\text{Ag}_{(\text{s})}$, $E^\circ_{\text{cell}} = 1.08 \text{ V}$. What will be the change in E°_{cell} if concentration of $\text{Co}^{2+}_{(\text{aq})}$ is doubled ?
 (A) doubles (B) halves (C) no change (D) increase less than half
40. When will the cell potential of electrochemical cell be zero ?
 (A) When $E_{\text{OX}(\text{anode})} = E_{\text{red}(\text{Cathode})}$
 (B) When $E^\circ_{\text{red}(\text{anode})} = E^\circ_{\text{red}(\text{cathode})}$
 (C) When $E_{\text{OX}(\text{anode})} = E_{\text{OX}(\text{cathode})}$
 (D) When concentration of solution of both half cells are equal.
41. For given options when will $E_{\text{cell}} = E^\circ_{\text{cell}}$ in electrochemical cell ?
 (A) Only when concentrations of both half-cells are same (B) If $K = 1$
 (C) When cell reaction reaches equilibrium (D) None of the given
42. If $E_{\text{cell}} = E^\circ_{\text{cell}}$ for a cell $\text{Zn} \mid \text{Zn}^{2+}_{(0.04\text{M})} \parallel \text{Ag}^+_{(\text{C}_2)} \mid \text{Ag}$, then what is the value of C_2 ?
 (A) 0.04M (B) 0.02M (C) 0.2M (D) 0.0016M
43. What will be the change in cell potential when concentration of cathode solution is increased in a cell $\text{Fe} \mid \text{Fe}^{3+}_{(\text{C}_1)} \parallel \text{Cl}^-_{(\text{C}_2)} \mid \text{Cl}_{2(\text{g})} \mid \text{Pt}$ at definite temperature ?
 (A) increase (B) decrease (C) no change (D) $E_{\text{cell}} = E^\circ_{\text{cell}}$
44. When identical decrease of 0.1 M is done in concentration of both the solution in a cell $\text{Mg} \mid \text{Mg}^{2+}_{(\text{C}_1)} \parallel \text{Fe}^{2+}_{(0.5\text{M})} \mid \text{Fe}$ at definite temperature then what will be the value of C_1 ?
 (A) 0.7 M (B) 0.5 M (C) 0.4 M (D) none of the given
45. What will be the change in cell potential if concentration of both half cell solutions is decreased by 0.1 M in a cell : $\text{Co} \mid \text{Co}^{2+}_{(\text{C}_1)} \parallel \text{Sn}^{2+}_{(\text{C}_2)} \mid \text{Sn}$; $\text{C}_2 > \text{C}_1$?
 (A) increase (B) decrease (C) No change (D) $E_{\text{cell}} = E^\circ_{\text{cell}}$
46. What will be the value of C_1 if cell potential is increases on increasing concentration of both solutions by 0.1M in a cell $\text{Ni} \mid \text{Ni}^{2+}_{(\text{C}_1)} \parallel \text{Cu}^{2+}_{(0.4\text{M})} \mid \text{Cu}$ at definite temperature ?
 (A) 0.8 M (B) 0.1 M (C) 0.4 M (D) none of the given

47. What will be the change in cell potential if concentration of both half cell solutions is decreased by 0.1 M in a cell : $\text{Cd} \mid \text{Cd}^{2+}_{(C_1)} \parallel \text{Cu}^{2+}_{(C_2)} \mid \text{Cu}$? (C_1 and $C_2 > 0.1 \text{ M}$)
 (A) increase (B) decrease (C) no change (D) cannot be said
48. Give oxidation reaction of $\text{Pt} \mid \text{H}_{2(g, 1.0 \text{ bar})} \mid \text{OH}^-_{(aq)}$ half cell.
 (A) $\text{H}_{2(g)} + 2\text{OH}^-_{(aq)} \rightleftharpoons 2\text{H}_2\text{O}_{(l)} + 2e^-$ (B) $2\text{OH}^-_{(aq)} \rightleftharpoons \text{H}_{2(g)} + \text{O}_{2(g)} + 2e^-$
 (C) $2\text{H}_2\text{O}_{(l)} + 2\text{OH}^-_{(aq)} \rightleftharpoons 3\text{H}_{2(g)} + 2e^-$ (D) $\text{H}_{2(g)} + 2\text{OH}^-_{(aq)} \rightleftharpoons 2\text{H}_2\text{O}_{(l)} + \text{O}_{2(g)} + 2e^-$
49. Which cell representation is not proper according to the actual cell reaction occurring in the cell at 25°C ?
 ($E^\circ_{\text{Pb}^{2+} \mid \text{Pb}} = -0.13 \text{ V}$, $E^\circ_{\text{Sn}^{2+} \mid \text{Sn}} = -0.14 \text{ V}$)
 (A) $\text{Sn} \mid \text{Sn}^{2+}_{(0.1 \text{ M})} \parallel \text{Pb}^{2+}_{(0.01 \text{ M})} \mid \text{Pb}$ (B) $\text{Sn} \mid \text{Sn}^{2+}_{(0.02 \text{ M})} \parallel \text{Pb}^{2+}_{(0.2 \text{ M})} \mid \text{Pb}$
 (C) $\text{Pb} \mid \text{Pb}^{2+}_{(0.01 \text{ M})} \parallel \text{Sn}^{2+}_{(0.1 \text{ M})} \mid \text{Sn}$ (D) $\text{Sn} \mid \text{Sn}^{2+}_{(0.05 \text{ M})} \parallel \text{Pb}^{2+}_{(0.5 \text{ M})} \mid \text{Pb}$
50. The cell potential of a cell constructed by joining $\text{Ag} \mid \text{Ag}^+_{(0.4 \text{ M})}$ and $\text{Al} \mid \text{Al}^{3+}_{(0.1 \text{ M})}$ half cells at 25°C , is 2.456 V then what will be standard cell potential ?
 (A) 1.46 V (B) 2.46 V (C) 2.64 V (D) 2.76 V
51. What will be the theoretical change in cell potential of a cell $\text{Ni} \mid \text{Ni}^{2+}_{(0.001 \text{ M})} \parallel \text{Ag}^{1+}_{(0.01 \text{ M})} \mid \text{Ag}$ when its temperature is increased ?
 (A) increase (B) decrease (C) no change (D) cannot be said
52. What will be the theoretical change in cell potential of a cell $\text{Zn} \mid \text{Zn}^{2+}_{(0.05 \text{ M})} \parallel \text{Co}^{2+}_{(0.08 \text{ M})} \mid \text{Co}$ when its temperature is increased ?
 (A) increase (B) decrease (C) no change (D) cannot be said
53. On decreasing the temperature of a cell : $\text{Mg} \mid \text{Mg}^{2+}_{(C \text{ M})} \parallel \text{Fe}^{2+}_{(0.08 \text{ M})} \mid \text{Fe}$ the cell potential increases theoretically, then what is the possible value of C ?
 (A) C = 0.5 (B) C = 0.02 (C) C = 0.05 (D) C = 0.04
54. On decreasing the temperature of a cell : $\text{Zn} \mid \text{Zn}^{2+}_{(C_1)} \parallel \text{Sn}^{2+}_{(C_2)} \mid \text{Sn}$ ($C_1 < C_2$), what will be theoretical change in cell potential ?
 (A) increase (B) decrease (C) no change (D) cannot be said
55. The values of E_{cell} and E°_{cell} at 25°C are 2.3629 V and 2.36 V respectively for a cell : $\text{Mg} \mid \text{Mg}^{2+}_{(0.2 \text{ M})} \parallel \text{H}^+_{(X \text{ M})} \mid \text{H}_{2(g, 1.0 \text{ bar})} \mid \text{Pt}$, then X =
 (A) 0.4 M (B) 0.5 M (C) 0.1 M (D) 0.25 M
56. If standard cell potential of a reaction $2\text{H}_2\text{O}_{(l)} \rightleftharpoons \text{O}_{2(g, 1.0 \text{ bar})} + 4\text{H}^+_{(aq)} + 4e^-$ is -1.23 V at 25°C and $[\text{H}^+] = 10^{-7} \text{ M}$, then what will be the potential of this cell ? or what will be the oxidation potential of pure water at 25°C ?
 (A) -0.41 V (B) -2.62 V (C) -0.817 V (D) 0.41 V

57. At 25° C, for a reaction $2\text{H}_2\text{O}_{(l)} + 2\text{e}^- \rightleftharpoons \text{H}_{2(g, 1.0 \text{ bar})} + 2\text{OH}^-_{(\text{aq}, 10^{-7} \text{ M})}$ $E = -0.417 \text{ V}$ or If reduction potential of pure water is -0.417 V then what will be the E° of this reaction ?

- (A) -0.83 V (B) -2.62 V (C) -0.817 V (D) 0.41 V

58. What are E_{cell} and K_{eq} respectively of $\text{Fe}_{(s)} + 2\text{Ag}^+_{(\text{aq}, 0.5 \text{ M})} \rightleftharpoons \text{Fe}^{2+}_{(\text{aq}, 0.1 \text{ M})} + 2\text{Ag}_{(s)}$ at 25°C ? ($E^\circ_{\text{Fe}^{2+}|\text{Fe}} = 0.44 \text{ V}$, $E^\circ_{\text{Ag}^+|\text{Ag}} = 0.80 \text{ V}$)

- (A) 1.25 V , $1.04 \times 10^{21} \text{ M}^{-1}$ (B) 1.23 V , $1.507 \times 10^{12} \text{ M}^{-1}$
(C) 1.23 V , $1.264 \times 10^6 \text{ M}^{-1}$ (D) 1.25 V , $1.081 \times 10^{42} \text{ M}^{-1}$

59. $E^\circ_{\text{Cr}^{3+}/\text{Cr}} = -0.74 \text{ V}$, $E^\circ_{\text{MnO}_4^-/\text{Mn}^{3+}} = 1.51 \text{ V}$, $E^\circ_{\text{Cr}_2\text{O}_7^{2-}/\text{Cr}^{3+}} = 1.33 \text{ V}$ and $E^\circ_{\text{Cl}/\text{Cl}^-} = 1.36 \text{ V}$, which of the following is strongest oxidizing agent according to given data ?

- (A) Cr^{3+} (B) Mn^{2+} (C) MnO_4^- (D) Cl^-

● **Applications of cell potential.**

(1) K_{eq} can be calculated.

(2) K_{sp} (solubility product of sparingly soluble salts), pH of acids and ionic product of water (K_w) can be calculated.

(3) Certain titrations can be carried out using cell potential.

(4) Spontainity of a reaction can be determined using cell potential.

60. What is the E°_{cell} of reaction if equilibrium constant $K = e^{20.2537}$ ($n = 2$) of a reaction, $\text{Cd}_{(s)} + \text{Sn}^{2+}_{(\text{aq})} \rightleftharpoons \text{Cd}^{2+}_{(\text{aq})} + \text{Sn}_{(s)}$ at 298 K temperature ?

($R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$, $F = 96500 \text{ coulomb mol}^{-1}$)

- (A) 0.52 V (B) 0.26 V (C) 0.13 V (D) 0.48 V

61. For a reaction occurring in an electrochemical cell at 25° C, $K_c = 1.3141 \times 10^{107} \text{ M}^{-1}$ and $n = 2$ then E°_{cell} for cell will be ?

- (A) 6.32 V (B) 0.1186 V (C) 0.32 V (D) 3.16 V

62. For a reaction occurring in an electrochemical cell $K_c = 1.3141 \times 10^{307} \text{ M}^8$ and $n = 6$. If standard reduction potential of cathode is 1.36 V , then what will be the standard oxidation potential of anode ?

- (A) 6.32 V (B) 1.66 V (C) 2.71 V (D) 3.16 V

63. The E°_{cell} of an electrochemical cell is 3.16 V at 25° C and value of $K_c = 1.727 \times 10^{214} \text{ M}^{-2}$ then give value of 'n' for cell reaction.

- (A) 1 (B) 2 (C) 3 (D) 4

64. What will be the oxidation potential of $\text{Pt} | \text{H}_{2(g, 1.0 \text{ bar})} | \text{H}^+_{(\text{aq}, \text{pH} = 4)}$ at 25° C ?

- (A) 0.118 V (B) 0.649 V (C) 0.236 V (D) -0.118 V

65. The oxidation potential of hydrogen half cell at 25° C temperature and 1.0 bar pressure is 0.118 V . What will be the pOH of its solution ?

- (A) 2 (B) 3 (C) 5 (D) 12

66. The E_{cell} of $\text{Pt} | \text{H}_{2(g, 1.0 \text{ bar})} | \text{HCl}_{(\text{XM})} || \text{Cu}^{+2}_{(0.01 \text{ M})} | \text{Cu}$ is 0.635 V at 25°C. What will be the pH of HCl ? ($E^\circ_{\text{Cu}^{+2}|\text{Cu}} = 0.34 \text{ V}$)

- (A) 2.0 (B) 5.0 (C) 6.0 (D) 4

67. The E_{cell} of $\text{Mg} \mid \text{Mg}^{2+}_{(0.01 \text{ M})} \parallel \text{HCl}_{(\text{XM})} \mid \text{H}_{2(\text{g}, 1.0 \text{ bar})} \mid \text{Pt}$ is 2.09V at 25°C. What will be the pH of HCl ? ($E^0_{\text{Mg}^{2+} \mid \text{Mg}} = -2.36 \text{ V}$)
 (A) 6.58 (B) 5.58 (C) 3.58 (D) 4.58
68. The E_{cell} of $\text{Pt} \mid \text{H}_{2(\text{g}, 1.0 \text{ bar})} \mid \text{HCl}_{(\text{XM})} \parallel \text{Au}^{3+}_{(0.001 \text{ M})} \mid \text{Au}$ is 1.6655 V. What will be the pH of HCl ? ($E^0_{\text{Au}^{3+} \mid \text{Au}} = 1.40 \text{ V}$)
 (A) 3.5 (B) 4.17 (C) 5.5 (D) 4.83
69. What is the potential of a cell : $\text{Pt} \mid \text{H}_{2(\text{g}, 1.0 \text{ bar})} \mid \text{OH}^-_{(\text{aq}, \text{pH} = 4.5)} \parallel \text{H}^+_{(\text{aq}, \text{pH} = 2.5)} \mid \text{H}_{2(\text{g}, 1.0 \text{ bar})} \mid \text{Pt}$ at 298 K ?
 (A) 0.118 V (B) 0.205 V (C) 0.08 V (D) 0.124 V
70. What is the potential of a cell : $\text{Pt} \mid \text{H}_{2(\text{g}, 1.0 \text{ bar})} \mid \text{OH}^-_{(\text{aq}, \text{pOH} = 10.5)} \parallel \text{H}^+_{(\text{aq}, \text{pH} = 2.0)} \mid \text{H}_{2(\text{g}, 1.0 \text{ bar})} \mid \text{Pt}$ at 298 K?
 (A) 0.5015 V (B) 0.0885 V (C) 0.0452 V (D) 0.05015 V
71. Which reaction will be spontaneous in forward direction at 25°C ? The standard oxidation potentials of $\text{Pt} \mid \text{I}_{2(\text{s})} \mid \text{I}^-$, $\text{Cu} \mid \text{Cu}^{2+}$, $\text{Cr} \mid \text{Cr}^{3+}$, $\text{Zn} \mid \text{Zn}^{2+}$, $\text{Sn} \mid \text{Sn}^{2+}$, $\text{Pb} \mid \text{Pb}^{2+}$, $\text{Ag} \mid \text{Ag}^+$ and $\text{Fe} \mid \text{Fe}^{3+}$ are -0.54 V, -0.34 V, 0.74 V, 0.76 V, 0.14 V, 0.13 V, -0.80 V and 0.037 V respectively.
 (A) $2\text{I}^-_{(\text{aq}, 0.1 \text{ M})} + \text{Cu}^{2+}_{(\text{aq}, 0.05 \text{ M})} \rightleftharpoons \text{I}_{2(\text{s})} + \text{Cu}_{(\text{s})}$
 (B) $2\text{Cr}^{3+}_{(\text{aq}, 0.001 \text{ M})} + 3\text{Zn}_{(\text{s})} \rightleftharpoons 2\text{Cr}_{(\text{s})} + 3\text{Zn}^{2+}_{(\text{aq}, 0.1 \text{ M})}$
 (C) $\text{Pb}^{2+}_{(\text{aq}, 0.02 \text{ M})} + \text{Sn}_{(\text{s})} \rightleftharpoons \text{Pb}_{(\text{s})} + \text{Sn}^{2+}_{(\text{aq}, 0.2 \text{ M})}$
 (D) $3\text{Ag}_{(\text{s})} + \text{Fe}^{3+}_{(\text{aq}, 0.01 \text{ M})} \rightleftharpoons 3\text{Ag}^+_{(\text{aq}, 0.1 \text{ M})} + \text{Fe}_{(\text{s})}$
72. E^0_{red} of $\text{Fe} \mid \text{Fe}^{2+}$ and $\text{Fe} \mid \text{Fe}^{3+}$ are -0.44 V and +0.77 V respectively. What is the E^0_{ox} value of $\text{Fe} \mid \text{Fe}^{3+}$?
 (A) 0.037 V (B) 0.33 V (C) -0.33 V (D) -0.11 V
73. If $E^0_{\text{Cu} \mid \text{Cu}^{2+}} = -0.34 \text{ V}$ and $E^0_{\text{Cu}^{2+} \mid \text{Cu}^+} = +0.16 \text{ V}$ then what is the value of $E^0_{\text{Cu} \mid \text{Cu}^+}$?
 (A) -0.12 V (B) -0.48 V (C) +0.48 V (D) -0.52 V
74. Standard oxidation potential of $\text{Co} \mid \text{Co}^{3+}$, $\text{Co}^{2+} \mid \text{Co}^{3+}$, $\text{Fe} \mid \text{Fe}^{3+}$ and $\text{Fe}^{2+} \mid \text{Fe}^{3+}$ are -0.4167 V, -1.81 V, 0.0367 V and -0.77 V respectively. What will be the standard cell potential of $\text{Fe} \mid \text{Fe}^{2+} \parallel \text{Co}^{2+} \mid \text{Co}$?
 (A) 0.72 V (B) -0.11 V (C) 1.0 V (D) 0.16 V
75. The value of E^0_{ox} of $\text{Pt} \mid \text{H}_{2(\text{g}, 1.0 \text{ bar})} \mid \text{OH}^-_{(\text{aq})}$ half cell at 50° C temperature is +0.83 V, then what will be the value of ionic product (K_w) of water at 50° C ?
 (A) 1.12×10^{-13} (B) 1.102×10^{-12} (C) 1.105×10^{-12} (D) 1.0×10^{-14}
76. What will be the oxidation potential of half cell at L.H.S. in a cell $\text{Sn} \mid \text{Sn}^{2+}_{(0.1 \text{ M})} \parallel \text{Pb}^{2+}_{(0.5 \text{ M})} \mid \text{Pb}$ at 25°C when equilibrium is established ? ($E^0_{\text{Sn}^{2+} \mid \text{Sn}} = -0.14 \text{ V}$, $E^0_{\text{Pb}^{2+} \mid \text{Pb}} = -0.13 \text{ V}$)
 (A) 0.128 V (B) 0.0 V (C) 0.114 V (D) 0.151 V

77. What will be the % decrease in concentration of $\text{Ni}^{2+}_{(\text{aq})}$ when a reaction $\text{Co}_{(\text{s})} + \text{Ni}^{2+}_{(\text{aq } 0.1 \text{ M})} \rightleftharpoons \text{Co}^{2+}_{(\text{aq } 0.01 \text{ M})} + \text{Ni}_{(\text{s})}$ at 25°C comes to an equilibrium ?
 $(E^0_{\text{Co}^{2+} | \text{Co}} = -0.28 \text{ V and } -0.23 \text{ V})$
 (A) 97.82 % (B) 8.74 % (C) 95.4 % (D) 92.5 %
78. An excess of liquid mercury is added into a solution of $1.0 \times 10^{-3} \text{ M Fe}^{3+}$. At 25°C temperature 5% Fe^{3+} is left at equilibrium. If only following reaction is possible, then what will be the value of $E^0_{\text{Hg}^{2+} | \text{Hg}}$? ($E^0_{\text{Fe}^{3+} | \text{Fe}^{2+}} = 0.77 \text{ V}$)
 $2\text{Hg}_{(\text{l})} + 2\text{Fe}^{3+}_{(\text{aq})} \rightleftharpoons \text{Hg}^{2+}_{2(\text{aq})} + 2\text{Fe}^{2+}_{(\text{aq})}$
 (A) 0.793 V (B) 0.643 V (C) -0.793 V (D) -0.643 V
79. What will be the values of reduction potentials of anode and cathode when equilibrium is established in electro chemical cell : $\text{Fe} | \text{Fe}^{2+}_{(0.1 \text{ M})} || \text{Cd}^{2+}_{(0.5 \text{ M})} | \text{Cd}$ at 25°C ? ($n = 2$). $E^0_{\text{Fe}^{2+} | \text{Fe}} = -0.44 \text{ V}$, $E^0_{\text{Cd}^{2+} | \text{Cd}} = -0.40 \text{ V}$.
 (A) -0.477 V (B) +0.477 V (C) -0.447 V (D) -0.575 V
80. The reaction occurring in a following cell is in equilibrium at 298 K, then which option is appropriate ?
 $\text{Zn} | \text{Zn}^{2+}_{(\text{XM})} || \text{Cu}^{2+}_{(\text{YM})} | \text{Cu}$
 (A) $E_{\text{Zn} | \text{Zn}^{2+}_{(\text{XM})}} = -E_{\text{Cu}^{2+}_{(\text{YM})} | \text{Cu}}$ (B) $E_{\text{Zn} | \text{Zn}^{2+}_{(\text{XM})}} = -E_{\text{Cu} | \text{Cu}^{2+}_{(\text{YM})}}$
 (C) $E_{\text{Zn} | \text{Zn}^{2+}_{(\text{XM})}} = E_{\text{Cu}^{2+}_{(\text{YM})} | \text{Cu}}$ (D) $E_{\text{Zn} | \text{Zn}^{2+}_{(\text{XM})}} + E_{\text{Cu}^{2+}_{(\text{YM})} | \text{Cu}} = 0.0 \text{ V}$
81. The reaction occurring in a cell $\text{Co} | \text{Co}^{2+}_{(1.0 \text{ M})} || \text{Ni}^{2+}_{(\text{XM})} | \text{Ni}$ at 298 K is in equilibrium, then x =
 $E^0_{\text{Co}^{2+} | \text{Co}} = -0.28 \text{ V and } E^0_{\text{Ni}^{2+} | \text{Ni}} = -0.23 \text{ V. (n = 2)}$
 (A) 1.0 M (B) 1.02 M (C) 0.02 M (D) 0.5 M
82. The following half-cell reactions are given :
 $\text{Mn}^{2+} + 2\text{e}^- \rightarrow \text{Mn}$; $E^0 = -1.18\text{V}$, $2(\text{Mn}^{3+} + \text{e}^- \rightarrow \text{Mn}^{2+})$; $E^0 = +1.51 \text{ V}$
 then what is E° of $3\text{Mn}^{2+} \rightarrow \text{Mn} + 2\text{Mn}^{3+}$? (and decide the spontaneity of a reaction)
 (A) -0.33 V; reaction spontaneous (B) -2.69 V; non spontaneous reaction
 (C) -2.69 V; reaction spontaneous. (D) -0.33 V; non spontaneous reaction

Answers : 27. (D), 28. (B), 29. (D), 30. (B), 31. (B), 32. (C), 33. (C), 34. (D), 35. (C), 36. (A), 37. (B), 38. (D), 39. (C), 40. (C), 41. (D), 42. (C), 43. (B), 44. (C), 45. (B), 46. (A), 47. (A), 48. (A), 49. (A), 50. (A), 51. (B), 52. (B), 53. (C), 54. (B), 55. (B), 56. (C), 57. (A), 58. (D), 59. (C), 60. (B), 61. (D), 62. (B), 63. (D), 64. (C), 65. (D), 66. (C) 67. (B), 68. (C), 69. (A), 70. (B), 71. (A), 72. (A), 73. (D), 74. (D), 75. (A) 76. (D), 77. (A), 78. (A), 79. (C), 80. (A), 81. (C), 82. (B)

Electrolysis : When electric current is passed into electrolytic cell containing aqueous solution of electrolyte or molten electrolyte with proper electrodes dipped in to it. Redox reaction takes place and products are obtained at electrodes. This reaction is called **electrolysis**.

Principle of electrolysis : Conversion of electrical energy into chemical energy.

● **Faraday's Laws of electrolysis :**

(1) First law : The amount of products liberated at electrodes during electrolysis is directly proportional to the quantity of electricity passed through electrolytic cell.

$$m \propto Q. \text{ Therefore } m = z \cdot Q, z = \text{electro chemical equivalent}$$

(2) Second law : When different electrolytic cells containing different electrolytes are connected in a series and same quantity of electricity is passed through them, the amount of products liberated at different electrodes is directly proportional to their equivalent weights.

$$m \propto E_{eq}. \text{ Therefore } m = E_{eq} \cdot Q, E_{eq} = \text{equivalent weight, } Q = \text{quantity of electricity passed.}$$

Modern interpretation of Faraday's laws :

“The number of moles of products obtained at electrodes by oxidation and reduction half reactions are stoichiometrically related to the quantity of electricity passed through electrolytic cell.”

The quantity of electric charge carried by 1 mole electrons is called 1 Faraday. Its symbol is 'F'.

$$\begin{aligned} 1 \text{ (F)} &= 1 \text{ mol} \times \text{electronic charge} \\ &= (6.022 \times 10^{23}) \times (1.602 \times 10^{19} \text{ coulomb}) \\ &= 96487 \text{ coulomb} \approx 96500 \text{ coulomb} \end{aligned}$$

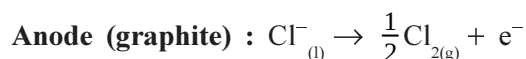
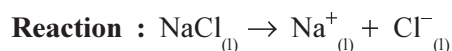
$$F = \frac{I \times t}{96500} \text{ Faraday, where } I = \text{electric current (ampere), } t = \text{time (second)}$$

The products obtained by electrolysis of aq. solution of electrolytes depend on following three factors.

(1) nature of electrodes used (2) concentration of solution (3) emf (electrical pressure)

● **Electrolysis of molten NaCl**

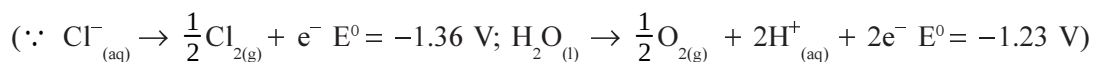
Electrolysis of molten NaCl using graphite anode and steel cathode gives ($\text{Cl}_{2(g)}$) gas at anode and ($\text{Na}_{(s)}$) metal at cathode. Reactions are as follows :



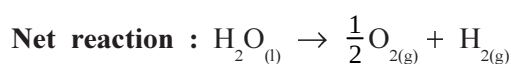
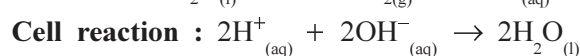
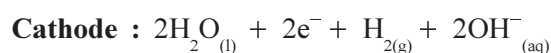
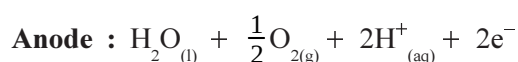
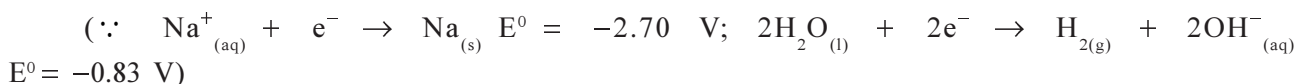
● **Electrolysis of dilute aqueous NaCl**

Electrolysis of dilute aqueous NaCl using inert electrodes like graphite or platinum is in reality electrolysis of water. As explained below electrolysis of dilute aq. NaCl using inert electrodes gives ($\text{O}_{2(g)}$) gas at anode and ($\text{H}_{2(g)}$) gas at cathode.

At anode : In dilute aq. NaCl, concentration of Cl^- is low and hence its oxidation is difficult. Compared to its oxidation of water is easier therefore instead of Cl_2 gas, oxygen gas is obtained.



At cathode : Reduction of Na^+ is difficult and compared to its reduction of water is easier therefore instead of Na^+ , water is reduced and H_2 gas is obtained.



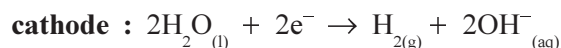
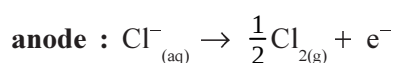
Thus electrolysis of dilute aq. NaCl using inert electrodes is in reality electrolysis of water. (The pH of solution does not change during electrolysis of dil. aq. NaCl using inert electrodes. Phenolphthalein will not give any colour change and solution will remain colourless during electrolysis. Similarly, methyl orange will also not show any colour change and as solution is neutral it will remain orange in colour. As amount of water decreases, concentration of NaCl increases in solution.)

● **Electrolysis of concentrated aqueous NaCl :**

Electrolysis of conc. aq. NaCl using inert electrodes like graphite or platinum gives $\text{Cl}_{2(\text{g})}$ gas at anode and $\text{H}_{2(\text{g})}$ gas at cathode as follows.

At anode : Concentration of Cl^- is higher in conc. aq. NaCl compared to that of H_2O and hence Cl^- is oxidized easily and $\text{Cl}_{2(\text{g})}$ gas produce at anode.

At cathode : Reduction of Na^+ is difficult and that of H_2O is comparatively easier and hence at cathode water is reduced and H_2 gas is obtained. ($\because \text{Na}^+_{(\text{aq})} + \text{e}^- \rightarrow \text{Na}_{(\text{s})} \quad E^0 = -2.70 \text{ V}; 2\text{H}_2\text{O}_{(\text{l})} + 2\text{e}^- \rightarrow \text{H}_{2(\text{g})} + 2\text{OH}^-_{(\text{aq})} \quad E^0 = -0.83 \text{ V}$)



In solution $\text{Cl}^-_{(\text{aq})}$ ions are displaced by $\text{OH}^-_{(\text{aq})}$ ions.

Thus electrolysis of concentrated aq. NaCl using inert electrodes gives $\text{Cl}_{2(\text{g})}$ gas at anode, $\text{H}_{2(\text{g})}$ gas at cathode and NaOH is produced in solution. Thus electrolysis of conc. aq. NaCl is in reality industrial production of NaOH.

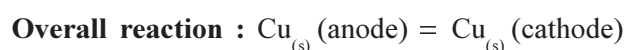
(As solution becomes basic by electrolysis of conc. aq. NaCl using inert electrodes the pH of solution increases. If electrolysis is carried out adding phenolphthalein, solution turns pink from colourless and if done adding methyl orange it turns yellow from orange.)

● **Electrolysis of aqueous solution of copper sulphate (CuSO_4) using active electrodes of copper (Cu)**

If electrolysis of aq. solution of CuSO_4 is carried out using active electrodes of copper (Cu) then by overall reaction copper of anode deposits at cathode.

As copper electrode is active electrode it undergo reaction during electrolysis.

During electrolysis as the time elapse $\text{Cu}_{(s)}$ atoms of copper anode undergo oxidation and produce Cu^{2+} ions and goes into the solution. Hence the mass of copper anode decrease as the time elapse. Cu^{2+} ions present in solution undergo reduction at the surface of cathode and converts into $\text{Cu}_{(s)}$ atoms and deposits at copper cathode. Hence the mass of copper cathode increases.



In the metallurgy of copper during electrochemical refining impure copper is taken as anode and when electrolysis is done at proper electrical pressure, impurities of inert metals like Au, Pt present in anode do not undergo oxidation and they collect at the bottom of the cell. This is called **anode-mud**.

Thus during electrolysis of aq. CuSO_4 using active electrodes of copper, no products are obtained at anode but at the bottom of the cell inert and precious metals like Ag, Au, Pt are obtained in anode mud and $\text{Cu}_{(s)}$ deposits at cathode.

When electrolysis of aq. CuSO_4 is done using active electrodes of Cu, there is no change in conc. of Cu^{2+} ions and therefore there is no change in blue colour and pH of solution.

If electrolysis of aq. CuSO_4 is carried out using inert electrodes like graphite or platinum then at anode $\text{O}_{2(g)}$ gas by oxidation of water and copper is obtained at cathode as explained below.

At anode : Oxidation of SO_4^{2-} ions is difficult compared to that of water and hence water is oxidized and produce H^{+} ions and O_2 gas.

At cathode : Reduction of Cu^{2+} ions present in solution takes place and copper metal is produced.

The Cu^{2+} ions in solution are replaced by H^{+} ions. Therefore H_2SO_4 is produced in solution.

Thus electrolysis of aq. (CuSO_4) using inert electrodes like graphite or platinum gives $\text{O}_{2(g)}$ gas at anode, Cu metal deposits at cathode and H_2SO_4 is produced in solution.

When electrolysis of aq. (CuSO_4) is carried out using inert electrodes like graphite or platinum, acidity of solution increase because H_2SO_4 is produced in solution and hence pH decreases.

(Cu^{2+} ions present in solution are reduced to $\text{Cu}_{(s)}$ and therefore the blue colour of solution fades.)

● Application of electrolysis (OR Importance)

(1) It is used in production of metals like Na, Mg, Al production of gases like Cl_2 , F_2 and production of chemicals like NaOH, KOH etc.

(2) Refining of metals like Au, Cu, Pt, Ag is done by electrolysis.

(3) Electrolysis is useful in electroplating.

No.	Electrolysis	Product at anode	Product at cathode
1.	molten NaCl	$\text{Cl}_{2(g)}$	Na metal
2.	Con. aq. NaCl	$\text{Cl}_{2(g)}$	$\text{H}_{2(g)}$ and NaOH in solution
3.	dil. aq. NaCl	$\text{O}_{2(g)}$	$\text{H}_{2(g)}$
4.	Al_2O_3 (Na_3AlF_6) graphite electrodes	$\text{O}_{2(g)}$, $\text{F}_{2(g)}$, $\text{CO}_{2(g)}$	Al metal
5.	KHF_2 in anhydrous HF	$\text{F}_{2(g)}$	$\text{H}_{2(g)}$

● **Difference between electrochemical cell and electrolytic cell**

Electrochemical cell	Electrolytic cell
(1) Chemical Energy is converted into electrical energy in this cell.	(1) Electrical energy is converted into chemical energy in this cell.
(2) Redox reaction is spontaneous and ($\Delta G < 0$)	(2) Redox reaction is not spontaneous and ($\Delta G > 0$)
(3) Generally the two electrodes are in different containers	(3) Both the electrodes are dipped in electrolytic solution or molten electrolyte.
(4) Anode is (–) and cathode is (+)	(4) Anode is (+) and cathode is (–). i.e. an electrode joined with positive terminal of battery is anode and that joined with negative terminal is cathode
(5) Generally salt bridge is required in its construction.	(5) Generally salt bridge is not required in its construction.
(6) eg. Daniel cell	(6) eg. Electrolytic cells used for production of Na, Al, Cl_2 etc.

83. The potential of a cell is 2.0 V. If ΔG for cell reaction is –50 Kcal, then how many coulombs of electric charge would have been drawn ? (1 cal = 4.184 J)
 (A) 1.08 coulomb (B) 104600 coulomb (C) 25000 coulomb (D) 0.26 coulomb
84. How many moles of $\text{O}_{2(g)}$ and $\text{H}_{2(g)}$ would obtain on passing 10 F electricity in electrolysis of water theoretically ?
 (A) 5 mol and 10 mol (B) 10 mol and 5 mol (C) 5 mol and 2.5 mol (D) 2.5 mol and 5 mol
85. How many grams of Ag would obtain at cathode on passing 5F of electricity from aq. AgNO_3 theoretically ? ($\text{Ag} = 108 \text{ gram.mol}^{-1}$)
 (A) 270 gram (B) 540 gram (C) 180 gram (D) 135 gram

86. How many grams of Al will obtain at cathode experimentally on passing 15.0 F of electricity from $\text{Al}^{3+}_{(l)}$? (efficiency of cell = 80 %.) (Atomic mass Al = 27 gram mol^{-1})
 (A) 135 gram (B) 121.5 gram (C) 108 gram (D) 94.5 gram
87. How much litres of $\text{O}_{2(g)}$ would obtain theoretically on passing 20 F electricity in electrolysis of water ?
 (A) 224 litre (B) 448 litre (C) 112 litre (D) 62 litre
88. At STP, 84 L of $\text{Cl}_{2(g)}$ is obtained experimentally on passing 10 F electrical charge in electrolysis of molten NaCl, then what is the efficiency of the cell ?
 (A) 80 % (B) 75 % (C) 50 % (D) 90 %
89. What will be the change in pH of a solution when aq. CuSO_4 is electrolysed using inert electrodes ?
 (A) pH increase (B) pH decrease (C) No change in pH (D) Cannot be said
90. The standard potential of an oxidation of sulphur dioxide into sulphur trioxide in closed container at 298 K is 0.182 V. The $\Delta G^0 = -3512.6 \text{ J}$ for this reaction. If standard free energy of formation of $\text{SO}_{2(g)}$ is $-300.37 \text{ KJ mol}^{-1}$, then what will be the same for $\text{SO}_{3(g)}$?
 ($R = 8.314 \text{ Jmol}^{-1} \text{ K}^{-1}$, $F = 96500 \text{ F mol electron}^{-1}$)
 (A) $-313.933 \text{ kg joule mol}^{-1}$ (B) $-235.335 \text{ kg joule mol}^{-1}$
 (C) $-296.854 \text{ kg joule mol}^{-1}$ (D) $-335.496 \text{ kg joule mol}^{-1}$
91. Reduction of H_2O takes place instead of that of $\text{Na}^+_{(aq)}$ in electrolysis of dil. solution of NaCl using inert electrodes. Because,
 (A) Standard reduction potential of $\text{Na}^+_{(aq)}$ is more than that of H_2O .
 (B) Standard oxidation potential of H_2O is very large.
 (C) inert electrodes are there.
 (D) Standard potential of reduction reaction of $\text{Na}^+_{(aq)}$ is very small.
92. What is the proportion of moles at cathodes when same quantity of electricity is passed through electrolytic cells containing molten NaCl, CaCl_2 and AlCl_3 joined in a series ?
 (A) 1 : 2 : 3 (B) 3 : 2 : 1 (C) 6 : 2 : 3 (D) 6 : 3 : 2
93. Choose correct option for given statements. (T = True statement, F = False statement)
 (i) The blue colour of solution fades on electrolysis of aq. CuSO_4 using active electrodes of Cu.
 (ii) The pOH of solution increase on electrolysis aq. CuSO_4 using inert electrodes.
 (iii) The solution becomes basic on electrolysis aq. CuSO_4 using active electrodes of Cu.
 (iv) The mass of cathode increase on electrolysis aq. CuSO_4 using inert electrodes.
 (A) FTFT (B) TFFT (C) FFTT (D) FTTF
94. What are the products obtained at cathode and anode respectively on electrolysis a mixture of KHF_2 in anhydrous HF ?
 (A) K and F_2 (B) K and H_2 (C) O_2 and F_2 (D) H_2 and F_2

95. How many moles of Ca will be obtained at cathode experimentally on passing 5 F electrical charge through molten CaCl_2 ?
 (A) 2.5 mol (B) less than 2.5 mol (C) more than 2.5 mol (D) 5 mol
96. What is the ratio of number of moles of metals obtained at different cathodes on passing same quantity of electricity through electrolytic cells containing CuSO_4 , AgNO_3 and NiSO_4 joined in a series ?
 (A) 2 : 1 : 2 (B) 2 : 2 : 1 (C) 1 : 1 : 2 (D) 1 : 2 : 1
97. In an experiment of electroplating 'm' gram Ag deposits at cathode on passing 4 ampere electric current for 2 minutes. How many grams of Ag will deposit if 6 ampere electric current is passed for 40 seconds ?
 (A) 2 m (B) 4 m (C) $\frac{m}{2}$ (D) $\frac{m}{4}$
98. How many faradays of electric charge are required theoretically in order to reduce 1 mole $\text{Cr}_2\text{O}_7^{2-}$ into Cr^{3+} ions ?
 (A) 6 (B) 3 (C) 1 (D) 4
99. Which relation is true for Faraday's second law of electrolysis ? Where m_1 and m_2 are amount of substances and E_1 and E_2 are their equivalent weights respectively.
 (A) $m_1 E_2 = m_2 E_1$ (B) $m_1 E_1 = m_2 E_2$ (C) $m_1 + m_2 = E_2 + E_1$ (D) $E_1 E_2 = m_1 m_2$
100. Electrolysis of CrCl_3 in order to do chromium plating was carried out using 220.0 gram iron plate as negative electrode by passing 10 ampere electric current for 1221 seconds. The mass of plate increased and became 221.84 gram. What will be the efficiency of this cell ? (At mass : Cr = 52)
 (A) 90.2 % (B) 83.90 % (C) 95 % (D) 63.89 %
101. How much quantity of electricity in coulombs is required theoretically to reduce 1 mol MnO_4^- into Mn^{2+} ?
 (A) 96500 C (B) 1.93×10^5 C (C) 5.62×10^5 C (D) 4.83×10^5 C
102. How much quantity of electricity is required theoretically in order to reduce all Ag^+ in 250 ml of 1.0 M AgNO_3 ?
 (A) 2412.5 C (B) 24125 C (C) 4825 C (D) 25250 C
103. On passing required quantity of electricity through $\text{Al}_{(l)}^{3+}$, 4.5 gram of Al is deposited at cathode experimentally. If same quantity of electricity is passed through solution containing enough concentration of $\text{H}^+_{(aq)}$ what volume of hydrogen will be produced at STP ?
 (At wt : Al = 27 g mol⁻¹)
 (A) 44.4 Litre (B) 222.4 Litre (C) 11.2 Litre (D) 5.6 Litre
104. By electrolysis CdCl_2 using 2g Hg cathode, Cd-Hg amalgam is obtained. How many amperes of electric current should be passed theoretically for 100 seconds in order to obtain Cd-Hg amalgam containing 20 % Cd at cathode ? (At mass Cd = 112.5 g mol⁻¹)
 (A) 34.32 A (B) 17.16 A (C) 4.29 A (D) 8.58 A

105. On electrolysing unknown salt solution of Pd by passing 5A electric current for 2.15 hours, 10.64 gram Pd is deposited at cathode theoretically. What will be the oxidation state of Pd in that salt ?
(Atomic mass Pd = 106.4 gmol⁻¹)
- (A) +2 (B) +3 (C) +4 (D) +1
106. Preparation of MnO₂ by electrolysis of aq. solution of MnSO₄ is done according to following equation. If 1.0 kg MnO₂ is obtained by passing 25A electric current for 30 hours, then what is the current efficiency ?
(molecular mass MnO₂ = 87 gmol⁻¹)
- $$\text{Mn}^{2+}_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} \rightarrow \text{MnO}_{2(\text{s})} + 2\text{H}^{+}_{(\text{aq})} + \text{H}_{2(\text{g})}$$
- (A) 82.16 % (B) 20.54 % (C) 25 % (D) 49.2 %
107. Calculate the experimental mass of metal depositing on cathode when 15 ampere electric current is passed for 2 hours through electrolytic cell having efficiency 75 %. Electrochemical equivalent of metal is 4.0 × 10⁻⁴ gram coulomb⁻¹.
- (A) 32.4 gram (B) 43.2 gram (C) 57.6 gram (D) 16.2 gram
108. The concentration of AgNO₃ decrease from 4M to 3M when aq. solution of AgNO₃ is electrolysed using platinum electrodes. If the same solution is electrolysed using Ag electrodes, what result is obtained ?
- (A) the result is same (B) concentration of solution increase
(C) decrease in concentration is less (D) no change in concentration of solution
109. What will be the theoretical concentration of Ni(NO₃)₂ solution if 0.5 L of 2.0 M Ni(NO₃)₂ is electrolysed by passing 9.65 A electric current for 3 hours using graphite anode and nickel cathode ?
- (A) 0.46 M (B) 1.46 M (C) 0.92 M (D) 0.36 M
110. What will be the decrease in concentration of Ag⁺_(aq) when 4L of 0.8 M AgNO₃ is electrolysed by passing 5 ampere electric current for 10 hours using inert electrodes ?
(Current efficiency = 80 %)
- (A) 0.466 M (B) 1.865 M (C) 1.492 M (D) 0.373 M
111. How much amperes of electric current should be passed through water in order to produce 100 ml O₂ per minute at 25°C temperature and 1 bar pressure ? Current efficiency = 90%.
 $R = 0.08314 \frac{\text{L bar}}{\text{mol K}}$
- (A) 23.16 A (B) 14.35 A (C) 28.85 A (D) 31.88 A
112. In order to obtain 36.47 gram sodium at cathode by electrolysis of molten NaCl for how much time 10 A electric current should be passed ? Current-efficiency = 85% (At mass Na = 23 gmol⁻¹)
- (A) 4.25 hr (B) 3.6 hr (C) 5 hr (D) 4 hr
113. When 5 L aq. solution of CuSO₄ is electrolysed using inert electrodes by passing 25A electric current, the molarity of CuSO₄ becomes 1.2 M from 0.7 M, then for how much time electric current would have been passed theoretically ?
- (A) 1.716 hr (B) 8.58 hr (C) 17.16 hr (D) 4.29 hr

114. When 10 L aq. solution of CuSO_4 is electrolysed using inert electrodes by passing electric current for 20 hours, the molarity of CuSO_4 becomes 0.2 M from 0.7 M, then how many amperes of electric current would have been passed theoretically ?
 (A) 13.4 A (B) 1.34 A (C) 6.7 A (D) 26.8 A
115. By electrolysing CdCl_2 using 2 gram Hg cathode, Cd-Hg amalgam is obtained. How many amperes of electric current should be passed theoretically for 1000 seconds to obtain Cd-Hg amalgam containing 20% Hg ? (At mass : Cd = 112.5 gmol^{-1})
 (A) 34.32 A (B) 17.16 A (C) 4.29 A (D) 13.72 A
116. To what is Faraday's law of electrolysis related ?
 (A) With atomic number of positive ion (B) With atomic number of negative ion
 (C) With speed of positive ion (D) With equivalent of electrolyte
117. What is the mass deposited at electrode when 1 coulomb electric charge is passed through solution of electrolyte ?
 (A) equal to 1 Chemical equivalent (B) equal to 1 atomic mass
 (C) equal to 1 gram (D) equal to 1 electro chemical equivalent
118. What electric charge will be required in order to deposit 1 equivalent of mass at electrode ?
 (A) 1 coulomb (B) electric charge on 1 mol e^-
 (C) 96500 faraday (D) None of the given
119. The electrochemical equivalent of a substance is 0.0006735 gram, what will be its chemical equivalent ?
 (A) 65 g (B) 0.0007635 g (C) 34.5 g (D) 130 g
120. On electrolysing aq. solution of acid 44800 ml O_2 is produced at anode, then what will be the volume of H_2 gas produced at cathode during this ?
 (A) 11200 ml (B) 44800 ml (C) 22400 ml (D) 89600 ml
121. On passing 2A electric current for 2 hours from aq. CuSO_4 'W' gram copper deposits at cathode. If 4A electric current is passed for 4 hours in the same cell what will be the mass of copper deposit at the cathode ?
 (A) 2W gram (B) $\frac{W}{2}$ gram (C) 4W gram (D) $\frac{W}{4}$ gram
122. When 9650 electrons are associated with electrolysis, the mass of metal deposited at cathode is 1.2 gram, then what will be the chemical equivalent of metal ?
 (A) 24 gm/eq (B) 0.12 gm/eq (C) 12 gm/eq (D) 2.4 gm/eq
123. How many amperes of electric current should be passed theoretically in order to collect 112 mL H_2 gas at cathode at STP from acidified water in 965 seconds ?
 (A) 0.1 A (B) 1.0 A (C) 0.5 A (D) 2.0 A
124. In a galvanic cell, in a 1 L of 1.0 M CuSO_4 aqueous solution Zn electrode having mass 100 gram is dipped. If this cell gives 1.0 A electric current continuously, then how long this cell will last ?
 (A) 26.8 hr (B) 53.61 hr (C) 82.48 hr (D) 33.78 hr

125. The surface area of a metallic state is 150 cm^2 . How long 15 ampere electric current should be passed from aq. solution of Ag^+ in order to coat its surface with 0.01 nm thick layer of Ag ?

(Current efficiency = 90 %) density of Ag = $10.5 \text{ gram cm}^{-3}$ Atomic mass Ag = $108 \frac{\text{gm}}{\text{mol}}$

(A) 227.979 second (B) 205.1811 second (C) 253.31 second (D) 233.45 second

126. For how much time 10 ampere electric current should be passed from aq. solution of Au^{3+} to coat metallic bars having dimensions $5 \text{ cm} \times 10 \text{ cm} \times 2 \text{ cm}$ with 0.01 nm thick gold layer ? (Current efficiency = 80%)

density of Au = $19.3 \text{ gram cm}^{-3}$ Atomic mass of Au = $197 \frac{\text{gram}}{\text{mol}}$

(A) 45393.63 second (B) 45034.94 second (C) 52572.23 second (D) 56748.51 second

127. For plating on a spoon 0.01 gram silver is consumed. How many spoons will be plated if 0.1A electric current is passed for 27 hours if electrolyte is aq. solution of AgNO_3 ?

(Atomic mass Ag = $108 \text{ gram mol}^{-1}$)

(A) 100 (B) 1088 (C) 108 (D) 80

128. For how much time 10 ampere electric current should be passed through aq. AgNO_3 in order to plate silver on 1080 spoons ? 0.02 gram silver is being plated on each spoon. (Current efficiency = 90%)

(Atomic mass of Ag = $108 \text{ gram mol}^{-1}$)

(A) 2144 second (B) 1544 second (C) 1930 second (D) 2130 second

129. When 19,3000 coulomb of electrical charge is passed through electrolytic cell 1 gram atomic weight of metal deposits on cathode theoretically. What will be the relation between molar mass (M) and equivalent weight (Eq) of that metal ?

(A) $M = 2\text{Eq}$ (B) $M = 4\text{Eq}$ (C) $M = \text{Eq}$ (D) $M = 3\text{Eq}$

130. 3.0 mole Ag deposits at cathode theoretically when 'x' coulombs of electricity is passed through aq. solution of AgNO_3 . How many moles of Al will deposit at cathode theoretically if 'x' coulombs of electricity is passed through aq. solution of $\text{Al}(\text{NO}_3)_3$?

(A) 1 mole (B) 2 mole (C) 9 mole (D) 3 mole

131. 'x' coulombs of electrical charge is passed through aq. solution of $\text{Al}(\text{NO}_3)_3$. When current efficiency is 90%, 3 mol Al deposits at cathode experimentally. If 'x' coulombs of electrical charge is passed through aq. solution of AgNO_3 and current efficiency is 80%, then how many moles of Ag will deposit at cathode experimentally ?

(A) 7.2 mol (B) 10 mol (C) 8 mol (D) 8.5 mol

Answers : 83. (B) 84. (D) 85. (B) 86. (C) 87. (C) 88. (B) 89. (B), 90. (D), 91. (D), 92. (D), 93. (A), 94. (D), 95. (B), 96. (D), 97. (C), 98. (A), 99. (A), 100. (B), 101. (D), 102. (B), 103. (D), 104. (D), 105. (C), 106. (A), 107. (A), 108. (D), 109. (C), 110. (D), 111. (C), 112. (C), 113. (B), 114. (A), 115. (D), 116. (D), 117. (D), 118. (B), 119. (A), 120. (D) 121. (A), 122. (C), 123. (A), 124. (B), 125. (C), 126. (D), 127. (B), 128. (A), 129. (A), 130. (A), 131. (C)

- **Electrical resistance**

The resistance of a uniform conductor is directly proportional to its length (l) and inversely proportional to its area of cross section (A).

Electric resistance is expressed by R. Its unit is ohm (Ω). It is measured by wheatstone bridge.

$$\therefore R \propto \frac{l}{A} \text{ where, } R = \text{resistance, } l = \text{length, } A = \text{area of cross section}$$

$\therefore R = \rho \left(\frac{l}{A} \right)$ where, ρ = resistivity (specific resistance) and its SI unit is (Ωm). Generally it is expressed by (Ωcm).

Resistivity (Specific resistance) : The resistance of a conductor having 1 m length and 1m^2 cross section of area is called resistivity or specific resistance.

SI unit of resistivity is ohm metre (Ωm). It is generally expressed ohm cm (Ωcm).

$$1 \Omega\text{m} = 100 \Omega\text{cm}$$

Conductivity : The inverse of resistance is called conductivity.

$$G = \frac{1}{R} \therefore G = \frac{A}{\rho \cdot l} \left(\because R = \rho \left(\frac{l}{A} \right) \right)$$

$$\therefore G = K \cdot \frac{A}{l} \text{ where } K = \frac{1}{\rho} = \text{specific conductivity}$$

The SI unit of conductance is Siemens (S). It is generally expressed as ohm^{-1} or $\text{ohm } \Omega^{-1}$ or mho ($\mathfrak{U}$).

Specific conductivity (k) : The conductance of a conductor having length equal to 1m and area of cross section equal to 1m^2 is called its specific conductivity or simply conductivity. It is the inverse of resistivity (ρ).

$$\therefore K = \frac{1}{\rho} \text{ and } \rho = \frac{R \cdot A}{l} \therefore K = \frac{1}{R \cdot A}$$

Unit of K : mho.cm^{-1} ($\mathfrak{U} \text{ cm}^{-1}$) SI unit = Sm^{-1} .

Cell constant (G^*) : The term $\frac{l}{A}$ in the formula of specific conductivity is known as cell constant G^* . Unit of cell constant (G^*) : cm^{-1} , SI unit is m^{-1} .

The conduction of electricity in metallic conductors is done by electrons present in outermost shell or conduction band of metal atoms.

The conduction of electricity in electrolytic solutions is by ions.

In metals there is no chemical change during the conduction of electricity.

The temperature of metals increase during conduction of electricity.

Molar conductivity (Λ_m) : The conductance of a solution kept between two electrodes at a distance of unit length with unit area of cross section containing 1 mole of electrolyte is called molar conductivity.

Suppose V litre of solution placed between two electrodes contain 1 mole electrolyte, therefore molarity of solution $M = \frac{1}{V}$ therefore $V = \frac{1}{M}$.

$G = k \cdot \frac{A}{l}$, where $l = 1 \text{ cm}$ and $A = V$ and $G = k \cdot V$, where according to definition, $G = \Lambda_m$

$$\therefore \Lambda_m = k \cdot V$$

$\therefore \Lambda_m = \frac{k}{M}$ (If molarity of solution is M , then $M \text{ mol} = 1 \text{ L}$ solution. Therefore solution will be

$1 \text{ mol } \frac{1}{M} \text{ litre.})$

$$M = \frac{\text{mol}}{\text{L}} = \frac{M \text{ mol}}{(\text{dm})^3} = \frac{M \text{ mol}}{(1000 \text{ cm})^3}$$

$$\Lambda_m = \frac{k}{M} = \frac{k}{\frac{M \text{ mol}}{(1000 \text{ cm})^3}} = \frac{(1000 \text{ cm})^3 \times k \text{ mho cm}^{-1}}{M \text{ mol}} = \frac{1000 \times k}{M} \text{ mho} \cdot (\text{cm})^2 \text{ mol}^{-1} \text{ or } S(\text{cm})^2 \text{ mol}^{-1}$$

$$1 \text{ Sm}^2 \text{ mol}^{-1} = 10^4 S \text{ cm}^2 \text{ mol}^{-1}$$

$$\text{Equivalent conductivity } (\Lambda) = \frac{1000 \times k}{\text{Normality (N)}} \text{ Unit : mho } (\text{cm})^2 \text{ eq}^{-1}, \text{ SI unit : } S (\text{cm})^2 \text{ eq}^{-1}$$

When aq. solution of any electrolyte is diluted by adding water into it the number of ions conducting electric current per unit volume decrease and hence specific conductance decrease. But due to dilution, dissociation of electrolyte increase and therefore the number of ions conducting electric current per mole increase and hence molar conductivity increases.

Super Conductors : The substances having zero resistivity or infinite conductivity are called super conductors.

Earlier metals and alloys at a temperature (0 to 15 K) were known to behave as super conductors, but now a days a number of ceramic materials and mixed oxides are also known to show super conductivity at temperatures as high as 150 K.

The conductivity of solutions is mainly due to the presence of ions in them. It is called ionic conductivity.

Factors affecting ionic conductivity are :

- (1) Nature of electrolyte added
- (2) Concentration of electrolyte
- (3) temperature
- (4) viscosity
- (5) Nature of solvent
- (6) size of the ions produced and their solvation.

132. Which is the correct order of specific conductance of the metals given ?

(A) $\text{Cu} > \text{Ag} > \text{Au} > \text{Na} > \text{Fe}$

(B) $\text{Ag} > \text{Cu} > \text{Au} > \text{Fe} > \text{Na}$

(C) $\text{Ag} > \text{Cu} > \text{Au} > \text{Na} > \text{Fe}$

(D) $\text{Ag} > \text{Au} > \text{Cu} > \text{Fe} > \text{Na}$

133. The resistance of aq. solution of KCl having conductivity " x " mho cm^{-1} at definite temperature is $y \Omega$. If resistance of aq. solution of NaCl measured with the same instrument is " z " Ω then what is the conductivity of this solution ?

(A) $\frac{yz}{x} \text{ mho } (\text{cm})^{-1}$

(B) $\frac{xy}{z} \text{ mho } (\text{cm})^{-1}$

(C) $\frac{xz}{y} \text{ mho } (\text{cm})^{-1}$

(D) $\frac{x}{yz} \text{ mho } (\text{cm})^{-1}$

134. The electrical resistance and conductivity (κ) of 0.2 M aq. solution of an electrolyte are $50\ \Omega$ and $1.3\ \text{Sm}^{-1}$ respectively. If electrical resistance of 0.4 M aq solution of same electrolyte is $260\ \Omega$, then what will be its molar conductivity ?
 (A) $6.25 \times 10^{-4}\ \text{Sm}^2\ \text{mol}^{-1}$ (B) $625\ \text{Sm}^2\ \text{mol}^{-1}$ (C) $62.5\ \text{Sm}^2\ \text{mol}^{-1}$ (D) $6.25 \times 10^{-2}\ \text{Sm}^2\ \text{mol}^{-1}$
135. The electrical resistance and specific conductivity of a cell containing $\frac{N}{50}$ KCl solution are $400\ \Omega$ and $0.002765\ \text{S cm}^{-1}$, then what will be the value of its cell constant ?
 (A) $6.91\ \text{cm}^{-1}$ (B) $1.106\ \text{cm}^{-1}$ (C) $14.46\ \text{cm}^{-1}$ (D) $2.212\ \text{cm}^{-1}$
136. If conductivity and electrical resistance of a conductivity cell containing $\frac{N}{10}$ KCl solution at 18°C are $1.12 \times 10^{-2}\ \text{S cm}^{-1}$ and $65\ \Omega$ respectively then what will be the value of cell constant of this cell ?
 (A) $0.728\ \text{cm}^{-1}$ (B) $0.580\ \text{cm}^{-1}$ (C) $0.172\ \text{cm}^{-1}$ (D) $0.0172\ \text{cm}^{-1}$
137. What will be the quantity of electricity passed when a potential difference of 20 V is applied to a wire having resistance $10\ \Omega$ for 2 minutes ?
 (A) 120 C (B) 240 C (C) 20 C (D) 4 C
138. $2.5\ \text{Sm}^{-1} = \dots\dots\dots\ \text{Scm}^{-1}$
 (A) 250 (B) 25 (C) 0.025 (D) 0.25
139. According to conventional symbol system $\frac{l}{AR} = \dots\dots\dots$.
 (A) ρ (B) $K \cdot G$ (C) G (D) $\frac{1}{\rho}$
140. At what temperature metals and alloys were termed as super conductors earlier ?
 (A) 150 K (B) -273°C to -288°C (C) 0°C to 15°C (D) 0 K to 15 K
141. Which substances are known as super conductors at 150 K temperature ?
 (A) metals (B) alloys
 (C) ceramic materials and mixed oxides (D) plastic
142. Whose conductivity is most at room temperature ?
 (A) 0.1M HCl (B) 0.1M NaCl (C) Teflon (D) glass
143. Which substance is semi conductor ?
 (A) Teflon (B) CuO (C) Glass (D) Cu_2O

Answers : 132. (C) 133. (B) 134. (A) 135. (B) 136. (B) 137. (B), 138. (C), 139. (D), 140. (D), 141. (C), 142. (A), 143. (B)

Kohlrausch law of independent migration of ions : The molar conductivity (Λ^0) of an electrolyte at infinite dilution is equal to the sum of molar conductivities of its cation and anion (λ^0_+ and λ^0_-) at infinite dilution.

● **Debye Huckel and Onsager equation for molar conductivity of aqueous solution of electrolyte**

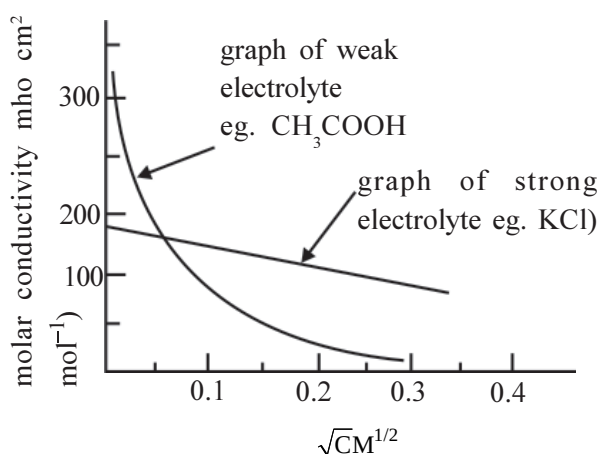
$\Lambda_m = \Lambda_m^0 - A \cdot \sqrt{C}$ where, Λ_m = molar conductivity of given solution, Λ_m^0 = Limiting molar conductivity

For aq. solution of strong electrolytes the graph of $\Lambda_m \rightarrow \sqrt{C}$ is straight line. The value of slope is equal to $-A$ and the intercept of Y-axis is equal to Λ_m^0 .

The value of A depends on type of electrolyte, solvent and temperature.

The value of A for same type of electrolytes is same (when solvent and temperature are same)

For aq. solutions of weak electrolytes the graph of $\Lambda_m \rightarrow \sqrt{C}$ is not a straight line but curve. Therefore, from the graph of $\Lambda_m \rightarrow \sqrt{C}$, molar conductivity (Λ_m^0) at infinite dilution of aqueous solutions of strong electrolytes can be determined but the same for aqueous solutions of weak electrolytes cannot be determined.



KCl, NaCl, CsCl ... etc are 1 : 1 type of electrolytes.

CuSO_4 , ZnSO_4 , FeSO_4 etc. are 1:2 type of electrolytes.

CaCl_2 , MgBr_2 ,etc. are 2 : 1 type of electrolytes. (Based on valency)

Ostwald's law of dilution : The increase in molar conductivity of aq. solution of weak electrolytes is specifically more when diluted by adding water compared to that for strong electrolytes. Because, the increase in dissociation is specifically more in aq. solution of weak electrolytes when diluted by water than that in strong electrolytes.

Application of Kohlrausch law : Molar conductivity (Λ^0) of weak electrolytes can be obtained from molar conductivities of strong electrolytes at infinite dilution by doing algebraic addition. For example, molar conductivity of weak electrolyte like CH_3COOH can be obtained from molar conductivities at infinite dilution of strong electrolytes like CH_3COONa , HCl and NaCl .

$\Lambda_{\text{CH}_3\text{COOH}}^0 = \Lambda_{\text{CH}_3\text{COONa}}^0 + \Lambda_{\text{HCl}}^0 - \Lambda_{\text{NaCl}}^0$ because according to the Kohlrausch law,

$$\begin{aligned} \Lambda_{\text{CH}_3\text{COONa}}^0 + \Lambda_{\text{HCl}}^0 - \Lambda_{\text{NaCl}}^0 &= (\lambda_{\text{CH}_3\text{COO}^+}^0 + \lambda_{\text{Na}^+}^0) + (\lambda_{\text{H}^+}^0 + \lambda_{\text{Cl}^-}^0) - (\lambda_{\text{Na}^+}^0 + \lambda_{\text{Cl}^-}^0) \\ &= \lambda_{\text{CH}_3\text{COO}^+}^0 + \lambda_{\text{Na}^+}^0 + \lambda_{\text{H}^+}^0 + \lambda_{\text{Cl}^-}^0 - \lambda_{\text{Na}^+}^0 - \lambda_{\text{Cl}^-}^0 \\ &= \lambda_{\text{CH}_3\text{COO}^+}^0 + \lambda_{\text{H}^+}^0 = \Lambda_{\text{CH}_3\text{COOH}}^0 \end{aligned}$$

144. $\Lambda_m^0 \text{Mg}^{2+} = 106 \text{ S cm}^2\text{mol}^{-1}$, $\Lambda_m^0 \text{Ca}^{2+} = 119 \text{ S cm}^2\text{mol}^{-1}$, $\Lambda_m^0 \text{Cl}^- = 76.3 \text{ S cm}^2\text{mol}^{-1}$, $\Lambda_m^0 \text{SO}_4^{2-} = 160 \text{ S cm}^2\text{mol}^{-1}$ Choose correct option for compound given in group-I and molar conductivity at infinite dilution in Group II.

Group-I compound	Group-2 $\Lambda_m^0 \text{ S cm}^2 \text{ mol}^{-1}$
(i) MgSO_4	(A) 195.3 (E) 182.3
(ii) CaCl_2	(B) 279 (F) 266
(iii) MgCl_2	(C) 186 (G) 219.5
(iv) CaSO_4	(D) 271.6 (H) 258.6

- (A) (i)-(C), (ii)-(D), (iii)-(H), (iv)-(B)
 (B) (i)-(F), (ii)-(A), (iii)-(E), (iv)-(G)
 (C) (i)-(F), (ii)-(D), (iii)-(H), (iv)-(B)
 (D) (i)-(C), (ii)-(G), (iii)-(A), (iv)-(E)

145. $\frac{1}{3} \Lambda_m^0 \text{Al}^{3+} = 63 \text{ S cm}^2\text{mol}^{-1}$, $\frac{1}{2} \Lambda_m^0 \text{Mg}^{2+} = 53 \text{ S cm}^2\text{mol}^{-1}$, $\Lambda_m^0 \text{OH}^- = 199.1 \text{ S cm}^2\text{mol}^{-1}$, $\frac{1}{2} \Lambda_m^0 \text{SO}_4^{2-} = 80 \text{ S cm}^2\text{mol}^{-1}$ Choose correct option for compound given in Group-I and molar conductivity at infinite dilution in Group-II.

Group-1 Compound	Group-2 $\Lambda_m^0 \text{ S cm}^2 \text{ mol}^{-1}$
(i) MgSO_4	(A) 504.2 (E) 786.3
(ii) $\text{Al}_2(\text{SO}_4)_3$	(B) 133 (F) 451.2
(iii) $\text{Mg}(\text{OH})_2$	(C) 266 (G) 858
(iv) $\text{Al}(\text{HO})_3$	(D) 660.3 (H) 366

- (A) (i)-(C), (ii)-(D), (iii)-(H), (iv)-(B)
 (B) (i)-(F), (ii)-(A), (iii)-(E), (iv)-(G)
 (C) (i)-(F), (ii)-(D), (iii)-(H), (iv)-(B)
 (D) (i)-(C), (ii)-(G), (iii)-(A), (iv)-(E)

146. For which of the given compound the graph of molar conductivity and $(\text{molarity})^{\frac{1}{2}}$ is straight line ?
 (A) CsCl (B) NH_4OH (C) HCOOH (D) All three given

147. To which compound $\Lambda_m = \Lambda_m^0 - A \cdot C^{\frac{1}{2}}$ is applicable ?

- (A) NaCl (B) NH_4OH (C) HCOOH (D) HCN

148. Whose equivalent conductivity at infinite dilution is most ?

- (A) $\text{K}^+_{(\text{aq})}$ (B) $\text{Na}^+_{(\text{aq})}$ (C) $\text{Cs}^+_{(\text{aq})}$ (D) $\text{Rb}^+_{(\text{aq})}$

149. For a strong electrolyte when $C = 0.04 \text{ M}$, $\Lambda_m = 250 \text{ S cm}^2\text{mol}^{-1}$ and when $C = 0.09 \text{ M}$ then $\Lambda_m = 200 \text{ S cm}^2\text{mol}^{-1}$ then what will be Λ and Λ_m^0 respectively for this electrolyte ?

- (A) 550, 265 $\text{S cm}^2\text{mol}^{-1}$ (B) 450, 365 $\text{S cm}^2\text{mol}^{-1}$
 (C) 500, 350 $\text{S cm}^2\text{mol}^{-1}$ (D) 340, 450 $\text{S cm}^2\text{mol}^{-1}$

150. For which given option slope of graph of $\Lambda_m \rightarrow \sqrt{C}$ is same for aq. solutions of all electrolytes ?
 (i) NaCl (ii) NH_4OH (iii) KNO_3 (iv) HCOOH (v) KBr (vi) HCN (vii) CaCl_2 (viii) FeCl_3
 (A) (i), (v), (vi) (B) (iii), (viii) (C) (i), (iii), (v) (D) (ii), (iv), (viii)
151. If values of Λ_m^0 of A_2B , X_3Y_2 and A_3Y are 2.4, 1.5 and 1.8 $\text{mho (cm)}^2 \text{ mol}^{-1}$ respectively then what will be the value of, Λ_m^0 for XB ?
 (A) 1.7 $\text{mho (cm)}^2 \text{ mol}^{-1}$ (B) 8.1 $\text{mho (cm)}^2 \text{ mol}^{-1}$
 (C) 2.1 $\text{mho (cm)}^2 \text{ mol}^{-1}$ (D) 0.7 $\text{mho (cm)}^2 \text{ mol}^{-1}$
152. $\Lambda_{\text{KCl}}^0 - \Lambda_{\text{NaCl}}^0 = 23.4 \text{ mho (cm)}^2 \text{ mol}^{-1}$ and $\Lambda_{\text{NaBr}}^0 - \Lambda_{\text{NaCl}}^0 = 1.8 \text{ mho (cm)}^2 \text{ mol}^{-1}$, which increasing order of molar conductivities at infinite dilution for NaCl, KCl, NaBr and KBr is correct ?
 (A) $\text{NaCl} < \text{KCl} < \text{NaBr} < \text{KBr}$ (B) $\text{NaCl} < \text{NaBr} < \text{KCl} < \text{KBr}$
 (C) $\text{KBr} < \text{NaCl} < \text{NaBr} < \text{KCl}$ (D) $\text{KCl} < \text{NaCl} < \text{NaBr} < \text{KBr}$
153. For an electrolyte, when $C = 0.01 \text{ M}$, $\Lambda_m = 255 \text{ S cm}^2 \text{ mol}^{-1}$ and when $C = 0.04 \text{ M}$, $\Lambda_m = 200 \text{ S cm}^2 \text{ mol}^{-1}$, then what will be Λ_m when $C = 0.09 \text{ M}$?
 (A) $400 \text{ S cm}^2 \text{ mol}^{-1}$ (B) $145 \text{ S cm}^2 \text{ mol}^{-1}$ (C) $150 \text{ S cm}^2 \text{ mol}^{-1}$ (D) $250 \text{ S cm}^2 \text{ mol}^{-1}$
154. Which increasing order of molar conductivities at infinite dilution for LiCl, NaCl and KCl is correct for aqueous solution ?
 (A) $\text{KCl} < \text{NaCl} < \text{LiCl}$ (B) $\text{LiCl} < \text{NaCl} < \text{KCl}$
 (C) $\text{LiCl} < \text{KCl} < \text{NaCl}$ (D) $\text{NaCl} < \text{KCl} < \text{LiCl}$
155. If resistance of a decinormal ($\frac{N}{10}$) salt solution placed between two platinum electrodes having area 5.4 cm^2 and 1.8 cm apart is 32Ω , then what will be the equivalent conductivity of that solution ?
 (A) $104.17 \text{ S cm}^2 \text{ g.eq}^{-1}$ (B) $10.41 \text{ S cm}^2 \text{ g.eq}^{-1}$
 (C) $1.0417 \text{ S cm}^2 \text{ g.eq}^{-1}$ (D) $1041.0 \text{ S cm}^2 \text{ g.eq}^{-1}$
156. The resistance of 0.05 M KOH at 298 K is 31.6Ω . If cell constant is 0.367 cm^{-1} , then equivalent conductivity of that KOH solution will be ?
 (A) $0.2322 \text{ S cm}^2 \text{ eq}^{-1}$ (B) $2.322 \text{ S cm}^2 \text{ eq}^{-1}$
 (C) $23.22 \text{ S cm}^2 \text{ eq}^{-1}$ (D) $232.28 \text{ S cm}^2 \text{ eq}^{-1}$
157. The resistance of a 0.05 M solution kept between two platinum electrodes 1.5 cm apart having area 10 cm^2 is 50Ω . What is the molar conductivity of this solution ?
 (A) $66.6 \text{ S cm}^2 \text{ mol}^{-1}$ (B) $15 \text{ S cm}^2 \text{ mol}^{-1}$ (C) $60 \text{ S cm}^2 \text{ mol}^{-1}$ (D) $6.66 \text{ S cm}^2 \text{ mol}^{-1}$

158. The molar conductivity at infinite dilution of a weak acid having concentration 0.01 M is 100 times the molar conductivity. What will be the degree of dissociation (α) of this acid ?
 (A) 0.1 (B) 0.001 (C) 10 (D) 0.01
159. If Λ_m^0 of $\text{Ag}^+ = 5.0 \times 10^{-3} \text{ S cm}^2 \text{ mol}^{-1}$ then what will be the ionic mobility of Ag^+ at infinite dilution ?
 (A) $5.2 \times 10^{-8} \frac{\text{cm} \cdot \text{sec}^{-1}}{\text{V} \cdot \text{cm}^{-1}}$ (B) $2.4 \times 10^{-8} \frac{\text{cm} \cdot \text{sec}^{-1}}{\text{V} \cdot \text{cm}^{-1}}$
 (C) $1.52 \times 10^{-8} \frac{\text{cm} \cdot \text{sec}^{-1}}{\text{V} \cdot \text{cm}^{-1}}$ (D) $8.25 \times 10^{-8} \frac{\text{cm} \cdot \text{sec}^{-1}}{\text{V} \cdot \text{cm}^{-1}}$
160. If $\Lambda_{\text{ClCH}_2\text{COONa}}^0 = 224 \text{ S cm}^2 \text{ mol}^{-1}$, $\Lambda_{\text{NaCl}}^0 = 38.2 \text{ S cm}^2 \text{ mol}^{-1}$ and $\Lambda_{\text{HCl}}^0 = 203 \text{ S cm}^2 \text{ mol}^{-1}$ then what will be the value of $\Lambda_{\text{ClCH}_2\text{COOH}}^0$?
 (A) $288.5 \text{ S cm}^2 \text{ g eq}^{-1}$ (B) $289.5 \text{ S cm}^2 \text{ g eq}^{-1}$
 (C) $388.8 \text{ S cm}^2 \text{ g eq}^{-1}$ (D) $59.5 \text{ S cm}^2 \text{ g eq}^{-1}$
161. The ionization constant of a weak electrolyte is 2.5×10^{-5} at 298 K and molar conductivity of its 0.01 M solution is $19.6 \text{ S cm}^2 \text{ mol}^{-1}$. What will be its approximate molar conductivity at infinite dilution ?
 (A) $250 \text{ S cm}^2 \text{ mol}^{-1}$ (B) $196 \text{ S cm}^2 \text{ mol}^{-1}$
 (C) $402 \text{ S cm}^2 \text{ mol}^{-1}$ (D) $384 \text{ S cm}^2 \text{ mol}^{-1}$
162. Specific conductivity of 0.001028 M acetic acid at 300 K is $4.95 \times 10^{-5} \text{ S cm}^2 \text{ mol}^{-1}$ and its limiting molar conductivity is $390 \text{ S cm}^2 \text{ mol}^{-1}$, then what will be its dissociation constant ?
 (A) $1.75 \times 10^{-6} \text{ M}$ (B) $1.78 \times 10^{-5} \text{ M}$ (C) $3.5 \times 10^{-4} \text{ M}$ (D) $3.5 \times 10^{-6} \text{ M}$
163. The equivalent conductivity at infinite dilution of aq HCl at 298 K is $425 \frac{\text{S cm}^2}{\text{Eq}}$ and its specific conductivity is $3.825 \frac{\text{S}}{\text{cm}}$. If HCl is 90% dissociated, then what will be the normality of HCl ?
 (A) 10.0 N (B) 1.0 N (C) 1.2 N (D) 0.9 N
164. What is the change in specific conductivity and molar conductivity respectively of aq. solution of electrolyte when diluted by water ?
 (A) Both increase (B) Both decrease
 (C) decreases and increases. (D) increases and decreases.
165. The molar conductivity of aq. solution of electrolyte at definite temperature increases by increasing its volume adding water. Because,
 (A) number of ions decrease. (B) degree of dissociation of electrolyte decrease.
 (C) distance between the ions increase. (D) number of ions conducting current increases.
166. If molar conductivity of a given solution is $1.26 \times 10^{-4} \text{ S cm}^2 \text{ mol}^{-1}$ and molarity is 0.01 M then what will be its specific conductivity ?
 (A) $1.26 \times 10^{-25} \text{ S cm}^2 \text{ mol}^{-1}$ (B) $1.26 \times 10^{-5} \text{ S cm}^2 \text{ mol}^{-1}$
 (C) $1.26 \times 10^{-4} \text{ S cm}^2 \text{ mol}^{-1}$ (D) $0.00063 \text{ S cm}^2 \text{ mol}^{-1}$

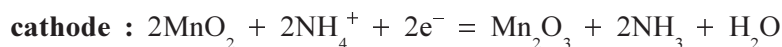
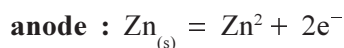
167. If 0.1 M KCl solution is added into aqueous solution of 0.1 M NaCl, then molar conductivity of solution
- (A) remains constant. (B) increases.
(C) decreases. (D) increases initially and then decreases.
168. If molar conductivity of aq. solution of sulphuric acid at definite temperature is $150 \frac{\text{Scm}^2}{\text{mol}}$ then what will be its equivalent conductivity ?
- (A) $75 \frac{\text{Scm}^2}{\text{Eq}}$ (B) $150 \frac{\text{Scm}^2}{\text{Eq}}$ (C) $300 \frac{\text{Scm}^2}{\text{Eq}}$ (D) none of the given
169. Equivalent conductivity of NaCl at concentration 'C' and infinite dilution are λ_c and λ_∞ respectively. Which of the following relation for λ_c and λ_∞ is true ? (where constant B is positive)
- (A) $\lambda_c = \lambda_\infty + (B)\sqrt{C}$ (B) $\lambda_c = \lambda_\infty + (B)C$ (C) $\lambda_c = \lambda_\infty + (B)C$ (D) $\lambda_c = \lambda_\infty - (B)\sqrt{C}$
170. The resistance of a 0.2 M electrolytic solution is 50Ω . The specific conductivity of solution is 1.4 Sm^{-1} . The resistance of the 0.5 M solution of same electrolyte is 280Ω . Then what will be the molar conductivity of 0.5 M solution of that electrolyte ?
- (A) 5×10^2 (B) 5×10^{-4} (C) 5×10^{-3} (D) 5×10^3
171. If molar conductivities of AgNO_3 , AgCl and NaCl at infinite dilution are 116.5, 121.6 and 110.3 $\frac{\text{Scm}^2}{\text{mol}}$ then what will be the molar conductivity of NaNO_3 at infinite dilution ?
- (A) $105.2 \frac{\text{Scm}^2}{\text{mol}}$ (B) $130.6 \frac{\text{Scm}^2}{\text{mol}}$ (C) $111.4 \frac{\text{Scm}^2}{\text{mol}}$ (D) $150.2 \frac{\text{Scm}^2}{\text{mol}}$
172. The molar conductivity of 0.1 N CH_3COOH at 398 K is $80 \frac{\text{Scm}^2}{\text{mol}}$. What is its molar conductivity at infinite dilution is $400 \frac{\text{Scm}^2}{\text{mol}}$. Then what will be the degree of dissociation of solution of CH_3COOH ?
- (A) 0.1 (B) 0.5 (C) 0.2 (D) 0.4

Answers : 132. (C) 133. (B) 134. (A) 135. (B) 136. (B) 137. (B), 138. (C), 139. (D), 140. (D), 141. (C), 142. (A), 143. (B), 144. (C), 145. (D), 146. (A), 147. (A), 148. (C), 149. (C), 150. (C), 151. (A), 152. (B), 153. (B), 154. (B), 155. (A), 156. (D), 157. (C), 158. (D), 159. (A), 160. (C), 161. (C), 162. (D), 163. (A), 164. (C), 165. (D), 166. (B), 167. (B), 168. (C), 169. (D), 170. (B), 171. (A), 172. (C)

Primary cells : Those cells which become dead after a long use and cannot be recharged are called primary cells. Eg. dry cell.

Secondary cells : Those cells which become dead after a long use but can be recharged are called secondary cells. eg. Lead storage cell, Ni-Cd storage cell.

• Dry cell (Lenclanche cell)



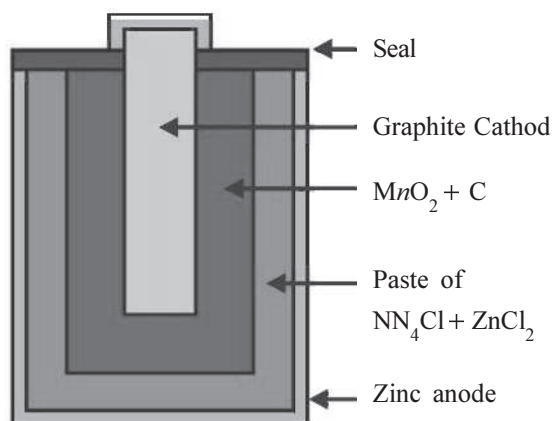
The manganese containing product obtained at cathode depends on the continuous use of cell and duration between two successive use of the cell.

Mn(III) cannot be oxidized into Mn(IV) by reversing the direction of current and hence this cell cannot be recharged once it becomes dead.

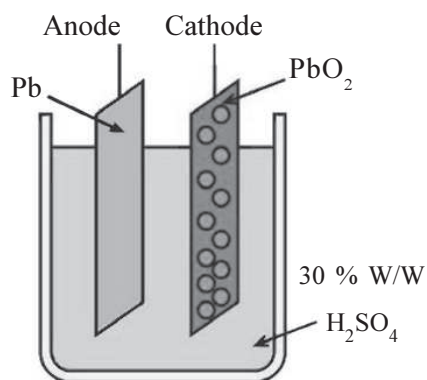
Dry cell is not dry in reality because it consists of moist paste of NH_4Cl and ZnCl_2 . If it is completely dry then it cannot conduct electric current.

The potential of this is 1.5 V.

Uses : It is used in torch, transistor, radio and other small and large instruments.

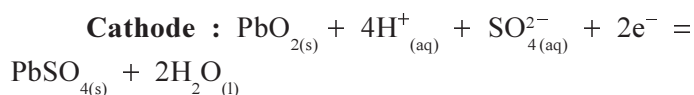
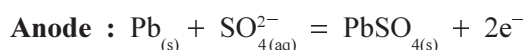


• Lead storage cell



When both the electrodes are connected with conducting wire, electric current is produced by following reactions.

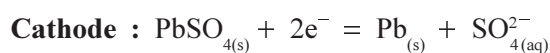
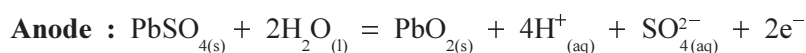
(Discharging reactions)



The potential of this cell is 2.0 V.

When this cell is working H_2SO_4 is consumed and water is produced therefore density of H_2SO_4 decreases. Initial density is $1.25 - 1.30 \text{ g mL}^{-1}$ and when the cell stops working it becomes $1.10 - 1.15 \text{ g mL}^{-1}$.

The charging reactions occurring at electrodes are as follows :

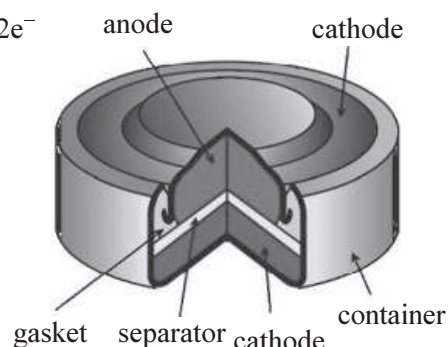


• Mercury Cell

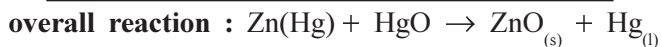
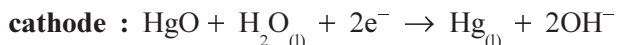
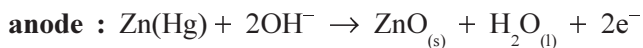
anode : Zinc-mercury (Zn-Hg) layer

cathode : Mercury oxide (HgO) and carbon

Electrolytes : KOH and ZnO paste



● Electrode reactions



cell potential : 1.35 V

No ions are produced during overall reaction in this cell.

● Nickel-Cadmium (Ni-Cd) storage cell

The life of this cell is more than that of lead storage cell but its production cost is high.



The potential of cell is 1.2 V.

● Hydrogen fuel cell

Hydrogen fuel cell : Hydrogen gas is used as fuel in this cell.

Construction : In a container between two membranes of porous carbon containing catalyst concentrated aq. NaOH solution is filled.

These membranes work as electrodes.

Platinum is used as catalyst in anode and mixed powder of platinum and silver oxide is used as catalyst in cathode.



The potential of cell is 1.23 V.

Theoretically current efficiency of this cell is expected to be 100% but in reality it is 70-75%.

$$\text{Efficiency of fuel cell} = \frac{\Delta G}{\Delta H} \times 100 \%$$

Advantages of fuel cell : Compared to other cells, fuel cell has many advantages.

It does not create air pollution.

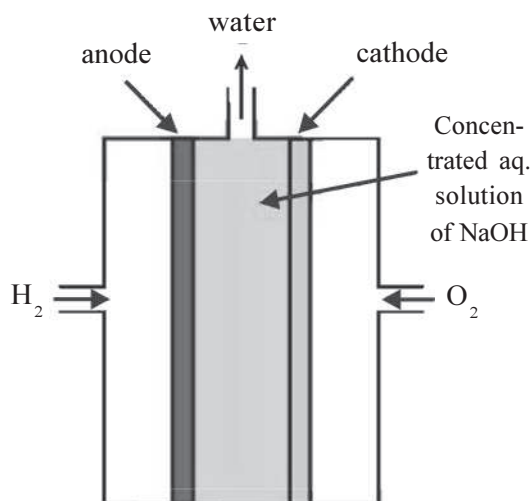
It does not create noise pollution.

Its current producing efficiency is very high compared to that of thermal power stations.

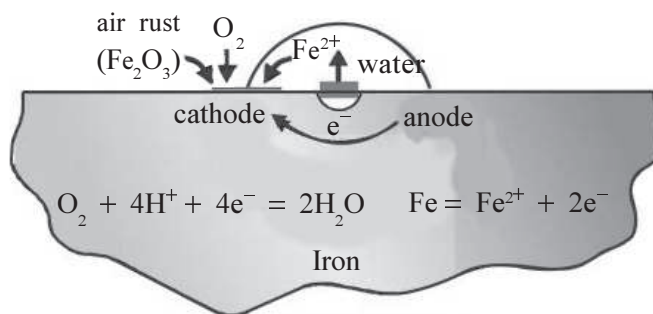
American scientists used this type of cell in Apollo space programme. In addition, the vapour of water produced during reaction was cooled and was used for drinking purpose.

Limitation : It works at very high temperature.

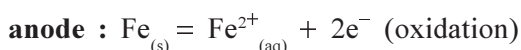
Corrosion : A salt is produced on the surface of metal by a redox reaction between metal and oxygen present in air on the surface of metal. This reaction is called corrosion.



The actual reactions of corrosion are complex. The rusting of iron can be explained as follows :

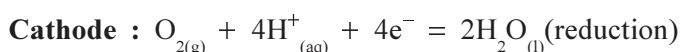


The iron atoms present at the bent surface of metal undergo oxidation.



The water required for this reaction is available from moist air.

The oxygen present in air undergo reduction in presence of H^+ . This point acts as cathode.



The H^+ ions required for the reduction are obtained by decomposition of H_2CO_3 formed on surface of metal by dissolution of CO_2 in moisture.

The $\text{Fe}_{(\text{aq})}^{2+}$ produced by oxidation are further oxidized into Fe^{3+} by oxygen of air and diffuse towards cathode and eventually rust $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ is formed.

If H^+ are not available as cathode then oxygen gas dissolved in moisture is reduced

$$\text{O}_{2(\text{aq})} + 2\text{H}_{2\text{O}(\text{l})} + 4\text{e}^- = 4\text{OH}_{(\text{aq})}^-$$

● Methods of preventing corrosion

One of the methods to prevent iron from rusting is that moisture should not be allowed to come in contact with it, so that oxidation reaction does not occur.

The most easiest method for this is applying paint on the surface of iron. But it does not last for long time and as the paint is removed rusting starts.

Iron does not rust if a thin layer of Zn is applied on it. Such iron coated with layer of Zn is called galvanised iron and this process is called galvanizing.

If a little layer of Zn is peeled off even then iron does not get rusted. Because $E_{\text{Zn/Zn}^{2+}}^0$ is greater than $E_{\text{Fe/Fe}^{2+}}^0$.

If a layer of tin (Sn) is applied on iron and a little layer of tin is peeled off rusting of iron takes place. Because $E_{\text{Fe/Fe}^{2+}}^0$ is greater than $E_{\text{Sn/Sn}^{2+}}^0$.

In another method of preventing rusting of iron, it is connected with metals like Mg or Zn having high E_{ox}^0 and metal is buried under the earth.

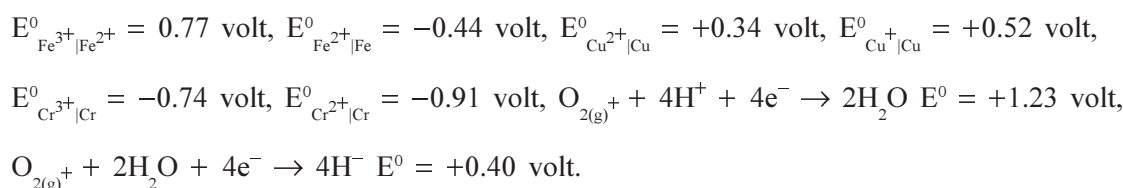
In order to prevent corrosion of the iron plates of steamer they are connected with large blocks of Mg or Zn and kept in contact with water. By doing so, iron plates act as cathode and Mg or Zn blocks act as anode. Thus blocks get corroded and hence to be replaced periodically. Therefore Mg and Zn blocks are called sacrificial anodes.

In addition to this, some chemicals called inhibitors are used. By using them they combine with metal surface by chemical bonds and prevents corrosion.

173. Which of the following cell cannot be recharged once it is dead ?
 (A) Lead storage cell (B) Ni-Cd storage cell (C) Leclanche cell (D) All three given
174. Which is the charging reaction occurring at anode in Lead storage cell ?
 (A) $\text{PbSO}_{4(s)} + 2\text{H}_2\text{O}_{(l)} \rightarrow \text{PbO}_{2(s)} + \text{SO}_4^{2-}_{(aq)} + 4\text{H}^+_{(aq)} + 2\text{e}^-$
 (B) $\text{PbSO}_{4(s)} \rightarrow \text{Pb}_{(s)} + \text{SO}_4^{2-}_{(aq)} + 2\text{e}^-$
 (C) $\text{Pb}_{(s)} + \text{SO}_4^{2-}_{(aq)} \rightarrow \text{PbSO}_{4(s)} + 2\text{e}^-$
 (D) $\text{PbSO}_{4(s)} + 2\text{H}_2\text{O}_{(l)} \rightarrow \text{Pb}_{2(s)} + \text{SO}_4^{2-}_{(aq)} + 4\text{H}^+_{(aq)} + 2\text{e}^-$
175. The reaction occurring in hydrogen fuel cell is $4\text{H}_{2(g)} + 2\text{O}_{2(g)} \rightarrow 4\text{H}_2\text{O}_{(l)}$. Give the value of ΔH_{rea} .
 (A) 571.7 KJ (B) 1503.4 KJ (C) 157.5 KJ (D) 1143.4 KJ
176. Which catalysts are used in fuel cell at anode and cathode respectively ?
 (A) Ag_2O and Pt (B) Pt and Pt + Ag_2O mixed powder
 (C) Pt and Ag_2O mixed powder (D) graphite and Pt
177. From the options given below which cell has different principle ?
 (A) Daniel cell (B) Lead storage cell (C) Leclanche cell (D) Electrolytic cell
178. From the research of which scientist on urea a separate branch of organic chemistry was evolved ?
 (A) Wohler (B) Faraday (C) Nernst (D) Raoult
179. What is the change in E^0_{cell} on multiplying the electrode reactions occurring in electrochemical cell by n ?
 (A) no change. (B) becomes n times. (C) becomes 1/n times. (D) becomes 2n times.
180. In Group-1 cells and in Group-2 potentials are given. Choose the correct option for that :
- | Group-1 | Group-2 | |
|------------------------|-----------------------|--|
| (i) Leclanche cell | (A) 1.23 V (E) 1.32 V | (A) (i)-(C), (ii)-(D), (iii)-(F), (iv)-(A) |
| (ii) Lead storage cell | (B) 2.35 V (F) 1.35 V | (B) (i)-(H), (ii)-(D), (iii)-(B), (iv)-(G) |
| (iii) Mercury cell | (C) 1.53 V (G) 1.75 V | (C) (i)-(E), (ii)-(D), (iii)-(F), (iv)-(A) |
| (iv) Fuel cell | (D) 2.0 V (H) 1.5 V | (D) (i)-(H), (ii)-(D), (iii)-(F), (iv)-(A) |
181. What is present as electrolyte in mercury cell ?
 (A) Paste of NH_4Cl and ZnCl_2 (B) Paste of KOH and HgO
 (C) Paste of KOH and ZnO (D) HgO and graphite
182. The dissociation constant of a weak acid is 1.77×10^{-5} . Its Λ^0_m is $390.5 \text{ S cm}^2 \text{ mol}^{-1}$, then what will be the molar conductivity of its 0.01 M aqueous solution ?
 (A) $4.53 \text{ S cm}^2 \text{ mol}^{-1}$ (B) $16.78 \text{ S cm}^2 \text{ mol}^{-1}$ (C) $45.3 \text{ S cm}^2 \text{ mol}^{-1}$ (D) $164.3 \text{ S cm}^2 \text{ mol}^{-1}$

183. What is the efficiency of hydrogen fuel cell ?
 (A) 35 % (B) 100 % (C) 70 to 75 % (D) 50 to 60 %
184. The blocks of which metals are used as sacrificial anodes to prevent rusting of iron plates of steamer ?
 (A) Sn and Mg (B) Zn and Co (C) Ni and Cu (D) Zn and Mg
185. Which of the given metal is beneficial for electroplating of iron in order to prevent it from rusting ?
 (A) Sn (B) Ni (C) Cu (D) Zn
186. The E_{ox} of $\text{Cr} | \text{Cr}^{3+}$ and $\text{Zn} | \text{Zn}^{2+}$ are 0.74 V and 0.76 V respectively. Which statements are true for reaction given below ?

$$2\text{Cr}_{(\text{aq}, 0.001\text{M})}^{3+} + 3\text{Zn}_{(\text{s})} \rightleftharpoons 2\text{Cr}_{(\text{s})} + 3\text{Zn}_{(\text{aq}, 0.1\text{M})}^{2+} \quad T = 298 \text{ K}$$
 (1) The rate of forward reaction is more than that of reverse reaction.
 (2) Forward reaction takes place but reverse reaction does not take place.
 (3) Both forward and reverse reactions take place.
 (4) The rate of reverse reaction is more than that of forward reaction.
 (5) Both forward and reverse reaction occurs at same rate.
 (A) (1), (3) (B) (2) (C) (5) (D) (3), (4)
187. Standard reduction potentials at 25°C are given as follows :



For the redox couples given in column-I, potentials are given in column-II, if column-I is correctly matched with column-II, then which option is true ?

Column-I	Column-II	P	Q	R	S
(P) $E_{\text{Fe}^{3+} \text{Fe}}^0$	(1) -0.18 volt	(A) 4	1	2	3
(Q) $4\text{H}_2\text{O} \rightarrow 4\text{H}^+ + 4\text{OH}^-$	(2) -0.40 volt	(B) 2	3	4	1
(R) $\text{Cu}^{2+} + \text{Cu} \rightarrow 2\text{Cu}^+$	(3) -0.04 volt	(C) 1	2	3	4
(S) $E_{\text{Cr}^{3+} \text{Cr}^{2+}}^0$	(4) -0.83 volt	(D) 3	4	1	2

188. Choose correct option for given statements. (T = True statement, F = false statement)
- Due to conduction of current the temperature of metal increases and the composition of aqueous solution of electrolyte does not change.
 - Due to conduction of current metal undergo chemical reaction and the composition of aqueous solution of electrolyte changes.
 - Due to conduction of current there is no change in composition of metal and aqueous solution of electrolyte.
 - Due to conduction of current the temperature of metal increase and the composition of aqueous solution of electrolyte changes.
- (A) FFFT (B) TFFT (C) TTFF (D) FFTF

189. Choose the correct option for given statements. (T = True statement, F = False statement)

- (i) The concentration of $\text{Na}^+_{(\text{aq})}$ increase on electrolysing conc. aq. NaCl using inert electrodes.
- (ii) The concentration of NaCl increase in the solution obtained on electrolysing dil. aq. NaCl using inert electrodes.
- (iii) The concentration of $\text{Cl}^-_{(\text{aq})}$ decrease on electrolysing con. aq. NaCl using inert electrodes.
- (iv) The concentration of $\text{OH}^-_{(\text{aq})}$ increase on electrolysing dil aq. NaCl using inert electrodes.

(A) TFTF (B) FTTT (C) FTFT (D) TTTT

190. Choose the correct option for given statements (T = True statement, F = False statement)

- (i) The blue colour fades on electrolysing aq. CuSO_4 using inert electrodes
- (ii) The pH of solution increase on electrolysing aq. CuSO_4 using inert electrodes.
- (iii) The mass of anode decrease on electrolysing aq. CuSO_4 using active electrodes of copper.
- (iv) Precious metals are separated from cathode on electrolysing aq. CuSO_4 using active electrodes of copper.

(A) FTFT (B) TFFF (C) TFFT (D) TFTF

191. Choose the correct option for given statements (T = True statement, F = False statement)

- (i) The pH of solution increase on electrolysing dilute aq NaCl using inert electrodes.
- (ii) The Cl_2 gas is produced at anode on electrolysing con. aq. NaCl using inert electrodes
- (iii) The H_2 gas is produced at cathode on electrolysing dil aq NaCl using inert electrodes.
- (iv) The solution obtained on electrolysing con. aq. NaCl using inert electrodes turns pink on adding phenolphthalein

(A) TFFT (B) FTTT (C) FFFT (D) TFTF

192. Choose the correct option for given statements (T = True statement, F = False statement)

- (i) The pH of solution increase on electrolysing dilute aq NaCl using ineert electrodes.
- (ii) The solution obtained on electrolysing dilute aq NaCl using inert electrodes turns orange on adding methyl orange
- (iii) The pOH of solution increase an electrolysing concentrated aq. NaCl using inert electrodes.
- (iv) The solution obtained on electrolysing concentrated aq. NaCl using inert electodes turns moist litmus paper blue

(A) TFTF (B) FTTT (C) FTFT (D) FFFT

193. In column-I the substance electrolysed and in column-II and column-III the products obtained at anode and cathode respectively are given, then match them properly :

Column-1	Column-2	Column-3
(1) NaCl (molten)	(A) $O_{2(g)}$	(P) Al metal
(2) NaCl (Conc..aq.)	(B) $O_{2(g)}$, $CO_{2(g)}$	(Q) Cl_2
(3) NaCl (dil. aq.)	(C) $Cl_{2(g)}$	(R) Na metal
(4) Al_2O_3 (Na_3AlF_6)	(D) $F_{2(g)}$	(S) $H_{2(g)}$ and NaOH in solution
(5) KHF_2 anhyd HF	(E) $H_{2(g)}$	(T) $H_{2(g)}$

(A) (1)-(C)-(R), (2)-(C)-(T), (3)-(A)-(T), (4)-(B)-(P), (5)-(D)-(T)

(B) (1)-(C)-(R), (2)-(C)-(S), (3)-(A)-(T), (4)-(B)-(P), (5)-(D)-(T)

(C) (1)-(C)-(R), (2)-(C)-(S), (3)-(A)-(Q), (4)-(B)-(P), (5)-(D)-(T)

(D) (1)-(C)-(R), (2)-(C)-(S), (3)-(C)-(T), (4)-(B)-(P), (5)-(D)-(T)

194. The cell potential at 298 K temperature for $Pt | H_{2(g, 1.0 \text{ bar})} | OH^-_{(aq, 0.02M)} || H^+_{(aq)} | H_{2(g, 1.0 \text{ bar})} | Pt$ is 0.61V, then what will be the pH of solution of half-cell at R.H.S. ? The ionic product of water (K_w) at 298K is 1.02×10^{-14} .

(A) 1.95

(B) 12.05

(C) 3.15

(D) 2.5

195. Choose the correct option for given statements with reference to electrochemical cell :



Assertion(A) : E_{cell} increase on increasing concentration of $Zn^{2+}_{(aq)}$

Reason (R) : E_{ox} of anode increase on increasing concentration of $Zn^{2+}_{(aq)}$.

(A) Assertion (A) and reason (R) both are correct and (R) is reason of (A).

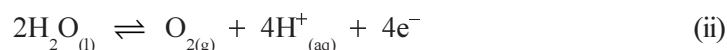
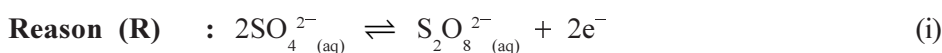
(B) Assertion (A) and reason (R) both are correct but (R) is not the reason of (A).

(C) Both assertion (A) and reason (R) are wrong.

(D) Assertion (A) is wrong and reason (R) is correct.

196. Two statements are given in every question given below. One is assertion (A) and another is reason (R). Study the statements carefully and choose proper option as per given instruction.

Assertion (A) : The oxygen gas is liberated at anode on electrolysis aq. Na_2SO_4 using Pt electrodes.



The standard potential of (ii) is more than that of (i)

(A) Assertion (A) and reason (R) both are correct and R is the reason of (A)

(B) Assertion (A) and reason (R) both are correct but (R) is not the reason of (A).

(C) Both assertion (A) and reason (R) are wrong.

(D) Assertion (A) is wrong and reason (R) is correct.

197. Choose correct option for given statements.

Assertion (A) : The molar conductivity of aq. solution of electrolyte increase when diluted by adding water.

Reason (R) : The dissociation of electrolyte decrease on adding water to aq. solution of electrolyte.

(A) Assertion (A) and reason (R) both are correct and R is the reason of (A)

(B) Assertion (A) and reason (R) both are correct but (R) is not the reason of (A).

(C) Both assertion (A) and reason (R) are wrong.

(D) Assertion (A) is wrong and reason (R) is correct.

198. The cell reaction occurring in a cell : $\text{Cd} \mid \text{CdCl}_{2(0.1 \text{ M})} \parallel \text{AgCl}_{(s)} \mid \text{Ag}$ is $\text{Cd}_{(s)} + 2\text{AgCl}_{(s)} \rightarrow 2\text{Ag}_{(s)} + \text{Cd}^{2+}_{(\text{aq})} + 2\text{Cl}^{-}_{(\text{aq})}$. The voltage of this cell at 273 K and 298 K is 0.6915 V and 0.6753 V respectively, then what will be the change in enthalpy of this reaction at 298 K ?

(A) -167.6 KJ

(B) -176 J

(C) -234 KJ

(D) 123.5 KJ

199. For the cell representations given in column-I there may be one or more than one true statements in column-II. Join the cell representations with 4×5 matrix given for column II properly.

Column-I	Column-II
(A) $\text{Mg}_{(s)} \mid \text{Mg}^{2+}_{(\text{aq}, 0.02\text{M})} \parallel \text{Cl}^{-}_{(\text{aq}, 0.05\text{M})} \mid \text{Cl}_{2(\text{g}, 1 \text{ bar})} \mid \text{Pt}$	(P) E_{cell} increase if conc. of half cell at RHS is increased keeping conc of half cell at LHS constant
(B) $\text{Pt} \mid \text{Br}_{2(l)} \mid \text{Br}^{-}_{(\text{aq}, 0.02\text{M})} \parallel \text{Au}^{3+}_{(\text{aq}, 0.05\text{M})} \mid \text{Au}$	(Q) E_{cell} increases if conc of half cell at LHS is increased keeping conc of half cell at RHS constant.
(C) $\text{Ni}_{(s)} \mid \text{Ni}^{2+}_{(\text{aq}, 0.02\text{M})} \parallel \text{Cu}^{2+}_{(\text{aq}, 0.05\text{M})} \mid \text{Cu}_{(s)}$	(R) E_{cell} increase if conc of half cells of LHS and RHS are increased by same xM.
(D) $\text{Pt} \mid \text{Br}_{2(l)} \mid \text{Br}^{-}_{(\text{aq}, 0.02\text{M})} \parallel \text{Cl}^{-}_{(\text{aq}, 0.05\text{M})} \mid \text{Cl}_{2(\text{g}, 1 \text{ bar})} \mid \text{Pt}$	(S) E_{cell} increase if conc of half cells at LHS and RHS are decreased by same xM
	(T) $Q_c > 1$

(A) (P) (Q) (R) (S) (T)

(B) (P) (Q) (R) (S) (T)

(C) (P) (Q) (R) (S) (T)

(D) (P) (Q) (R) (S) (T)

(A) (P) (Q) (R) (S) (T)

(B) (P) (Q) (R) (S) (T)

(C) (P) (Q) (R) (S) (T)

(D) (P) (Q) (R) (S) (T)

- 200.** For the electrolyses given in Column-I there may be one or more true statements in column-II. Connect the electrolyses of Column-I properly with 4×5 matrix given for column-II.

Column-I	Column-II
(A) On electrolysis of dilute aq. NaCl using inert electrodes.	(P) O_2 gas is obtained at anode
(B) On electrolysis of concentrated aq. NaCl using inert electrodes.	(Q) H_2 gas is obtained at cathode.
(C) On electrolysis of aq. $CuSO_4$ using inert electrodes.	(R) pH of solution decreases.
(D) On electrolysis of aq. Na_2SO_4 using inert electrodes.	(S) pH of solution increases.
	(T) No. of spectator ions increases.

- (A) ☐ P ☐ Q ☐ R ☐ S ☐ T
- (B) ☐ P ☐ Q ☐ R ☐ S ☐ T
- (C) ☐ P ☐ Q ☐ R ☐ S ☐ T
- (D) ☐ P ☐ Q ☐ R ☐ S ☐ T

- (A) ☒ P ☒ Q ☐ R ☐ S ☐ T
- (B) ☐ P ☒ Q ☐ R ☒ S ☒ T
- (C) ☒ P ☐ Q ☒ R ☐ S ☒ T
- (D) ☒ P ☒ Q ☐ R ☐ S ☒ T

Answers : 173. (C) 174. (A) 175. (D) 176. (B) 177. (D) 178. (A), 179. (A), 180. (D), 181. (C), 182. (B), 183. (C), 184. (D), 185. (D), 186. (D), 187. (D), 188. (A), 189. (D), 190. (D), 191. (B), 192. (C), 193. (B), 194. (A), 195. (D), 196. (A), 197. (C), 198. (A).

