Solutions

(2025)

Q.1 In case of association, abnormal molar mass of solute will

(1 Mark) (CBSE 2025 - 56/1/1)

A. remain same

B. increase

C. decrease

D. first increase and then decrease

Q.2 An unripe mango placed in a concentrated salt solution to prepare pickle, shrivels because _____ .

(1 Mark) (CBSE 2025 - 56/1/1)

A. it loses water due to osmosis

B. it gains water due to osmosis

C. it gains water due to reverse osmosis

D. it loses water due to reverse osmosis

Q.3 Which of the following solutions will have the highest boiling point in water ?

(1 Mark) (CBSE 2025 - 56/7/1)

A. 1% glucose

B. 1% urea

C. 1% KCl

D. 1% $CaCl_2$

Q.4 Assertion (A) : Cooking time is reduced in pressure cooker.
Reason (R) : Boiling point of water inside the pressure cooker is elevated.

(1 Mark) (CBSE 2025 - 56/7/1)

A. Assertion (A) is false, but Reason (R) is true.

B. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

C. Assertion (A) is true, but Reason (R) is false.

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

Q.5 Which of the following aqueous solutions will have the highest freezing point?

(1 Mark) (CBSE 2025 - 56/5/1)

A. 1.0M$AlCl_3$

B. 1.0MNa2SO_4

C. 1.0MGlucose

D. 1.0MKCl

Q.6 Assertion (A) : Henry's law constant (K_H) decreases with increase in temperature.
Reason (R) : As the temperature increases, solubility of gases in liquids decreases.

(1 Mark) (CBSE 2025 - 56/5/1)

A. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

B. Assertion (A) is true, but Reason (R) is false.

C. Assertion (A) is false, but Reason (R) is true.

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

Q.7 The value of Henry's constant K_H is :

(1 Mark) (CBSE 2025 - 56/4/1)

A. constant for all gases

B. greater for gases with lower solubility

C. greater for gases with higher solubility

D. not related to the solubility of gases

Q.8 The freezing point of one molal KCl solution, assuming KCl to be completely dissociated in water, is : (K_f for water $=1.86$ K kg mol^{-1})

(1 Mark) (CBSE 2025 - 56/6/1)

A. $-3{\cdot}72^{\circ}C$

B. $-1{\cdot}86^{\circ}C$

C. $+2{\cdot}72^{\circ}C$

D. $+3{\cdot}72^{\circ}C$

Q.9 A solution of acetone in ethanol :

(1 Mark) (CBSE 2025 - 56/6/1)

A. obeys Raoult's law.

B. shows a positive deviation from Raoult's law.

C. forms an ideal solution.

D. shows a negative deviation from Raoult's law.

Q.10 Give reasons :
(a) Cooking is faster in pressure cooker than in an open pan.
(b) On mixing liquid X and liquid Y , volume of the resulting solution decreases. What type of deviation from Raoult's law is shown by the resulting solution ? What change in temperature would you observe after mixing liquids X and Y ?

(2 Mark) (CBSE 2025 - 56/1/1)

Q.11 Define Azeotrope. What type of Azeotrope is formed by negative deviation from Raoult's law ? Give an example.

(2 Mark) (CBSE 2025 - 56/1/1)

Q.12 What is meant by positive deviation from Raoult's law ? Give an example. What type of azeotrope is formed by positive deviation ?

(2 Mark) (CBSE 2025 - 56/7/1)

Q.13 Calculate the elevation of boiling point of a solution when 3 g of $CaCl_2$ (Molar mass = 111 g mol^{-1}) was dissolved in 260 g of water, assuming that $CaCl_2$ undergoes complete dissociation. (K_b for water = 0.52 K kg mol^{-1})

Q.14 Liquids ' X ' and ' Y ' form an ideal solution. The vapour pressure of pure 'X' and pure 'Y' are 120 mm Hg and 160 mm Hg respectively. Calculate the vapour pressure of the solution containing equal moles of ' X ' and ' Y '.

(2 Mark) (CBSE 2025 - 56/5/1)

Q.15 State Henry's law. Why are aquatic species more comfortable in cold water as compared to warm water?

(2 Mark) (CBSE 2025 - 56/6/1)

Q.16 A solution of glucose (molar mass =180 g mol^{-1}) in water has a boiling point of 100.20°C. Calculate the freezing point of the same solution. Molal constants for water K_f and K_b are 1.86 K kg mol^{-1} and 0.512 K kg mol^{-1} respectively.

(3 Mark) (CBSE 2025 - 56/1/1)

Q.17 0.3 g of acetic acid (Molar mass = 60 g mol^{-1}) dissolved in 30 g of benzene shows a depression in freezing point equal to 0.45 °C. Calculate the percentage association of acid if it forms a dimer in the solution. (Given : K_f for benzene = 5.12 K kg mol^{-1})

(3 Mark) (CBSE 2025 - 56/7/1)

Q.18 Shweta mixed two liquids A and B of 10 mL each. After mixing, the volume of the solution was found to be 20.2 mL.

(i) Why was there a volume change after mixing the liquids?
(ii) Will there be an increase or decrease of temperature after mixing?
(iii) Give one example for this type of solution.

(3 Mark) (CBSE 2025 - 56/5/1)

Q.19 (i) How does sprinkling of salt help in clearing the snow-covered roads in hilly areas?
(ii) What happens when red blood cells are kept in 0.5% (mass/vol) NaCl solution? Justify your answer.
(iii) Write an application of reverse osmosis.

(3 Mark) (CBSE 2025 - 56/2/1)

Q.20 At 25°C the saturated vapour pressure of water is 24 mm Hg. Find the saturated vapour pressure of a 5% aqueous solution of urea at the same temperature. (Molar mass of urea = 60 g mol^{-1})

Q.21 An aqueous solution of NaOH was made and its molar mass from the measurement of osmotic pressure at 27°C was found to be 25 g mol^{-1}. Calculate the percentage dissociation of NaOH in this solution.

[Atomic mass : Na = 23u, O = 16u, H = 1u]

(3 Mark) (CBSE 2025 - 56/4/1)

Q.22 Vapour pressure of pure water at 298 K is 24.8 mm Hg. Calculate the lowering in vapour pressure of an aqueous solution which freezes at −0.3°C. (K_f of water = 1.86 K kg mol^{-1})

(3 Mark) (CBSE 2025 - 56/6/1)

Q.23 The spontaneous flow of the solvent through a semipermeable membrane from a pure solvent to a solution or from a dilute solution to a concentrated solution is called osmosis. The phenomenon of osmosis can be demonstrated by taking two eggs of the same size. In an egg, the membrane below the shell and around the egg material is semipermeable. The outer hard shell can be removed by putting the egg in dilute hydrochloric acid. After removing the hard shell, one egg is placed in distilled water and the other in a saturated salt solution. After some time, the egg placed in distilled water swells-up while the egg placed in

salt solution shrinks. The external pressure applied to stop the osmosis is termed as osmotic pressure (a colligative property). Reverse osmosis takes place when the applied external pressure becomes larger than the osmotic pressure.

(a) Define reverse osmosis. Name one SPM which can be used in the process of reverse osmosis.

(b) (i) What do you expect to happen when red blood corpuscles (RBC's) are placed in 0.5%NaCl0.5%NaCl solution?

(4 Mark) (CBSE 2025 - 56/2/1)

Q.24 According to the generally accepted definition of the ideal solution there are equal interaction forces acting between molecules belonging to the same or different species. (This is equivalent to the statement that the activity of the components equals the concentration.) Strictly speaking, this condition is fulfilled only in exceptional cases for mixtures (optical isomers, isotopic mixtures of an element, hydrocarbon mixtures). It is still usual to talk about ideal solutions as limiting cases in reality since very dilute solutions behave ideally with respect to the solvent. This view is further supported by the fact that Raoult's law empirically found for describing the behaviour of the solvent in dilute solutions can be deduced thermodynamically via the assumption of ideal behaviour of the solvent.

Answer the following questions :

(a) Give one example of miscible liquid pair which shows negative deviation from Raoult's law. What is the reason for such deviation?

(b) (i) State Raoult's law for a solution containing volatile components.

(4 Mark) (CBSE 2025 - 56/4/1)

Answer

Q.1. B

Q.2. A

Q.3 D

Q.4 B

Q.5 C

Q.6 C

Q.7 B

Q.8 A

Q.9 B

Q.10 (a) Due to high pressure inside the pressure cooker, higher is the boiling point and faster is the cooking.
(b) Negative deviation
Temperature increases.

Q.11 Same composition in liquid and in vapour phase and boil at a constant temperature.
Maximum Boiling Azeotrope

68%HNO_3 + 32%H_2O (Or any other correct example) (Percentage can be ignored)

Q.12 When vapour pressure of the solution is higher than expected from the ideal behaviour.

Example : ethanol and acetone/ carbon disulphide and acetone (or any other suitable example) Minimum boiling azeotrope

Q.13

$$\Delta \mathrm{T_b} = \mathrm{iK_b m}$$
$$\Delta T_\mathrm{b} = \mathrm{i}\frac{K_\mathrm{b} \times 1000 \times w_2}{M_2 \times w_1}$$
$$\mathrm{i} = 3$$
$$\Delta\ \mathrm{T_b} = \frac{3 \times 0.52 \times 3 \times 1000}{111 \times 260}$$
$$= 0.162\ \mathrm{K}$$

Q.14

Given

$$n_X = n_Y$$

$$\chi_x = \chi_y = 0.5$$

$$P_T = p_X{}^0 x_{x+} p_Y{}^0 x_Y / p_{total} = x_1 p_1^0 + x_2 p_2^0$$

$$= 120 \times 0.5 + 160 \times 0.5$$

$$= 60 + 80$$

$$= 140 \text{ mmHg}$$

Q.15 At a constant temperature, the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of liquid or solution/ the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution

Because the solubility of oxygen increases with decrease in temperature/ Because of low solubility of O_2 in warm water.

Q.16

T_b of glucose solution $= 100.20^\circ C$

$$\Delta T_b = T_b - T^\circ{}_b$$

$$= 100.20^\circ - 100^\circ C = 0.20^\circ C \text{ or } 0.20 \text{ K}$$

$$\Delta T_b = K_b \cdot m$$

$$m = \frac{0.20}{0.512} = 0.390 \text{ mol/kg}$$

$$\Delta T_f = K_f \cdot m$$

$$\Delta T_f = 1.86 \text{ K kg/mol} \times 0.390 \text{ mol/kg}$$

$$\Delta T_f = 0.725 \text{ K}$$

Freezing point of solution

$$= 273.15 - 0.725$$

$$= 272.425 \text{ K}$$

Or

$$-0.725^\circ C$$

Q.17

$$\Delta T_f = iK_f m$$

$$\Delta T_f = \frac{i \times K_f \times w_2 \times 1000}{M_2 \times w_1}$$

$$0.45 = \frac{i \times 5.12 \times 0.3 \times 1000}{60 \times 30}$$

$$i = 0.527$$

$$\alpha = \frac{i-1}{1/n-1}$$

$$\alpha = \frac{0.527-1}{1/2-1}$$

(n=2)

$$\alpha = 0.946$$

or

$$94.6\%$$

Q.18 (i) The solution is non ideal, shows positive deviation from Raoult's law / A-B interactions are weaker than A—A and B—B interactions
(ii) Decrease in temperature
(iii) Ethanol and acetone (or any other suitable example)

Q.19 (i) Salt lowers the freezing point of water and prevents formation of ice and hence its easy to clean.
(ii)-Red blood cells swell up
-As the solution is hypotonic, water will flow into the cell/ As the solution is hypotonic, endosmosis occurs.
(iii) Desalination of sea water

Q.20

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{w_2 \times M_1}{M_2 \times w_1}$$

$$\frac{24 - p_1}{24} = \frac{5 \times 18}{60 \times 95}$$

$$\frac{24-p_1}{24}=\frac{3}{190}$$
$$24-p_1=\frac{3\times 24}{190}$$
$$p_1=23.62\ \text{mmHg}\quad /23.64\ \text{mmHg}$$

(Deduct
$\frac{1}{2}$
mark for no or incorrect unit).

Q.21

$$\text{i}=\text{ Normal molar mass}/\text{Abnormal molar mass}$$
$$\text{i}=40/25$$
$$=1.6$$
$$\alpha=\text{i}-1/\text{n}-1$$
$$=\frac{1.6-1}{1}$$
$$=0.6\times 100$$
$$=60\%$$

Q.22

$$\Delta T_\text{f}=K_\text{f}\text{m}$$
$$\text{m}=\Delta\text{T}_\text{f}/\text{K}_\text{f}$$
$$\text{m}=0.3/1.86$$
$$=0.16\ \text{m}$$
$$\text{m}=\frac{x_2\text{X}1000}{M_A}$$
$$\text{x}_2=\frac{0.16\times 18}{1000}=2.88\times 10^{-3}$$
$$\frac{p_1^0-p_1}{p_1^0}=x_2$$
$$\frac{24.8-p_1}{24.8}=2.88\times 10^{-3}$$
$$p_1^0-p_1=x_2p_1^0$$
$$=2.88\times 10^{-3}\times 24.8\ \text{mmHg}$$
$$=0.07\ \text{mmHg}$$

Q.23 (a)

When external pressure is larger than the osmotic pressure, then the movement of solvent is from solution to solvent side through semi permeable membrane. / The direction of osmosis can be reversed if a pressure larger than the osmotic pressure is applied to the solution side.

Cellulose acetate / Or any other suitable example.

(b) (i) RBC swells up / Cells swell and may even burst due to endo-osmosis.

Q.24 (a)Chloroform and Acetone

(or Any other correct example)

A − B interactions are stronger than A − A and B − B interaction.

(b)(i) For any solution the partial vapour pressure of each volatile component is directly proportional to its mole fraction.

(2024)

Q.1 Isotonic solutions have the same

(1 Mark) (CBSE 2024 - 56/5/1)

A. osmotic pressure

B. volume

C. density

D. refractive index

Q.2 Van't Hoff factor for $Na_2SO_4.10H_2O$ solution, assuming complete ionization is

(1 Mark) (CBSE 2024 - 56/5/1)

A. 13

B. 22

C. 33

D. 11

Q.3 For an electrolyte undergoing association in a solvent, the van't Hoff factor :

(1 Mark) (CBSE 2024 - 56/1/1)

A. is always less than one

B. has negative value

C. has zero value

D. is always greater than one

Q.4 Assertion (A) : When NaCl is added to water a depression in freezing point is observed.
Reason (R) : NaCl undergoes dissociation in water.

(1 Mark) (CBSE 2024 - 56/1/1)

A. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

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

C. Assertion (A) is false, but Reason (R) is true.

D. Assertion (A) is true, but Reason (R) is false.

Q.5 A % solution of solute ' X ' is isotonic with a 6%6% solution of sucrose (molar mass = 342 g mol^{-1}). The molar mass of solute ' X ' is :

(1 Mark) (CBSE 2024 - 56/3/1)

A. 57 g mol^{-1}

B. 114 g mol^{-1}

C. 3.42 g mol^{-1}

D. 34.2 g mol^{-1}

Q.6 Assertion (A) : Addition of ethylene glycol to water lowers its freezing point. Reason (R): Ethylene glycol is insoluble in water due to lack of its ability to form hydrogen bonds with water molecules.

(1 Mark) (CBSE 2024 - 56/3/1)

A. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

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

C. Assertion (A) is true, but Reason (R) is false.

D. Assertion (A) is false, but Reason (R) is true.

Q.7 An azeotropic solution of two liquids has boiling point lower than either of them when it:

(1 Mark) (CBSE 2024 - 56/2/1)

A. shows no deviation from Raoult's law

B. shows positive deviation from Raoult's law

C. shows negative deviation from Raoult's law

D. is saturated

Q.8 The relative lowering of vapour pressure of an aqueous solution containing non-volatile solute is 0.0225. The mole fraction of the non-volatile solute is :

(1 Mark) (CBSE 2024 - 56/2/1)

A. 0·0225

B. 0·725

C. 0·15

D. 0·80

Q.9 (a) Define molal depression constant. How is it related to enthalpy of fusion ?

(2 Mark) (CBSE 2024 - 56/3/1)

Q.10 (b) What type of deviation is shown by ethanol and acetone mixture? Give reason. What type of azeotropic mixture is formed by that deviation?

(2 Mark) (CBSE 2024 - 56/4/1)

Q.11 18 g of a non-volatile solute is dissolved in 200 g of H_2O freezes at 272.07 K. Calculate the molecular mass of solute (K_f for water = 1.86 K kg mol^{-1})

(2 Mark) (CBSE 2024 - 56/4/1)

Q.12 A 6% solution of glucose (molar mass = 180 g mol^{-1}) is isotonic with 2.5% solution of an unknown organic substance. Calculate the molecular weight of the unknown organic substance.

(2 Mark) (CBSE 2024 - 56/4/1)

Q.13 A solution is prepared by dissolving 5 g of a non-volatile solute in 200 g of water. It has a vapour pressure of 31.84 mm Hg at 300 K . Calculate the molar mass of the solute.

(Vapour pressure of pure water at 300 K = 32 mmHg)

(3 Mark) (CBSE 2024 - 56/3/1)

Q.14 The vapour pressure of a solvent at 283 K is 100 mm Hg. Calculate the vapour pressure of a dilute solution containing 1 mole of a strong electrolyte AB in 50 moles of the solvent at 283 K (assuming complete dissociation of solute AB).

(3 Mark) (CBSE 2024 - 56/2/1)

Q.15 (a) (i) Ishan's automobile radiator is filled with 1.0 kg of water. How many grams of ethylene glycol (Molar mass = 62 g mol^{-1}) must Ishan add to get the freezing point of the solution lowered to 2.8°C. K_f for water is 1.86 K kg. mol^{-1}.

(ii) What type of deviation from Raoult's law is shown by ethanol and acetone mixture? Give reason.

(5 Mark) (CBSE 2024 - 56/5/1)

Q.16 (b) (i) Boiling point of water at 750 mm Hg pressure is 99.68°C. How much sucrose (Molar mass = 342 g mol^{-1}) is to be added to 500 g of water such that it boils at 100°C?(K_b for water = 0.52 K $kgmol^{-1}$).

(ii) State Henry's law and write its any one application.

(5 Mark) (CBSE 2024 - 56/5/1)

Q.17 (a) (i) At the same temperature, CO_2 gas is more soluble in water than O_2 gas. Which one of them will have higher value of K_H and why ?

(ii) How does the size of blood cells change when placed in an aqueous solution containing more than 0.9% (mass/volume) sodium chloride?

(iii) 1 molal aqueous solution of an electrolyte A_2B_3 is 60% ionized.

Calculate the boiling point of the solution. (Given : K_b for H_2O = 0.52 K kg mol^{-1})

(5 Mark) (CBSE 2024 - 56/1/1)

Q.18 (b) (i) The vapour pressures of A and B at 25°C are 75 mm Hg and 25 mm Hg, respectively. If A and B are mixed such that the mole fraction of A in the mixture is 0.4, then calculate the mole fraction of BB in vapour phase.

(ii) Define colligative property. Which colligative property is preferred for the molar mass determination of macromolecules?

(iii) Why are equimolar solutions of sodium chloride and glucose not isotonic?

(5 Mark) (CBSE 2024 - 56/1/1)

Q.19 (a) (i) Define reverse osmosis.

(ii) Why are aquatic species more comfortable in cold water in comparison to warm water?

(iii) A solution containing 2 g of glucose (M = 180 g mol^{-1}) in 100 g of water is prepared at 303 K. If the vapour pressure of pure water at 303 K is 32.8 mm Hg, what would be the vapour pressure of the solution?

(5 Mark) (CBSE 2024 - 56/4/1)

Q.20 (b) (i) Predict whether Van't Hoff factor will be less or greater than one, when Ethanoic acid is dissolved in benzene.

(ii) Define ideal solution.

(iii) Calculate the mass of $CaCl_2$ (molar mass = 111 g mol^{-1}) to be dissolved in 500 g of water to lower its freezing point by 2 K, assuming that $CaCl_2$ undergoes complete dissociation.

(K_f for water = 1.86 K kg mol^{-1})

(5 Mark) (CBSE 2024 - 56/4/1)

Answer

Q.1. B

Q.2. B

Q.3 D

Q.4 B

Q.5 A

Q.6 C

Q.7 B

Q.8 A

Q.9 (a) Molal depression constant is the depression in freezing point observed in 1 molal solution. The depression in freezing point when one mole of non. volatile solute is dissolved in 1 kg or 1000 g of the solvent.

$$K_f = \frac{R \times M_{solvent} \times T_f^0}{1000 \times \Delta_{fus} H^0}$$

Q.10 (b) Positive deviation. Because ethanol - acetone interaction is weaker than pure ethanol and pure acetone molecular interactions.
Minimum boiling azeotropes

Q.11

$$\Delta T_f = K_f m$$
$$M_B = \frac{K_f \times w_B \times 1000}{w_A \times \Delta T_f}$$
$$\Delta T_f = T_f^o - T_f$$
$$\Delta T_f = 273 \cdot 15 - 272 \cdot 07 = 1 \cdot 08 \text{ K}$$
$$M_B = \frac{1 \cdot 86 \times 18 \times 1000}{200 \times 1 \cdot 08}$$
$$= 155 \text{ g mol}^{-1}$$

Q.12

$$\pi_{\text{Glucose}} = \pi_{\text{Unknown}}$$
$$\text{C}_\text{G} = \text{C}_\text{U}$$
$$\frac{W_G}{M_G} = \frac{W_U}{M_U}$$
$$\frac{6}{180} = \frac{2 \cdot 5}{\text{M}_\text{U}}$$
$$\text{M}_\text{U} = \frac{2 \cdot 5 \times 180}{6} \text{ g mol}^{-1}$$
$$= 75 \text{ g mol}^{-1}$$

Q.13

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{\text{w}_2 \times M_1}{M_2 \times \text{w}_1}$$
$$\frac{(32 - 31 \cdot 84)}{32} = \frac{5 \text{ g}}{\text{M}_2} \times \frac{18}{200 \text{ g}}$$
$$\text{M}_2 = 90 \text{ g/mol}$$
(Deduct half mark for no or incorrect unit)

Q.14

$$\frac{p^\circ - p_s}{P^\circ} = i \times \chi$$

$$AB \longrightarrow A^+ + B^-$$

$$i = 2$$

$$\frac{100 - P_S}{100} = 2 \times \frac{n_{AB}}{n_{\text{solvent}}}$$

(For dilute solution)

$$\frac{100 - \mathrm{P_s}}{100} = 2\frac{1}{50}$$

$$100 - \mathrm{P_s} = 4$$

$$\mathrm{P_S} = 96\ \mathrm{mmHg}$$

Q.15

a) (i)

$$\Delta T_f = 2.8^\circ\mathrm{C}$$

$$\Delta T_f = K_f \times W_B/M_B \times W_A(\ \mathrm{kg})$$

$$2.8 = 1.86 \times W_B/62 \times 1$$

$$W_B = (2.8 \times 62)/1.86$$

$$W_B = 93.33\ \mathrm{g}(\text{ Deduct } 1/2 \text{ mark for incorrect unit or no unit })$$

(ii) Positive deviation

Interaction between ethanol-ethanol is stronger than ethanol-acteone.

Q.16

b) (i) $\Delta \mathrm{T_b} = 100 - 99.68^\circ\mathrm{C} = 0.32^\circ\mathrm{C}$

$$\Delta \mathrm{T_b} = \mathrm{K_b} \times \mathrm{W_B}/\mathrm{M_B} \times \mathrm{W_A}(\mathrm{kg})$$

$$0.32 = 0.52 \times \mathrm{w_B} \times 1000/342 \times 500$$

$\mathrm{w_B} = 0.32 \times 342/0.52 \times 2 = 105.23\ \mathrm{g}$ (Deduct $1/2$ mark for incorrect unit or no unit.)

(ii) At a constant temperature, the solubility of a gas in a liquid is directlyproportional to the partial pressure of the gas present above the surface of liquid or solution. / The partial pressure of the gas in vapour phase $(\boldsymbol{p})$ is proportional to the mole fraction of the gas $(\boldsymbol{x})$ in the solution.

Application: To increase the solubility of $\mathrm{CO_2}$ in soft drinks and soda water, thebottle is sealed under high pressure. (or any other)

Q.17

(a)(i)As $\mathrm{K_H} \propto \frac{1}{\text{Solubility}}$ of Gas

$\therefore$ O_2 gas has higher $\mathrm{K_H}$; because higher the $\mathrm{K_H}$ value, lower the solubility of gas in liquid.

(ii) Blood cells shrink.

(iii) $\Delta T_b = iK_bm$

$\mathrm{T_b - T_b{}^0 = i \times 0.52\ KKgmol^{-1} \times 1\ molKg^{-1}}$

$\alpha = \frac{i-1}{\mathrm{n}-1}$

$\mathrm{n = 5}$

$0 \cdot 6 = \frac{i-1}{5-1}$

$\mathrm{i = 3.4}$

$\mathrm{T_b - 373\ K = 3.4 \times 0.52 \times 1}$

$\mathrm{T_b = 1.768 + 373\ K}$

$\mathrm{T_b = 374.768\ K}$ (If boiling point of water is 373.15 K then $\mathrm{T_b = 374.918\ K}$)

Q.18

(b)

(i)

$$\mathrm{P_T = p_A{}^0 x_A + p_B{}^0 x_B}$$

$\mathrm{P_T = 75 \times 0.4 + 25 \times 0.6}$

$\mathrm{P_T = 30 + 15 = 45\ mmHg}$

In Vapour phase

$\mathrm{p_B = y_{B}{}_x P_T}$

$y_B = p_B/P_T = \frac{p_B^o x_B}{P_T}$

$\mathrm{y_B = \frac{15}{45} = \frac{1}{3} = 0.33\ mmHg}$

(ii) The property which depends upon the number of solute particles but not on the nature of solute. ; Osmotic pressure.

(iii)Because sodium chloride undergoes dissociation ($i = 2$) in water while glucose does not./ $\pi = i$ C R T ; For NaCl , i=2 and for glucose $i = 1$

Q.19 (a) (i) If a pressure larger than the osmotic pressure is applied to the solution side, resulting in the movement of solvent particles from solution to solvent.

(ii) Solubility of gases in water decreases with rise in temperature. More oxygen will be available in the cold water.

(iii)

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{n_2}{n_1}$$

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{\mathrm{w}_2 \times M_1}{M_2 \times \mathrm{w}_1}$$

$$\frac{32.8 - p_1}{32.8} = \frac{2 \times 18}{180 \times 100}$$

$$32.8 - p_1 = 0.0656$$

$$p_1 = 32.734\ \mathrm{mmHg}$$

(Deduct $1/2$ mark for no unit or incorrect unit)

Q.20 (a) (i) i will be less than 1.

(ii) Solution which obeys Raoult's law over the entire range of concentration.

(iii) i = 3

$$\Delta T_f = i \times K_f \times m$$

$$\Delta T_f = \frac{i \times K_f \times w_B \times 1000}{M_B \times w_A}$$

$$2K = \frac{3 \times 1.86 \times w_B \times 1000}{111 \times 500}$$

$$\mathrm{w_B} = \frac{2 \times 111 \times 500}{3 \times 1.86 \times 1000}$$

$$= 19.89 \text{ g}$$

(Deduct $\frac{1}{2}$ mark for no unit or incorrect unit)

Previous Years' CBSE Board Questions

1.2 Expressing Concentration of Solutions

Mass Percentage, Mole Fraction, Molarity, Molality

MCQ

1. **Assertion (A) :** Molality of a solution in liquid state changes with temperature.
Reason (R) : The volume of solution changes with the change in temperature.
(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of Assertion (A).
(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of Assertion (A).
(c) Assertion (A) is correct, but Reason (R) is incorrect statement.
(d) Assertion (A) is incorrect, but Reason (R) is correct statement. *(2020 C)*

2. 50 mL of an aqueous solution of glucose $C_6H_{12}O_6$ (Molar mass : 180 g/mol) contains 6.02×10^{22} molecules. The concentration of the solution will be
(a) 0.1 M (b) 0.2 M
(c) 1.0 M (d) 2.0 M *(2020)*

VSA (1 mark)

3. Define the following term : Molality (*m*)
(NCERT, 1/2, Delhi 2017, 1/5 AI 2014 C) R

4. Define the following term : Molarity (*M*)
(NCERT, 1/2, Delhi 2017, 1/5 AI 2014) R

5. Define the following term :
Mole fraction *(NCERT, 1/5 AI 2014 C)* R

SA I (2 marks)

6. Calculate the molarity of 9.8% (*w/W*) solution of H_2SO_4 if the density of the solution is 1.02 g mL^{-1}. (Molar mass of H_2SO_4 = 98 g mol^{-1})
(2/5, Foreign 2014) Ev

7. Differentiate between molarity and molality of a solution. How can we change molality value of a solution into molarity value? *(Delhi 2014 C)* An

SA II (3 marks)

8. A solution of glucose (molar mass = 180 g mol^{-1}) in water is labelled as 10% (by mass). What would be the molality and molarity of the solution?
(Density of solution = 1.2 g mL^{-1})
(NCERT, 3/5, AI 2014)

1.3 Solubility

Solubility of Gas in a Liquid (Henry's Law)

MCQ

9. On dissolving ammonium chloride in water at room temperature, the solution feels cool to touch. Under which of the following conditions does salt dissolve faster?
(a) Powdered salt in cold water
(b) Powdered salt in hot water
(c) Salt crystals in cold water
(d) Salt crystals in hot water *(2023)*

10. Low concentration of oxygen in the blood and tissues of people living at high altitude is due to
(a) high atmospheric pressure
(b) low temperature
(c) low atmospheric pressure
(d) both low temperature and high atmospheric pressure. *(2023)*

11. An unknown gas '*X*' is dissolved in water at 2.5 bar pressure and has mole fraction 0.04 in solution. The mole fraction of '*X*' gas when the pressure of gas is doubled at the same temperature is
(a) 0.08 (b) 0.04 (c) 0.02 (d) 0.92
(Term I, 2021-22) An

VSA (1 mark)

12. Why aquatic animals are more comfortable in cold water than in warm water? *(1/3, 2018)* Ap

13. Gas (*A*) is more soluble in water than gas (*B*) at the same temperature. Which one of the two gases will have the higher value of K_H (Henry's constant) and why?
(1/2, AI 2016)

SA I (2 marks)

14. What is Henry's law? Give one application of it. *(2023)*

15. State Henry's law. Why is air diluted with helium in the tanks used by scuba divers? *(2/5, 2020)* An

16. State Henry's law. Calculate the solubility of CO_2 in water at 298 K under 760 mm Hg.
(K_H for CO_2 in water at 298 K is 1.25×10^6 mm Hg)
(2020)

17. State Henry's law and mention two of its important applications. *(2020 C)* U

18. Give reasons for the following.
(a) Aquatic species are more comfortable in cold water than in warm water.
(b) At higher altitudes people suffer from anoxia resulting in inability to think. *(AI 2019)* Ap

1.4 Vapour Pressure of Liquid Solutions

Raoult's Law

MCQ

19. Which of the following formula represents Raoult's law for a solution containing non-volatile solute?
    (a) $p_{solute} = p^{\circ}_{solute} \cdot x_{solute}$
    (b) $p = K_H \cdot x$
    (c) $P_{total} = p_{solvent}$
    (d) $p_{solute} = p^{\circ}_{solvent} \cdot x_{solvent}$
    (Term I, 2021-22) U

VSA (1 mark)

20. Identify which liquid will have a higher vapour pressure at 90°C if the boiling points of two liquids *A* and *B* are 140°C and 180°C, respectively.
    (One word, 2020) U
21. Define Raoult's law. *(1/5 AI 2014C)*

SA I (2 marks)

22. State Raoult's law for a solution containing volatile components. What is the similarity between Raoult's law and Henry's law? *(2020, Delhi 2014)* R
23. State Raoult's law for a solution containing volatile components. Name the solution which follows Raoult's law at all concentrations and temperatures.
    (2/5, Foreign 2014) R

1.5 Ideal and Non-ideal Solutions

Ideal Solutions

MCQ

24. Which one of the following pairs will form an ideal solution?
    (a) Chloroform and acetone
    (b) Ethanol and acetone
    (c) *n*-Hexane and *n*-heptane
    (d) Phenol and aniline *(Term I, 2021-22)* Ap

VSA (1 mark)

25. Define the following term : Ideal solution
    (1/2, Delhi 2017, 1/5, AI 2017 C)

SA II (3 marks)

26. (a) Differentiate between Ideal solution and Non-ideal solution.
    (b) 30 g of urea is dissolved in 846 g of water. Calculate the vapour pressure of water for this solution if vapour pressure of pure water at 298 K is 23.8 mm Hg. *(2023)*

Non-ideal Solutions

MCQ

27. On mixing 20 mL of acetone with 30 mL of chloroform, the total volume of the solution is
    (a) < 50 mL (b) = 50 mL
    (c) > 50 mL (d) = 10 mL
    (Term I, 2021-22) Ev

VSA (1 mark)

28. What happens when acetone is added to pure ethanol? *(1/2, 2020)* Ev

SA I (2 marks)

29. What type of deviation from Raoult's law is observed by mixing chloroform and acetone?
    Why is a decrease in a vapour pressure observed in mixing chloroform and acetone? *(2021C)* Ap
30. Write two differences between ideal solutions and non-ideal solutions.
    (2/3, 2020 C, Delhi 2019, 2/5, AI 2017)
31. What is meant by positive deviations from Raoult's law? Give an example. What is the sign of $\Delta_{mix}H$ for positive deviation? *(Delhi 2015)*

    OR

    What is meant by negative deviation from Raoult's law? Give an example. What is the sign of $\Delta_{mix}H$ for negative deviation? *(Foreign 2015)*
32. What type of deviation is shown by a mixture of ethanol and acetone? Give reason. *(2/5, AI 2014)*

Azeotropes

MCQ

33. An azeotropic solution of two liquids has a boiling point lower than either of the two when it
    (a) shows a positive deviation from Raoult's law
    (b) shows a negative deviation from Raoult's law
    (c) shows no deviation from Raoult's law
    (d) is saturated. *(Term I, 2021-22)*

VSA (1 mark)

34. In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes?
    (1/2, AI 2016)
35. Some liquids on mixing form 'azeotropes'. What are 'azeotropes'? *(Delhi 2014)*

    OR

    Define the following term :
    Azeotrope *(1/5, Foreign 2014)*

SA I (2 marks)

36. What type of azeotropic mixture will be formed by a solution of acetone and chloroform? Justify on the basis of strength of intermolecular interactions that develop in the solution. *(AI 2019)* U

37. Define azeotropes. What type of azeotrope is formed by positive deviation from Raoult's law? Give an example. *(Delhi 2015)*

38. Define azeotropes. What type of azeotrope is formed by negative deviation from Raoult's law? Give an example. *(Foreign 2015)*

1.6 Colligative Properties and Determination of Molar Mass

Relative Lowering in Vapour Pressure

VSA (1 mark)

39. Define the following term :
Colligative properties *(1/2, Delhi 2017)*

40. How is the vapour pressure of a solvent affected when a non-volatile solute is dissolved in it?
(1/2, Delhi 2014C) U

SA I (2 marks)

41. A solution is prepared by dissolving 10 g of non-volatile solute in 200 g of water. It has a vapour pressure of 31.84 mm Hg at 308 K. Calculate the molar mass of the solute.
(Vapour pressure of pure water at 308 K = 32 mm Hg) *(2023)*

SA II (3 marks)

42. Give reasons :
(a) Measurement of osmotic pressure method is preferred for the determination of molar masses of macromolecules such as proteins and polymers.
(b) Aquatic animals are more comfortable in cold water than in warm water.
(c) Elevation of boiling point of 1 M KCl solution is nearly double than that of 1 M sugar solution. *(2023)*

43. Vapour pressure of water at 293 K is 17·536 mm Hg. Calculate the vapour pressure of aqueous solution when 20 g of glucose (Molar mass = 180 g mol^{-1}) is dissolved in 500 g of water. *(2021 C)*

44. 30 g of urea (M = 60 g mol^{-1}) is dissolved in 846 g of water. Calculate the vapour pressure of water for this solution if vapour pressure of pure water at 298 K is 23.8 mm Hg. *(3/5, AI 2017)*

LA (5 marks)

45. (a) State Henry's law and mention its two applications.
(b) 5% aqueous solution of a non-volatile solute was made and its vapour pressure at 373 K was found to be 745 mm. Vapour pressure of pure water at this temperature was 760 mm. Calculate the molar mass of solute.
(2020C) Ap

Elevation of Boiling Point

MCQ

46. The boiling point of a 0.2 m solution of a non-electrolyte in water is
(K_b for water = 0.52 K kg mol^{-1})
(a) 100 °C (b) 100.52 °C
(c) 100.104 °C (d) 100.26 °C
(Term I, 2021-22) Cr

47. **Assertion (A) :** Elevation in boiling point is a colligative property.
Reason (R) : Elevation in boiling point is directly proportional to molarity.
(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is correct, but Reason (R) is wrong statement.
(d) Assertion (A) is wrong, but Reason (R) is correct statement. *(2020)* R

VSA (1 mark)

48. Define the following term :
Molal elevation constant (K_b) *(1/5, AI 2014)*

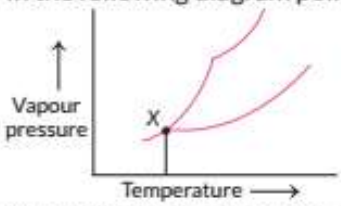
SA I (2 marks)

49. Why does a solution containing non-volatile solute have higher boiling point than the pure solvent? Why is elevation of boiling point a colligative property?
(AI 2015) An

Depression of Freezing Point

MCQ

50. In the following diagram point '*X*' represents



(a) boiling point of solution
(b) freezing point of solvent
(c) boiling point of solvent
(d) freezing point of solution.
(Term I, 2021-22) Cr

SA I (2 marks)

51. Nisha took two aqueous solutions – one containing 7.5 g of urea (Molar mass = 60 g/mol) and the other containing 42.75 g of substance Z in 100 g of water, respectively. It was observed that both the solutions froze at the same temperature. Calculate the molar mass of Z. *(2020)* Ev

52. Calculate the freezing point of a solution containing 60 g of glucose (molar mass = 180 g mol^{-1}) in 250 g of water. (K_f of water = 1.86 K kg mol^{-1}) *(2018)*

53. Calculate the mass of compound (molar mass = 256 g mol^{-1}) to be dissolved in 75 g of benzene to lower its freezing point by 0.48 K. (K_f = 5.12 K kg mol^{-1}). *(Delhi 2014)*

SA II (3 marks)

54. An antifreeze solution is prepared by dissolving 31 g of ethylene glycol (Molar mass = 62 g mol^{-1}) in 600 g of water. Calculate the freezing point of the solution. (K_f for water = 1.86 K kg mol^{-1}) *(2020)*

55. Calculate the mass of ascorbic acid (Molar mass = 176 g mol^{-1}) to be dissolved in 75 g of acetic acid, to lower its freezing point by 1.5°C . (K_f = 3.9 K kg mol^{-1}) *(NCERT Intext, 2020)*

56. A 4% solution (w/w) of sucrose (M = 342 g mol^{-1}) in water has a freezing point of 271.15 K. Calculate the freezing point of 5% glucose (M = 180 g mol^{-1}) in water. (Given : Freezing point of pure water = 273.15 K) *(Delhi 2019)* Ev

57. 1.00 g of a non-electrolyte solute dissolved in 50 g of benzene lowered the freezing point of benzene by 0.40 K. The freezing point depression constant of benzene is 5.12 K kg mol^{-1}. Find the molar mass of the solute. *(3/5, Delhi 2019 C)*

58. A 5% solution (by mass) of cane-sugar in water has freezing point of 271 K. Calculate the freezing point of 5% solution (by mass) of glucose in water if the freezing point of pure water is 273.15 K.
[Molecular masses : Glucose $C_6H_{12}O_6$: 180 amu; Cane-sugar $C_{12}H_{22}O_{11}$: 342 amu]
(NCERT, 3/5, Delhi 2019C) Ev

59. A 10% solution (by mass) of sucrose in water has freezing point of 269.15 K. Calculate the freezing point of 10% glucose in water, if freezing point of pure water is 273.15 K.
(Given : Molar mass of sucrose = 342 g mol^{-1}, molar mass of glucose = 180 g mol^{-1}) *(Delhi 2017)* Ev

60. Calculate the freezing point of the solution when 31 g of ethylene glycol ($C_2H_6O_2$) is dissolved in 500 g of water. (K_f for water = 1.86 K kg mol^{-1}) *(AI 2015)*

61. Some ethylene glycol, $HOCH_2CH_2OH$, is added to your car's cooling system along with 5 kg of water. If the freezing point of water-glycol solution is –15.0°C, what is the boiling point of the solution?
(K_b = 0.52 K kg mol^{-1} and K_f = 1.86 K kg mol^{-1} for water) *(Delhi 2014 C)*

Osmosis and Osmotic Pressure

MCQ

62. The colligative property used for the determination of molar mass of polymers and proteins is
(a) osmotic pressure
(b) depression in freezing point
(c) relative lowering in vapour pressure
(d) elevation in boiling point. *(2023)*

63. **Assertion(A) :** A raw mango placed in saline solution loses water and shrivel into pickle.
Reason (R) : Through the process of reverse osmosis raw mango shrivel into pickle.
(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is correct, but Reason (R) is incorrect statement.
(d) Assertion (A) is incorrect, but Reason (R) is correct statement. *(Term I, 2021-22)* Ap

64. **Assertion (A) :** Osmotic pressure is a colligative property.
Reason (R) : Osmotic pressure is directly proportional to molarity.
(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is correct, but Reason (R) is incorrect statement.
(d) Assertion (A) is incorrect, but Reason (R) is correct statement. *(2020)*

VSA (1 mark)

65. What happens when a pressure greater than osmotic pressure is applied on the solution side separated from solvent by a semi-permeable membrane? *(1/2, 2020)* Ap

66. Give reason for the following :
Measurement of osmotic pressure method is preferred for the determination of molar masses of macromolecules such as proteins and polymers. *(1/2, 2018)* U

67. Define the following term :
Osmotic pressure *(1/5, AI 2017 C)* R

68. What are isotonic solutions? *(Delhi 2014)* R

SA I (2 marks)

69. For a 5% solution of urea (Molar mass = 60 g/mol), calculate the osmotic pressure at 300 K. [R = 0.0821 L atm K^{-1} mol^{-1}] *(2020)*

70. Give reasons :
(a) Cooking is faster in pressure cooker than in cooking pan.
(b) Red Blood Cells (RBC) shrink when placed in saline water but swell in distilled water. *(2019)*

71. (i) Out of 1 M glucose and 2 M glucose, which one has a higher boiling point and why?

(ii) What happens when the external pressure applied becomes more than the osmotic pressure of solution? *(2/5, Delhi 2016)* An

72. Blood cells are isotonic with 0.9% sodium chloride solution. What happens if we place blood cells in a solution containing
(i) 1.2% sodium chloride solution?
(ii) 0.4% sodium chloride solution?
(2/5, Delhi 2016) Ap

SA II (3 marks)

73. At 300 K, 30 g of glucose present in a litre of its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of a glucose solution is 1.52 bar at the same temperature, what would be its concentration? *(AI 2019)*

74. A solution containing 15 g urea (molar mass = 60 g mol^{-1}) per litre of solution in water has the same osmotic pressure (isotonic) as a solution of glucose (molar mass = 180 g mol^{-1}) in water. Calculate the mass of glucose present in one litre of its solution. *(3/5, AI 2014)*

75. Define the following terms :
(i) Osmotic pressure
(ii) Colligative properties *(Foreign 2014)* R

1.7 Abnormal Molar Masses

van't Hoff and Abnormal Molar Mass

VSA (1 mark)

76. Define the following term :
van't Hoff factor *(Delhi 2017)*

77. Define the following term :
Abnormal molar mass *(Delhi 2017)*

SA I (2 marks)

78. Predict the state of the solute in the solution in the following situations :
(a) When '*i*' is found to be more than one.
(b) When '*i*' is found to be less than one. *(2020)*

79. What is van't Hoff factor? What types of values can it have if in forming the solution the solute molecules undergo
(i) dissociation
(ii) association? *(2/5, AI 2014 C)* U

van't Hoff and Elevation in Boiling Point

VSA (1 mark)

80. Give reason for the following :
Elevation of boiling point of 1 M KCl solution is nearly double than that of 1 M sugar solution.
(1/2, 2018) U

SA I (2 marks)

81. Give reasons :
(i) 0.1 M KCl has higher boiling point than 0.1 M glucose.
(ii) Meat is preserved for a longer time by salting.
(2020) An

SA II (3 mark)

82. (a) Out of 0·1 molal aqueous solution of glucose and 0·1 molal aqueous solution of KCl, which one will have higher boiling point and why ?
(b) Predict whether van't Hoff factor, (*i*) is less than one or greater than one in the following :
(i) CH_3COOH dissolved in water
(ii) CH_3COOH dissolved in benzene *(2019)*

83. Calculate the boiling point elevation for a solution prepared by adding 10 g of $CaCl_2$ to 200 g of water. (K_b for water = 0.52 K kg mol^{-1}, molar mass of $CaCl_2$ = 111 g mol^{-1}) *(3/5, AI 2017C, Foreign 2014)*

84. Calculate the boiling point of solution when 4 g of $MgSO_4$ (M = 120 g mol^{-1}) was dissolved in 100 g of water, assuming $MgSO_4$ undergoes complete ionization.
(K_b for water = 0.52 K kg mol^{-1}) *(AI 2016)*

LA (5 marks)

85. (i) Why is boiling point of 1 M NaCl solution more than that of 1 M glucose solution?
(ii) A non-volatile solute *X* (molar mass = 50 g mol^{-1}) when dissolved in 78 g of benzene reduced its vapour pressure to 90%. Calculate the mass of *X* dissolved in the solution.
(iii) Calculate the boiling point of elevation for a solution prepared by adding 10g of $MgCl_2$ to 200 g of water assuming $MgCl_2$ is completely dissociated.
(K_b for water = 0.512 K kg mol^{-1}, molar mass $MgCl_2$ = 95 g mol^{-1}) *(2023)*

van't Hoff and Depression in Freezing Point

MCQ

86. Out of the following 1.0 M aqueous solutions which one will show largest freezing point depression?
(a) NaCl (b) Na_2SO_4
(c) $C_6H_{12}O_6$ (d) $Al_2(SO_4)_3$ *(2023)*

SA I (2 marks)

87. Assuming complete dissociation, calculate the expected freezing point of a solution prepared by dissolving 6.00 g of Glauber's salt, $Na_2SO_4 \cdot 10H_2O$ in 0.100 kg of water. (K_f for water = 1.86 K kg mol^{-1}, atomic masses : Na = 23, S = 32, O = 16, H = 1)
(2/5, AI 2014C) Ap

SA II (3 marks)

88. When 19.5 g of $F—CH_2—COOH$ (molar mass = 78 g mol^{-1}) is dissolved in 500 g of water, the depression

in freezing point is observed to be 1°C. Calculate the degree of dissociation of $F—CH_2—COOH$.
[Given : K_f for water = 1.86 K kg mol^{-1}] *(3/5, 2020)* Ev

89. The freezing point of a solution containing 5 g of benzoic acid (M = 122 g mol^{-1}) in 35 g of benzene is depressed by 2.94 K. What is the percentage association of benzoic acid if it forms a dimer in solution? (K_f for benzene = 4.9 K kg mol^{-1}) *(2020)* An

90. A 0.01 m aqueous solution of $AlCl_3$ freezes at –0.068 °C. Calculate the percentage of dissociation.
[Given : K_f for water = 1.86 K kg mol^{-1}] *(2020)* Ev

91. Calculate the freezing point of solution when 1.9 g of $MgCl_2$ (M = 95 g mol^{-1}) was dissolved in 50 g of water, assuming $MgCl_2$ undergoes complete ionization.
(K_f for water = 1.86 K kg mol^{-1}) *(Delhi 2016)*

92. When 2.56 g of sulphur was dissolved in 100 g of CS_2, the freezing point lowered by 0.383 K. Calculate the formula of sulphur (S_x). (K_f for CS_2 = 3.83 K kg mol^{-1}, atomic mass of sulphur = 32 g mol^{-1})
(3/5 Delhi 2016) Cr

93. 3.9 g of benzoic acid dissolved in 49 g of benzene shows a depression in freezing point of 1.62 K. Calculate the van't Hoff factor and predict the nature of solute (associated or dissociated).
(Given : Molar mass of benzoic acid = 122 g mol^{-1}, K_f for benzene = 4.9 K kg mol^{-1}) *(Delhi 2015)* Ev

94. Calculate the mass of NaCl (molar mass = 58.5 g mol^{-1}) to be dissolved in 37.2 g of water to lower the freezing point by 2°C, assuming that NaCl undergoes complete dissociation. (K_f for water = 1.86 K kg mol^{-1})
(Foreign 2015)

LA (5 marks)

95. (a) Give two differences between ideal and non-ideal solutions.
(b) Calculate the amount of NaCl (M = 58.5 g mol^{-1}) that must be added to 100 g of water so that freezing point is depressed by 2 K. K_f for water is 1.86 K/m. *(2020C)*

96. (a) Write two characteristics of non-ideal solution.
(b) 2 g of benzoic (C_6H_5COOH) dissolved in 25 g of benzene shows a depression in freezing point equal to 1.62 K. Molal depression constant for benzene is 4.9 K kg mol^{-1}. What is the percentage association of acid if it forms dimer in solution ?
(2019)

van't Hoff and Osmotic Pressure

SA II (3 marks)

97. A solution contains 5.85 g NaCl (Molar mass = 58.5 g mol^{-1}) per litre of solution. It has an osmotic pressure of 4.75 atm at 27°C. Calculate the degree of dissociation of NaCl in this solution.
(Given : R = 0.082 L atm K^{-1} mol^{-1}) *(3/5, 2020)*

98. A solution 0.1 M of Na_2SO_4 is dissolved to the extent of 95%. What would be its osmotic pressure at 27°C?
(R = 0.0821 L atm K^{-1} mol^{-1}) *(2019)*

99. (a) Draw the graph between vapour pressure and temperature and explain the elevation in boiling point of a solvent in solution.
(b) Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 litres of water at 25°C assuming it to be completely dissociated.
(Atomic masses : K = 39 u, S = 32 u, O = 16 u)
(2019)

LA (5 marks)

100. (i) What is the value of van't Hoff factor for ethanoic acid in benzene close to 0.5?
(ii) Determine the osmotic pressure of a solution prepared by dissolving 2.32×10^{-2} g of K_2SO_4 in 2 L of solution at 25°C, assuming that K_2SO_4 is completely dissociated.
(iii) When 25.6 g of sulphur was dissolved in 1000 g of benzene, the freezing point lowered by 0.512 K. Calculate the formula of sulphur (S_x).
(K_f for benzene = 5.12 K kg mol^{-1}, Atomic mass of sulphur = 32 g mol^{-1}) *(2023)*

CBSE Sample Questions

1.2 Expressing Concentration of Solutions

MCQ

1. Given below are two statements labelled as assertion (A) and Reason (R).
Assertion (A) : Molarity of a solution changes with temperature.
Reason (R) : Molarity is a colligative property.
Select the most appropriate answer from the options given below:
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true. *(Term I, 2021-22)* R

1.3 Solubility

MCQ

2. Solubility of gases in liquids decreases with rise in temperature because dissolution is an

(a) endothermic and reversible process
(b) exothermic and reversible process
(c) endothermic and irreversible process
(d) exothermic and irreversible process.

(Term I, 2021-22)

In the following question a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following.

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

3. **Assertion :** Aquatic species are more comfortable in cold waters rather than in warm waters.
Reason : Different gases have different K_H values at the same temperature. *(2020-21)*

SA II (3 marks)

4. Answer the following questions :
(a) State Henry's law and explain why are the tanks used by scuba divers filled with air diluted with helium (11.7% helium, 56.2% nitrogen and 32.1% oxygen)?
(b) Assume that argon exerts a partial pressure of 6 bar. Calculate the solubility of argon gas in water. (Given Henry's law constant for argon dissolved in water, K_H = 40 kbar) *(2022-23)*

1.4 Vapour Pressure of Liquid Solutions

MCQ

5. Identify the law which is stated as
"For any solution, the partial vapour pressure of each volatile component in the solution is directly proportional to its mole fraction."
(a) Henry's law (b) Raoult's law
(c) Dalton's law (d) Gay-Lussac's Law

(Term I, 2021-22) Ap

6. When 1 mole of benzene is mixed with 1 mole of toluene the vapour will contain
(Given : Vapour pressure of benzene = 12.8 kPa and vapour pressure of toluene = 3.85 kPa).
(a) equal amount of benzene and toluene as it forms an ideal solution
(b) unequal amount of benzene and toluene as it forms a non-ideal solution
(c) higher percentage of benzene
(d) higher percentage of toluene. *(2020-21)* U

1.5 Ideal and Non-ideal Solutions

MCQ

In the following question a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following.

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

7. **Assertion :** Nitric acid and water form maximum boiling azeotrope.
Reason : Azeotropes are binary mixtures having the same composition in liquid and vapour phase.

(2020-21)

1.6 Colligative Properties and Determination of Molar Mass

MCQ

8. In which of the following cases blood cells will shrink?
(a) When placed in water containing more than 0.9% (mass/ volume) NaCl solution.
(b) When placed in water containing less than 0.9% (mass /volume) NaCl solution.
(c) When placed in water containing 0.9% (mass/ volume) NaCl solution.
(d) When placed in distilled water.

(Term I, 2021-22) An

9. How much ethyl alcohol must be added to 1 litre of water so that the solution will freeze at – 14°C ? (K_f for water = 1.86°C/mol)
(a) 7.5 mol (b) 8.5 mol
(c) 9.5 mol (d) 10.5 mol

(Term I, 2021-22)

10. Water retention or puffiness due to high salt intake occurs due to
(a) diffusion
(b) vapour pressure difference
(c) osmosis
(d) reverse osmosis. *(Term I, 2021-22)*

11. Given below are two statements labelled as assertion (A) and Reason (R).
Assertion (A) : Cryoscopic constant depends on nature of solvent.
Reason (R) : Cryoscopic constant is a universal constant.
Select the most appropriate answer from the options given below:
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.
(d) A is false but R is true. (2020-21) U

SA I (2 marks)

12. A glucose solution boils at 101.04°C at 1 atm. What will be relative lowering of vapour pressure of an aqueous solution of urea which is equimolal to given glucose solution?
(Given : K_b for water is 0.52 K kg mol^{-1}) (2020-21) Ev

1.7 Abnormal Molar Masses

Case Based (4 marks)

13. Henna is investigating the melting point of different salt solutions.
She makes a salt solution using 10 mL of water with a known mass of NaCl salt.
She puts the salt solution into a freezer and leaves it to freeze. She takes the frozen salt solution out of the freezer and measures the temperature when the frozen salt solution melts. She repeats each experiment.

S.No.	Mass of the salt used in g	Melting point in °C	
		Readings Set 1	Readings Set 2
1	0.3	−1.9	−1.9
2	0.4	−2.5	−2.6
3	0.5	−3.0	−5.5
4	0.6	−3.8	−3.8
5	0.8	−5.1	−5.0
6	1.0	−6.4	−6.3

Assuming the melting point of pure water as 0°C, answer the following questions :
(a) One temperature in the second set of results does not fit the pattern. Which temperature is that? Justify your answer.
(b) Why did Henna collect two sets of results?
(c) In place of NaCl, if Henna had used glucose, what would have been the melting point of the solution with 0.6 g glucose in it?

OR

What is predicted melting point, if 1.2 g of salt is added to 10 mL of water? Justify your answer.
(2022-23)

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. (d): Molality of a solution in liquid state does not change with temperature as mass does not change with temperature. The volume of solution changes with change in temperature so, does the molarity changes.

2. (d): 1 mole of glucose = N_A molecules

6.02×10^{22} molecules $= \frac{1}{N_A} \times 6.02 \times 10^{22}$ mole = 0.1 mole

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (mL)}} \times 1000$$

$$= \frac{0.1}{50} \times 1000 = 2 \text{ mol L}^{-1} \text{ or } 2 \text{ M}$$

3. Molality (m) is defined as the number of moles of the solute per kilogram of the solvent and is expressed as :

$$\text{Molality } (m) = \frac{\text{Moles of solute}}{\text{Mass of solvent (in kg)}}$$

4. It is the number of moles of the solute dissolved per litre of the solution. It is denoted by M.

$$\therefore \quad \text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution in litre}}$$

$$= \frac{n_2}{V(\text{in mL})} \times 1000 = \frac{w_2 \times 1000}{M_2 \times V(\text{in mL})} \qquad \left(\therefore n_2 = \frac{w_2}{M_2}\right)$$

5. Mole fraction is the ratio of number of moles of solute or solvent to total number of moles of solution. It is denoted by x.

$$x_{\text{solute}} = \frac{n_2}{n_1 + n_2}, \; x_{\text{solvent}} = \frac{n_1}{n_1 + n_2}$$

6. Mass of solute = 9.8 g; Mass of solution = 100 g
Density of solution = 1.02 g mL^{-1}

$$\therefore \quad \text{Volume of solution} = \frac{\text{Mass of solution}}{\text{Density of solution}}$$

$$= \frac{100 \text{ g}}{1.02 \text{ g mL}^{-1}} = 98.039 \text{ mL} = 0.098 \text{ L}$$

$$\text{Number of moles of solute, } n = \frac{9.8}{98} = 0.1 \text{ mol}$$

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in L)}} = \frac{0.1 \text{ mol}}{0.098 \text{ L}} = 1.02 \text{ M}$$

Answer Tips
- Remember unit conversion (mL into L), 1 L = 1000 mL

7.

Molarity	Molality
Number of moles of solute dissolved in one litre solution is called molarity.	Number of moles of solute dissolved in one kg solvent is called molality.
$M = \frac{\text{No. of moles of solute}}{\text{Volume of solution in litre}}$	$m = \frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}}$
Molarity depends on temperature as volume depends on temperature. Molarity decreases with rise in temperature.	Molality is independent of temperature as mass does not change with temperature.

If M_B is the molar mass of solute, d is the density of solution then molality (m) of a solution can be converted to molarity (M) by using the formula, $M = \frac{md}{\left(1+\frac{mM_B}{1000}\right)}$

Commonly Made Mistake

➲ Molarity (mol L^{-1}), Molality (mol kg^{-1})

8. Given : Mass of solute, $W_2 = 10$ g
Mass of solvent, $W_1 = 90$ g
Molar mass of solute, $M_2 = 180$ g mol^{-1}
Density of solution = 1.2 g mL^{-1}

$$\text{Molality} = \frac{W_2 \times 1000}{M_2 \times W_1} = \frac{10 \times 1000}{180 \times 90} = 0.62 \text{ m}$$

$$\text{Volume of solution} = \frac{\text{Mass}}{\text{Density}} = \frac{100 \text{ g}}{1.2 \text{ g mL}^{-1}}$$

$$\text{Molarity} = \frac{W_2 \times 1000}{M_2 \times V}$$

$$M = \frac{10 \times 1000}{180 \times \frac{100}{1.2}} = \frac{10 \times 1000 \times 1.2}{180 \times 100} = 0.67 \text{ M}$$

9. (b): Powdered salt dissolves faster in hot water. Dissolution of ammonium chloride in water is an endothermic reaction, hence high temperature will favor the dissolution of ammonium chloride in water.

10. (c): At high altitudes, the partial pressure of oxygen is less than at the ground level. As a result, there is a low concentration of oxygen in the blood and tissues of the people living at high altitudes.

11. (a): According to Henry's law, $p = K_H x$
2.5 bar = $K_H \times 0.04$

$$K_H = \frac{2.5}{0.04} = 62.5 \text{ bar}$$

When pressure is doubled, then x is
5 bar = $62.5 \times x \Rightarrow x = 0.08$

12. Increase in temperature decreases the solubility of oxygen in water. As a result, amount of dissolved oxygen decreases. It becomes more difficult to breathe as oxygen is less. Hence, the aquatic species are not comfortable in warm water.

13. According to Henry's law, the solubility of a gas is inversely proportional to the Henry's law constant (K_H) for that gas. Hence, gas (B) being less soluble, would have a higher K_H value.

14. Henry's law states that the solubility of a gas in a liquid at constant temperature is directly proportional to the pressure of the gas present above the surface of liquid or solution.

$p \propto x$ or $p = K_H x$

Here, p = partial pressure of the gas in vapour phase
x = mole fraction of the gas in the solution
K_H = Henry's law constant

Application of Henry's law :
Soft drinks and soda water bottle are sealed under high pressure to increase the solubility of CO_2.

15. Henry's law states that, the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.
$p = K_H \cdot x$ where, K_H = Henry's law constant. Different gases have different K_H values at the same temperature.
To minimise the painful effects of decompression sickness in deep sea divers, oxygen diluted with less soluble helium gas is used as breathing gas.

16. Henry's law states that, the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.
$p = K_H \cdot x$ where, K_H = Henry's law constant. Different gases have different K_H values at the same temperature.

$$\text{Solubility of } CO_2 = \frac{p}{K_H} = \frac{760}{1.25 \times 10^6} = 6.08 \times 10^{-4}$$

17. Henry's law states that, the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.
$p = K_H \cdot x$ where, K_H = Henry's law constant. Different gases have different K_H values at the same temperature.
Applications of Henry's law :
(i) To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.
(ii) To minimise the painful effects of decompression sickness in deep sea divers, oxygen diluted with less soluble helium gas is used as breathing gas.

18. (a) Increase in temperature decreases the solubility of oxygen in water. As a result, amount of dissolved oxygen decreases. It becomes more difficult to breathe as oxygen is less. Hence, the aquatic species are not comfortable in warm water.
(b) At high altitudes, the partial pressure of oxygen is less than at the ground level. As a result, there is a low concentration of oxygen in the blood and tissues of the people living at high altitudes. Thus, they feel weak and are unable to think properly.

Concept Applied

➲ Apply concept of solubility of gases in liquid.

19. (c): When a non-volatile solute added to the volatile liquid, then partial pressure is only due to volatile component.
So, $p_{total} = p_{solvent}$

20. The liquid with a lower boiling point will vaporise first and has a higher vapour pressure. Hence, liquid A will have a higher vapour pressure.

21. **Raoult's law :** For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ . x$
where, p° = vapour pressure of pure component
x = mole fraction of that component

22. Henry's law : It states that partial pressure of a volatile liquid (or gas) in a liquid is directly proportional to its mole fraction.

$P \propto x \Rightarrow P = K_H x$ (K_H = Henry's constant)

If we compare both equation, we can say that those are very similar and it seems that Raoult's law is a special case of Henry's law. When $K_H = P^\circ$.

23. **Raoult's law :** For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ . x$
where, p° = vapour pressure of pure component
x = mole fraction of that component
Let a solution consists of two volatile liquids A and B with their mole fractions x_A and x_B respectively. If p_A and p_B are their partial vapour pressures,
then, $p_A \propto x_A \Rightarrow p_A = p_A^\circ x_A$ and $p_B \propto x_B \Rightarrow p_B = p_B^\circ x_B$
where p_A° and p_B° represent the vapour pressures of pure liquid components A and B. $P_{total} = p_A + p_B$
Ideal solutions obey Raoult's law at all concentrations and temperature.

24. (c): *n*-Hexane and *n*-heptane will form an ideal solution.

25. A solution which obeys Raoult's law of vapour pressure for all compositions is called ideal solution.
For ideal solution $\Delta V_{mix} = 0, \Delta H_{mix} = 0$
$A-B$ interaction = $A-A$ and $B-B$ interactions.

26. (a) The differences between ideal solutions and non ideal solutions are as follows :
(i) In ideal solutions $\Delta V_{mix} = 0$ and $\Delta H_{mix} = 0$ whereas in non-ideal solutions,
$$\Delta V_{mix} \neq 0 \text{ and } \Delta H_{mix} \neq 0.$$
(ii) In ideal solutions, each component obeys Raoult's law at all temperatures and concentrations whereas in non ideal solutions, they do not obey Raoult's law.
(b) Given, weight of urea (W_2) = 30 g
Weight of water (W_1) = 846 g
Vapour pressure of water p_1° = 23.8 mm Hg

$$n_B = \frac{30}{60} = 0.5, \; n_A = \frac{846}{18} = 47$$

$$\text{Mole fraction of water } (x_A) = \frac{n_A}{n_A + n_B}$$

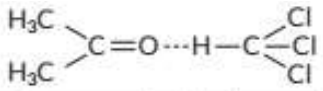
$$= \frac{47}{47 + 0.5} = \frac{47}{47.5} = 0.99$$

$p_A = p_A^\circ \times x_A = 23.8 \times 0.99 = 23.5$ mm Hg

27. (a): Acetone and chloroform form H-bonding due to which molecules come closer to each other and the volume of solution decreases.

28. A mixture of ethanol and acetone shows positive deviation from Raoult's law. When acetone is added to ethanol, some of the H-bonds between the ethanol molecules break down resulting in an increase in the vapour pressure of the mixture.

29. Mixture of chloroform and acetone shows negative deviation from Raoult's law, thus it forms maximum boiling azeotrope. This is because chloroform molecule is able to form hydrogen bond with acetone molecule as shown:

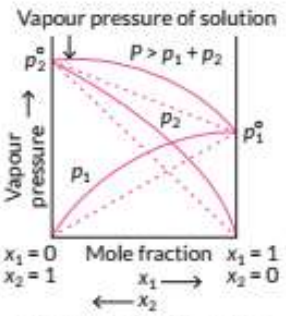


This decreases the escaping tendency of molecules of each component and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law.

30. The differences between ideal solutions and non ideal solutions are as follows :
(i) In ideal solutions $\Delta V_{mix} = 0$ and $\Delta H_{mix} = 0$ whereas in non ideal solutions, $\Delta V_{mix} \neq 0$ and $\Delta H_{mix} \neq 0$.
(ii) In ideal solutions, each component obeys Raoult's law at all temperatures and concentrations whereas in non ideal solutions, they do not obey Raoult's law.

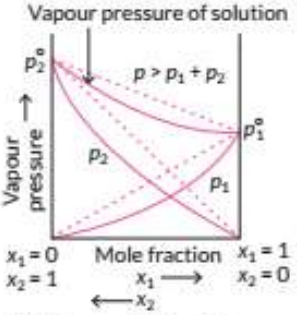
31. **Positive deviation :** For non-ideal solutions, if the vapour pressure is higher, than as expected from Raoult's law then it is said to exhibit positive deviation.
$A-B$ interactions are weaker than $A-A$ or $B-B$ interactions. Due to this, vapour pressure increases which results in positive deviation.

In positive deviation, intermolecular force decreases, volume increases, vapour pressures increases. enthalpy increases. Therefore, ΔH_{mix} = +ve, ΔV_{mix} = + ve. *e.g.*, ethanol + acetone and carbon disulphide + acetone show positive deviation.



Plot for non-ideal solution showing positive deviation

Negative deviation : For non-ideal solution, if the vapour pressure is lower than as expected from Raoult's law, then it is said to exhibit negative deviation. $A-B$ interactions are stronger than $A-A$ and $B-B$ interactions. Due to this, vapour pressure decreases which results in negative deviation. In negative deviation, intermolecular force increases, volume decreases, vapour pressure decreases and heat is released. Therefore, ΔH_{mix} = – ve, ΔV_{mix} = – ve. For example, phenol + aniline and chloroform + acetone show negative deviation.



Plot for non-ideal solution showing negative deviation

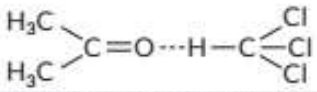
32. A mixture of ethanol and acetone shows positive deviation from Raoult's law. Pure ethanol possesses hydrogen bonding. Introduction of acetone between the molecules of ethanol results in breaking of some of these hydrogen bonds. Due to weakening of interactions, the solution shows positive deviation from Raoult's law.

33. (a): Solutions which show positive deviation from Raoult's law are minimum boiling azeotropes or have a lower boiling point than either of the two components.

34. Non-ideal solutions that show negative deviation from Raoult's law form maximum boiling azeotropes.

35. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phase and boil at constant temperature.

36. Mixture of chloroform and acetone shows negative deviation from Raoult's law, thus it forms maximum boiling azeotrope. This is because chloroform molecule is able to form hydrogen bond with acetone molecule as shown:



This decreases the escaping tendency of molecules of each component and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law.

37. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phase and boil at constant temperature.
A minimum boiling azeotrope is formed by solutions showing a large positive deviation from Raoult's law at a specific composition. For example an ethanol-water mixture containing approximately 95% ethanol by volume.

38. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phase and boil at constant temperature.
A maximum boiling azeotrope is formed by solutions showing a large negative deviation from Raoult's law at a specific composition.
For example, chloroform + acetone mixture.

39. The properties which depend upon the number of solute particles irrespective of their nature relative to the total number of particles present in the solution are called colligative properties.

40. When a non-volatile solute is added to a solvent, the vapour pressure of the solvent decreases as compared to the vapour pressure of pure solvent.

41. $W_2 = 10$ g, $W_1 = 200$ g, $T = 308$ K
$P_A^\circ = 32$ mm Hg, $P_S = 31.84$ mm Hg, $M_1 = 18$, $M_2 = ?$

$$\frac{P_A^\circ - P_S}{P_A^\circ} = \frac{n_2}{n_1 + n_2} = \frac{n_2}{n_1} \quad \text{(Solution is very dilute, } n_1 + n_2 = n_1\text{)}$$

$$\frac{32 - 31.84}{32} = \frac{10 \times 18}{M_2 \times 200}$$

$M_2 = 180$

42. (a) In osmotic pressure method, pressure can be measured at room temperature and the molarity of the solution is used instead of molality. That is why this method is used for determination of molar masses of macromolecules such as proteins as they are generally not stable at higher temperatures and polymers have poor solubility.
(b) Increase in temperature decreases the solubility of oxygen in water. As a result, amount of dissolved oxygen decreases. It becomes more difficult to breathe as oxygen is less. Hence, the aquatic species are not comfortable in warm water.

(c) i for 1 M KCl = 2
i for sugar solution = 1
$\therefore \Delta T_b = iK_b m = 2K_b$ (for KCl)
$\Delta T_b = K_b$ (for sugar)
$\therefore$ ΔT_b of 1 M KCl solution is double than that of 1 M sugar solution.

43. Given, $P_s^\circ = 17.536$ mm, $P_s = ?$,
$w_2 = 20$ g, $M_2 = 180$ g mol^{-1}, $w_1 = 500$ g, $M_1 = 18$ g

$$\frac{P_s^\circ - P_s}{P_s^\circ} = x_2 = \frac{w_2/M_2}{w_1/M_1 + w_2/M_2}$$

$$\frac{17.536 - P_s}{17.536} = \frac{\frac{20}{180}}{\frac{500}{18} + \frac{20}{180}} \approx \frac{\frac{20}{180}}{\frac{500}{18}} \qquad \left(\because \frac{20}{180} \lll \frac{500}{18}\right)$$

$$(17.536 - P_s) = \frac{20}{180} \times \frac{18}{500} \times 17.536 = 0.070$$

$P_s = 17.536 - 0.070 = 17.466$ mm

Concept Applied

- Relative lowering of vapour pressure of a solution is equal to mole fraction of solute, *i.e.*, $\frac{p^\circ - p_S}{p^\circ} = X_B$.

44. Given, weight of urea (W_2) = 30 g
Weight of water (W_1) = 846 g
Vapour pressure of water $p_1^\circ = 23.8$ mm Hg

$$n_B = \frac{30}{60} = 0.5, \quad n_A = \frac{846}{18} = 47$$

$$\text{Mole fraction of water } (x_A) = \frac{n_A}{n_A + n_B} = \frac{47}{47 + 0.5} = \frac{47}{47.5} = 0.99$$

$p_A = p_A^\circ \times x_A = 23.8 \times 0.99 = 23.5$ mm Hg

45. (a) Henry's law states that, the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.
$p = K_H \cdot x$ where, K_H = Henry's law constant. Different gases have different K_H values at the same temperature.
Applications of Henry's law:
(i) To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.
(ii) To minimise the painful effects of decompression sickness in deep sea divers, oxygen diluted with less soluble helium gas is used as breathing gas.
(b) Given, $w_2 = 5$ g, $w_1 = 95$ g, $P_s = 745$ mm
$P_s^\circ = 760$ mm, $M_2 = ?$

$$\frac{P_s^\circ - P_s}{P_s^\circ} = x_2 = \frac{n_2}{n_1 + n_2} = \frac{w_1/M_2}{w_1/M_1 + w_2/M_2}$$

$$\frac{760 - 745}{760} = \frac{5/M_2}{95/18 + 5/M_2} = \frac{5/M_2}{95/18} \qquad \left(\because \frac{95}{18} \ggg \frac{5}{M_2}\right)$$

$$\frac{15}{760} \times \frac{95}{18} = \frac{5}{M_2}$$

$$\Rightarrow \quad M_2 = \frac{5 \times 760 \times 18}{15 \times 95} = 48 \text{ g mol}^{-1}$$

46. (c): $\Delta T_b = K_b \times m$

$T_b - T_b^\circ = 0.52 \times 0.2 \Rightarrow T_b = 0.104 + T_b^\circ$

$T_b = (0.104 + 100)\,^\circ C = 100.104\,^\circ C$

47. (c): Assertion is correct but reason is wrong as elevation in boiling point is directly proportional to molality not molarity.

$\Delta T_b \propto m$

$\Delta T_b = K_b m$

48. Molal elevation constant may be defined as the elevation in boiling point when the molality of the solution is unity (*i.e.*, 1 mole of the solute is dissolved in 1 kg (1000 g) of the solvent). The units of K_b are therefore, K/m or °C/m or K kg mol^{-1}.

49. The boiling point of the solution is always higher than that of the pure solvent. As the vapour pressure of the solution is lower than that of the pure solvent and vapour pressure increases with increase in temperature, hence, the solution has to be heated more to make the vapour pressure equal to the atmospheric pressure.

Elevation of boiling point is a colligative property because it depends on number of solute particles present in a solution.

50. (d): *X* represents freezing point of solution.

51. Molality (m) of urea $= \dfrac{7.5\times1000}{60\times100} = 1.25$ m ...(i)

Molality of substance,

$Z = \dfrac{42.75\times1000}{\text{Molar mass}\times100} = \dfrac{427.5}{\text{Molar mass}}$ ...(ii)

As both the solutions have same depression in freezing point so they have same molality.

From eqn. (i) and (ii), we get

$1.25 = \dfrac{427.5}{\text{Molar mass}}$

Molar mass of Z = 342 g/mol

52. Mass of glucose ($C_6H_{12}O_6$), W_2 = 60 g

Mass of water, W_1 = 250 g

M_2 (Mol. mass of $C_6H_{12}O_6$) = 180 g mol^{-1}

K_f = 1.86 K kg mol^{-1}, T_f = ?

Using formula, $\Delta T_f = K_f \times \dfrac{W_2\times1000}{M_2\times W_1} = 1.86\times\dfrac{60\times1000}{180\times250}$ K

$\Delta T_f = T_f^\circ - T_f$ or $T_f = T_f^\circ - \Delta T_f = 273 - 2.48 = 270.52$ K

Key Points

- As there is depression in freezing point so, $T_f < T_f^\circ \;\therefore\; \Delta T_f = T_f^\circ - T_f$ = +ve

53. Given: W_2 = ?, M_2 = 256 g mol^{-1}, ΔT_f = 0.48 K

W_1 = 75 g, K_f = 5.12 K kg mol^{-1}

$\Delta T_f = \dfrac{K_f\times W_2\times1000}{M_2\times W_1}$

$W_2 = \dfrac{\Delta T_f\times M_2\times W_1}{K_f\times1000} = \dfrac{0.48\times256\times75}{5.12\times1000} = 1.8$ g

54. Mass of ethylene glycol ($C_2H_6O_2$), W_2 = 31 g

Mass of water, W_1 = 600 g

M_2 (Mol. mass of $C_2H_6O_2$) = 62 g mol^{-1},

K_f = 1.86 K kg mol^{-1}, T_f = ?

Using formula, $\Delta T_f = K_f \times \dfrac{W_2\times1000}{M_2\times W_1}$

$= 1.86\times\dfrac{31\times1000}{62\times600}$ K = 1.55 K

$\Delta T_f = T_f^\circ - T_f$ or $T_f = T_f^\circ - \Delta T_f = 273 - 1.55 = 271.45$ K

55. Given, M_2 = 176 g mol^{-1}, ΔT_f = 1.5°C

w_1 = 75 g, K_f = 3.9 K kg mol^{-1}, w_2 = ?

$\Delta T_f = \dfrac{K_f\times w_2\times1000}{M_2\times w_1}$

$w_2 = \dfrac{\Delta T_f\times M_2\times w_1}{K_f\times1000} = \dfrac{1.5\times176\times75}{3.9\times1000} = 5.077$ g

56. Molality of sucrose solution (m) $= \dfrac{w_2\times1000}{M_2\times w_1}$

$= \dfrac{4\times1000}{342\times96} = 0.121$ m

ΔT_f for sucrose solution = 273.15 – 271.15 = 2 K

$K_f = \dfrac{\Delta T_f}{m} = \dfrac{2}{0.121} = 16.52$ K/m

Molality of glucose solution $= \dfrac{5\times1000}{180\times95} = 0.292$ m

$\Delta T_f = K_f \times m = 16.52 \times 0.292 = 4.82$ K

Freezing point of glucose solution = 273.15 – 4.82 = 268.33 K

57. W_2 = 1.00 g, W_1 = 50 g, K_f = 5.12 K kg mol^{-1}, ΔT_f = 0.40 K

$\Delta T_f = \dfrac{K_f\times W_2\times1000}{M_2\times W_1}$

$M_2 = \dfrac{K_f\times W_2\times1000}{W_1\times\Delta T_f} = \dfrac{5.12\times1\times1000}{50\times0.40} = 256$ g mol^{-1}

58. Molality of sugar solution

$= \dfrac{W_2\times1000}{M_2\times W_1} = \dfrac{5}{342}\times\dfrac{1000}{95} = 0.154$ m

$\Delta T_f = T_f^\circ - T_f = 273.15 - 271 = 2.15$ K

$\Delta T_f = K_f \times m \;\therefore\; K_f = \dfrac{\Delta T_f}{m} = \dfrac{2.15}{0.154}$

Molality of glucose solution

$= \dfrac{W_2\times1000}{M_2\times W_1} = \dfrac{5}{180}\times\dfrac{1000}{95} = 0.292$ m

$\therefore\;\; \Delta T_f$ (Glucose) $= K_f \times m = \dfrac{2.15}{0.154}\times0.292 = 4.08$ K

$\therefore$ Freezing point of glucose solution = 273.15 – 4.08 = 269.07 K

59. Molality (m) of sucrose solution

$= \dfrac{w_2\times1000}{M_2\times w_1} = \dfrac{10}{342}\times\dfrac{1000}{90} = 0.325$ m

ΔT_f for sucrose solution $= T_f^\circ - T_f = (273.15 - 269.15)$ K = 4 K

$\therefore\;\; K_f = \dfrac{\Delta T_f}{m} = \dfrac{4\text{ K}}{0.325\text{ m}} = 12.308$ K/m $\because \Delta T_f = K_f \times m$

Molality of glucose solution $= \dfrac{10}{180}\times\dfrac{1000}{90} = 0.617$ m

$\Delta T_f = K_f \times m$

$\therefore\;\; \Delta T_f = 12.308$ K/m $\times$ 0.617 m = 7.59 = 7.6 K

∴ Freezing point of glucose solution,

$T_f^\circ - \Delta T_f = (273.15 - 7.60)\ K = 265.55\ K$

60. Mass of ethylene glycol ($C_2H_6O_2$), $W_2 = 31$ g
Mass of water, $W_1 = 500$ g
M_2 (Mol. mass of $C_2H_6O_2$) = 62 g mol^{-1},
$K_f = 1.86$ K kg mol^{-1}, $T_f = ?$

Using formula, $\Delta T_f = K_f \times \frac{W_2 \times 1000}{M_2 \times W_1}$

$= 1.86 \times \frac{60 \times 1000}{180 \times 250} K$

$\Delta T_f = T_f^\circ - T_f$ or $T_f = T_f^\circ - \Delta T_f = 273 - 2.48 = 270.52 K$

61. $T_f = -15°C$, $K_f = 1.86$ K kg mol^{-1}

$\Delta T_f = T_f^\circ - T_f = 0 - (-15°C) = 15°C$

$\Delta T_f = K_f \times m$

$15 = 1.86 \times \frac{\text{Number of moles of solute}}{5}$

$\Rightarrow$ Number of moles of solute = 40.32 moles

$\Delta T_b = K_b \times m$

$\Delta T_b = 0.52 \times \frac{\text{Moles of solute}}{\text{Mass of solvent (kg)}}$

$\Delta T_b = 0.52 \times \frac{40.32}{5\,kg} = 4.19$

$\Delta T_b = T_b - T_b^\circ \Rightarrow 4.19 = T_b - 373$

$T_b = 373 + 4.19 = 377.19\ K$

Key Points

- Same moles of solute are used here for the calculation of boiling point and freezing point.

62. (a): In osmotic pressure method, pressure can be measured at room temperature and the molarity of the solution is used instead of molality. That is why this method is used for determination of molar masses of macromolecules such as proteins as they are generally not stable at higher temperatures and polymers have poor solubility.

63. (c): A raw mango shriveled into pickle due to osmosis.

64. (a): Colligative properties of ideal solutions depend only on the number of particles of solute dissolved in a definite amount of the solvent and do not depend on the nature of solute.

Answer Tips

- $\pi = CRT$ where C is Molarity.

65. When the external pressure applied becomes more than the osmotic pressure of solution then the solvent molecules from the solution pass through the semi-permeable membrane to the solvent side and the process is called reverse osmosis.

66. In osmotic pressure method, pressure can be measured at room temperature and the molarity of the solution is used instead of molality. That is why this method is used for determination of molar masses of macromolecules such as proteins as they are generally not stable at higher temperatures and polymers have poor solubility.

67. Osmotic pressure is the extra pressure which is applied on the solution to prevent the flow of solvent into the solution through a semi-permeable membrane.

68. Two solutions having same osmotic pressure at a given temperature are called isotonic solutions.

69. Molarity (M) of urea solution

$= \frac{w \times 1000}{M \times \text{Volume of solvent (mL)}} = \frac{5 \times 1000}{60 \times 100} = 0.833M$

Osmotic pressure (π) = $CRT = 0.833 \times 0.0821 \times 300$
$= 20.51$ atm

70. (a) When we cook the food inside the pressure cooker, high pressure is created inside the cooker. Pressure will increase so, the boiling point will increase. Thus, cooking is faster in pressure cooker than in cooking pan.
(b) When red blood cells (RBC) are placed in saline water, water will flow out of the cells (low conc. to high conc.) and they would shrink. Such a solution is called hypertonic. On the other hand when red blood cells (RBC) are placed in distilled water, water will flow into the cell and they would swell. Such solution is called hypotonic.

71. (i) The elevation in boiling point of a solution is a colligative property which depends on the number of moles of solute added. Higher the concentration of solute added, higher will be the elevation in boiling point. Thus, 2 M glucose has higher boiling point than 1 M glucose solution.
(ii) When the external pressure applied becomes more than the osmotic pressure of solution then the solvent molecules from the solution pass through the semi-permeable membrane to the solvent side and the process is called reverse osmosis.

72. (i) 1.2% sodium chloride solution is hypertonic with respect to 0.9% sodium chloride solution or blood cells thus, on placing blood cells in this solution exosmosis takes place that results in shrinking of cells.
(ii) 0.4% sodium chloride solution is hypotonic with respect to 0.9% sodium chloride solution or blood cells thus, on placing blood cells in this solution endosmosis takes place that results in swelling of cells.

Concept Applied

- **Exosmosis :** The outward flow of solvent (water) from the cell when placed in more concentrated solution (hypertonic). Cell shrinks in this case.
- **Endosmosis :** The inflow of solvent (water) into a cell from outside when cell is placed in distilled water. Cell swells up in this case.

73. $\pi = cRT$, $c = \frac{w_2}{M_2 \times V}$

w_2 = weight of solute
M_2 = molar mass of solute

$\frac{\pi_1}{\pi_2} = \frac{c_1 RT_1}{c_2 RT_2}$. Given, $T_1 = T_2$

$$\frac{\pi_1}{\pi_2}=\frac{c_1}{c_2} \Rightarrow \frac{4.98}{1.52}=\frac{\frac{30}{180\times1}}{c_2} \Rightarrow c_2=\frac{30\times1.52}{180\times4.98}=0.051 \text{ mol/L}$$

74. Mass of urea = 15 g
Molar mass of urea = 60 g mol^{-1}
Molar mass of glucose = 180 g mol^{-1}
Mass of glucose = ?
For isotonic solution, osmotic pressure, $\pi_{1(\text{urea})} = \pi_{2(\text{glucose})}$
$n_1 = n_2$ (when volume is same)

or $\frac{W_1}{M_1}=\frac{W_2}{M_2} \Rightarrow \frac{15}{60}=\frac{W_2}{180} \Rightarrow W_2=\frac{15\times180}{60}=45 \text{ g}$

Answer Tips

- $\pi = cRT = \frac{n}{V(\text{in L})}RT = \frac{W}{M\times V(\text{in L})}\times RT$

75. (i) Osmotic pressure is the extra pressure which is applied on the solution to prevent the flow of solvent into the solution through a semi-permeable membrane.
(ii) Properties which depend upon the number of solute particles irrespective of their nature relative to the total number of particles present in the solution are called colligative properties.

76. **van't Hoff factor** : It is defined as the ratio of the experimental value of colligative property to the calculated value of the colligative property and is used to find out the extent of dissociation or association. Mathematically, it is represented as

$$i=\frac{\text{Experimental (or observed) value of colligative property}}{\text{Calculated (or normal) value of colligative property}}$$

77. The molar mass which is either lower or higher than the expected or normal value is known as abnormal molar mass.

78. (a) When $i > 1$, solute is in dissociated state in the solution.
(b) When $i < 1$, solute is in associated state in the solution.

79. **van't Hoff factor** : It is defined as the ratio of the experimental value of colligative property to the calculated value of the colligative property and is used to find out the extent of dissociation or association. Mathematically, it is represented as

$$i=\frac{\text{Experimental (or observed) value of colligative property}}{\text{Calculated (or normal) value of colligative property}}$$

(i) van't Hoff factor (i) > 1 for solutes undergoing dissociation
(ii) van't Hoff factor (i) < 1 for solutes undergoing association

80. i for 1 M KCl = 2
i for sugar solution = 1
$\therefore$ $\Delta T_b = iK_b m = 2K_b$ (for KCl)
$\Delta T_b = K_b$ (for sugar)
$\therefore$ ΔT_b of 1 M KCl solution is double than that of 1 M sugar solution.

81. (i) As KCl is an electrolyte and one formula unit of KCl dissociates to give two ions (K^+ and Cl^-), therefore molar concentration of particles in the solution = 0.1 × 2 M = 0.2 M
As elevation of boiling point (or any colligative property) is directly proportional to number of particles in solution, hence 0.1 M KCl has higher boiling point than that 0.1 M glucose.
(ii) Salting is used because most bacteria, fungi and other potentially pathogenic organisms cannot survive in a highly salty environment, due to the hypertonic nature of salt. Any living cell in such an environment will become dehydrated through osmosis and die or become temporarily deactivated.

Key Points

- High concentration of salt - Hypertonic
- Low concentration of salt - Hypotonic

82. (a) i for 0.1 m KCl = 2
i for 0.1 m glucose = 1
$\therefore$ $\Delta T_b = i K_b m = 2K_b \times 0.1$ (for KCl)
$\Delta T_b = 1K_b \times 0.1$ (for glucose)
Thus, ΔT_b for KCl will be higher than for glucose solution as KCl will undergo dissociation and i is greater than 1.
(b) (i) i will be greater than 1 when CH_3COOH is dissolved in water as it undergoes dissociation.
$CH_3COOH + H_2O \longrightarrow CH_3COO^- + H_3O^+$
(ii) i will be less than 1 when CH_3COOH is dissolved in benzene as it undergoes association.
$2CH_3COOH \xrightarrow{\text{benzene}} (CH_3COOH)_2$ (Dimerisation)

83. Mass of $CaCl_2$ (W_2) = 10 g
Mass of water (W_1) = 200 g
Molar mass of $CaCl_2$ (M_2) = 111 g mol^{-1}
Molal elevation constant (K_b) = 0.52 K kg mol^{-1}

$$m=\frac{W_2\times1000}{M_2\times W_1} \Rightarrow m=\frac{10}{111}\times\frac{1000}{200}=0.450 \text{ m}$$

$\Delta T_b = iK_b m = 3 \times 0.52 \times 0.450 = 0.702$ K

84. $W_2 = 4$ g, $M_2 = 120$ g mol^{-1}
$W_1 = 100$ g, $K_b = 0.52$ K kg mol^{-1}
For complete dissociation, $i = 2$
Using formula, $\Delta T_b = iK_b m$

or $\Delta T_b=\frac{i\times K_b\times W_2\times1000}{M_2\times W_1}=2\times0.52\times\frac{4\times1000}{120\times100}=0.34$ K

$\therefore$ $T_b = T_b^\circ + \Delta T_b = 100 + 0.34 = 100.34°C$

85. (i) The boiling point of 1M NaCl solution is more than that of 1M glucose solution as the value of 'i', *i.e.*, van't Hoff factor is 2 for NaCl and it is 1 for glucose. Also,

$$\Delta T_b = i \times K_b \times m$$

Hence, from the above mathematical reaction, it is clear that the increase in boiling point will be more for NaCl than that of glucose.
(ii) Let $p°$ be the vapour pressure of pure benzene. The vapour pressure of the solution will be $\frac{90}{100}p° = 0.9p°$.
Molar mass of solute (M_2) and benzene (M_1) are 50 g mol^{-1} and 78.1 g mol^{-1} respectively. Mass of benzene (w_1) is 78 g.

$$\frac{p°-p}{p°}=\frac{w_2}{M_2}\times\frac{M_1}{w_1}$$

$$\frac{p^\circ - 0.9p^\circ}{p^\circ} = \frac{w_2}{50} \times \frac{78.1}{78}$$

$\Rightarrow w_2 = 5$ g

Thus, the mass of *X* dissolved in the solution is 5 g.

(iii) It is given that $MgCl_2$ is completely dissociated in the solution.

$$MgCl_{2(s)} \xrightarrow{(aq)} Mg^{2+}_{(aq)} + 2Cl^-_{(aq)}$$

$\therefore$ $i = 3$, $w_B = 10$ g; $w_A = 200$ g $= 0.2$ kg

$K_b = 0.512$ K kg mol^{-1}

$$\Delta T_b = i \times K_b \times m = \frac{i \times K_b \times w_B}{M_B \times w_A}$$

$$\Delta T_b = \frac{(3) \times (0.512\,\text{K kg mol}^{-1}) \times (10\,\text{g})}{(95\,\text{g mol}^{-1}) \times (0.2\,\text{kg})} = 0.80\,\text{K}$$

86. (d): $NaCl \longrightarrow Na^+ + Cl^-$ $\quad i = 2$

$Na_2SO_4 \longrightarrow 2Na^+ + SO_4^{2-}$ $\quad i = 3$

$C_6H_{12}O_6$ (non-ionisable) $\quad i = 1$

$Al_2(SO_4)_3 \longrightarrow 2Al^{3+} + 3SO_4^{2-}$ $\quad i = 5$

Greater the number of ions produced on dissociation, greater is the van't Hoff factor.

$\because$ $\Delta T_f \propto i$

$\therefore$ $Al_2(SO_4)_3$ shows largest freezing point depression.

87. Molecular mass of Glauber's salt ($Na_2SO_4 \cdot 10H_2O$)

$= [2 \times 23 + 32 + 16 \times 4 + 10 \times (2 \times 1 + 16)]$

$= (46 + 32 + 64 + 180)$ g mol^{-1} $= 322$ g mol^{-1}

$Na_2SO_4 \cdot 10H_2O$ ionises as :

$Na_2SO_4 \cdot 10H_2O \rightleftharpoons 2Na^+ + SO_4^{2-} + 10H_2O$

$\Rightarrow$ $i = 3$

$$m = \frac{n_B}{W_A} = \frac{W_B}{M_B \times W_A} = \frac{6.00\,\text{g}}{322\,\text{g mol}^{-1} \times 0.1\,\text{kg}}$$

$$= 0.186\,\text{mol kg}^{-1} = 0.186\,\text{m}$$

Also, $\Delta T_f = i K_f \cdot m = 3 \times 1.86$ K m$^{-1} \times 0.186$ m $= 1.04$ K

$\Rightarrow$ $T_f = T_f^\circ - \Delta T_f$

$= (273 - 1.04)$ K $= 271.96$ K

88. Given : $W_2 = 19.5$ g, $W_1 = 500$ g, $K_f = 1.86$ K kg mol^{-1}

$\Delta T_{f(obs)} = 1.0$ K

$$\therefore \quad M_{2(obs)} = \frac{1000 \times K_f \times W_2}{W_1 \times \Delta T_{f(obs)}} = \frac{1000 \times 1.86 \times 19.5}{500 \times 1}$$

$$= 72.54\,\text{g mol}^{-1}$$

$M_{2(cal)}$ for $F{-}CH_2{-}COOH = 78$ g mol^{-1}

$$i = \frac{M_{2(cal)}}{M_{2(obs)}} = \frac{78}{72.54} = 1.0753$$

$$F{-}CH_2{-}COOH \rightleftharpoons F{-}CH_2{-}COO^- + H^+$$

Initial moles	C	0	0
Moles at eqm.	$C - C\alpha$	$C\alpha$	$C\alpha$

Total no. of moles $= C - C\alpha + C\alpha + C\alpha = C(1 + \alpha)$

$$i = \frac{C(1+\alpha)}{C} = 1 + \alpha$$

or $\alpha = i - 1 = 1.0753 - 1 = 0.0753 = 7.53\%$

Answer Tips

- Since ΔT is the difference between values of temperatures, it is independent of the unit it is measured in *i.e.*, $\Delta T = 1^\circ C = 1$ K.

89. Given, $W_2 = 5$ g, $M_2 = 122$ g mol^{-1}, $W_1 = 35$ g

$\Delta T_f = 2.94$ K, $K_f = 4.9$ K kg mol^{-1}

$$\Delta T_f = i K_f m = i \times K_f \times \frac{W_2 \times 1000}{M_2 \times W_1}$$

or $\quad 2.94 = i \times 4.9 \times \frac{5 \times 1000}{122 \times 35}$ $\quad$ or $i = 0.512$

As $i < 1$, solute is associated.

$$2C_6H_5COOH \rightleftharpoons (C_6H_5COOH)_2$$

Initial moles	1	0
Moles at eqm.	$1 - \alpha$	$\alpha/2$

Total no. of moles after association : $1 - \alpha + \alpha/2 = 1 - \alpha/2$

$$\therefore \quad i = \frac{1 - \alpha/2}{1} = 1 - \frac{\alpha}{2}$$

$$\Rightarrow \quad 1 - \frac{\alpha}{2} = 0.512$$

or $\alpha = 2 \times (1 - 0.512) = 0.976$ or 97.6%

Concept Applied

- For association of solute, $i = 1 - \alpha + \frac{\alpha}{n}$

  here $n = 2$, so, $i = 1 - \frac{\alpha}{2}$

90. Given, $\Delta T_f = 0.068^\circ C$ or 0.068 K

$m = 0.01$ M, $\quad K_f = 1.86$ K kg mol^{-1}

$\Delta T_f = iK_f \cdot m$

$\Rightarrow$ $0.068 = i \times 1.86 \times 0.01$

$$\Rightarrow \quad i = \frac{0.068}{1.86 \times 0.01} = 3.65$$

$AlCl_3$ dissociates as

$$AlCl_3 \rightleftharpoons Al^{3+} + 3Cl^-$$

Initially	1	0	0
At eqm.	$1 - \alpha$	α	3α

Total no. of moles after dissociation $= 1 - \alpha + \alpha + 3\alpha = 1 + 3\alpha$

$$i = \frac{1 + 3\alpha}{1} = 3.65$$

$\Rightarrow$ $1 + 3\alpha = 3.65 \Rightarrow 3\alpha = 3.65 - 1 = 2.65$

$$\Rightarrow \quad \alpha = \frac{2.65}{3} = 0.883$$

Percentage association $= 88.3\%$

91. $\Delta T_f = iK_f \cdot m$

i for $MgCl_2 = 3$

$$\text{Molality, } m = \frac{W_2 \times 1000}{M_2 \times W_1} = \frac{1.9 \times 1000}{95 \times 50} = 0.4\,\text{m}$$

$\Delta T_f = 3 \times 1.86 \times 0.4 = 2.232$ K

Freezing point of solution, $T_f = T_f^\circ - \Delta T_f = 273 - 2.232$ K

$= 270.77$ K

92. $W_2 = 2.56$ g, $W_1 = 100$ g, $\Delta T_f = 0.383$ K

$K_f = 3.83$ K kg mol^{-1}, $\Delta T_f = K_f \times m$

$$\Rightarrow \quad \Delta T_f = K_f \times \frac{W_2}{M_2} \times \frac{1000}{W_1} \Rightarrow M_2 = \frac{W_2 \times 1000}{\Delta T_f \times W_1} \times K_f$$

$$= \frac{2.56 \times 1000}{0.383 \times 100} \times 3.83 = 256\,\text{g mol}^{-1}$$

$\because$ $i = \dfrac{\text{Normal atomic mass}}{\text{Observed atomic mass}} = \dfrac{32}{256} = \dfrac{1}{8}$

Sulphur exists as S_x *i.e.*, S_8.

Concept Applied

➲ Value of observed atomic mass is used to calculate the value of *x* here.

93. $W_2 = 3.9$ g, $W_1 = 49$ g, $\Delta T_f = 1.62$ K, $M_2 = 122$ g mol^{-1}, $K_f = 4.9$ K kg mol^{-1}

$$\Delta T_f = i K_f m = i \times K_f \times \frac{W_2 \times 1000}{M_2 \times W_1}$$

$$\Rightarrow \quad 1.62 = \frac{i \times 4.9 \times 3.9 \times 1000}{122 \times 49} \Rightarrow i = \frac{1.62 \times 122 \times 49}{4.9 \times 3.9 \times 1000} = 0.506$$

As $i < 1$, solute is associated.

94. $$\Delta T_f = iK_f m = \frac{i \times K_f \times W_2 \times 1000}{M_2 \times W_1}$$

$$2 = \frac{2 \times 1.86 \times W_2 \times 1000}{58.5 \times 37.2} \Rightarrow W_2 = 1.17 \text{ g}$$

95. (a) The differences between ideal solutions and non-ideal solutions are as follows :

(i) In ideal solutions $\Delta V_{mix} = 0$ and $\Delta H_{mix} = 0$ whereas in non ideal solutions, $\Delta V_{mix} \neq 0$ and $\Delta H_{mix} \neq 0$.

(ii) In ideal solutions, each component obeys Raoult's law at all temperatures and concentrations whereas in non ideal solutions, they do not obey Raoult's law.

(b) $$\Delta T_f = iK_f m = \frac{i \times K_f \times W_2 \times 1000}{M_2 \times W_1}$$

$$2 = \frac{2 \times 1.86 \times W_2 \times 1000}{58.5 \times 100} \Rightarrow W_2 = 3.145 \text{ g}$$

96. (a) The two characteristics of non-ideal solution are :

(i) They do not obey Raoult's law over the entire range of concentration.

(ii) The vapour pressure of non-ideal solution is either higher or lower than that predicted by Raoult's law.

(b) Given, $w_2 = 2$ g, $M_2 = 122$ g mol^{-1}, $w_1 = 25$ g,

$\Delta T_f = 1.62$ K, $K_f = 4.9$ kg mol^{-1}

$\Delta T_f = i K_f m$

$$1.62 = i \times 4.9 \times \frac{2}{122 \times 25} \times 1000$$

$$\Rightarrow \quad i = \frac{1.62 \times 122 \times 25}{4.9 \times 2 \times 1000} = 0.5042$$

$$\alpha_{association} = \frac{1 - i}{1 - \frac{1}{n}} = \frac{1 - 0.5042}{1 - \frac{1}{2}} = 0.4958 \times 2 = 0.9916$$

% of association = 0.9916 × 100 = 99.16%

97. $$\pi = iCRT = i \cdot \frac{n}{V} RT = i \times \frac{w}{M} \times \frac{1}{V} RT$$

or $$4.75 = i \times \frac{5.85}{58.5} \times \frac{1}{1} \times 0.082 \times 300 \text{ or } i = 1.93$$

$$\underset{\text{Initial moles}}{\text{NaCl}} \longrightarrow \underset{0}{\text{Na}^+} + \underset{0}{\text{Cl}^-}$$

$$\underset{\text{Moles at eqm.}}{C - C\alpha} \qquad \underset{C\alpha}{} \qquad \underset{C\alpha}{}$$

Total no. of moles = $C(1 + \alpha)$

$$i = \frac{C(1+\alpha)}{C} \text{ or } i = 1 + \alpha \text{ or } 1 + \alpha = 1.93$$

or $\alpha = 0.93$ or 93%

Concept Applied

➲ For dissociation, $i = 1 - \alpha + x\alpha + y\alpha$
for NaCl, $x = 1$, $y = 1$ so, $i = 1 + \alpha$

98. Given : $\alpha = 95\%$, $C = 0.1$ M, $T = 27°C = 300$ K,

$R = 0.0821$ L atm K^{-1} mol^{-1}

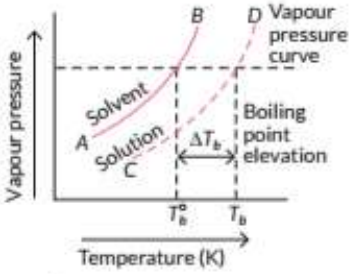
For Na_2SO_4, $\alpha_{dissociation} = \dfrac{i-1}{n-1}$

$$\frac{95}{100} = \frac{i-1}{3-1} \Rightarrow i = 2.9$$

$\pi = i CRT$

$\pi = 2.9 \times 0.1 \times 0.0821 \times 300 = 7.14$ atm

99. (a) Let T_b° is the boiling point of pure solvent and T_b is the boiling point of solution. The increase in the boiling point, $\Delta T_b = T_b - T_b^\circ$ is known as elevation of boiling point.



(b) Given, $W_2 = 25$ mg $= 25 \times 10^{-3}$ g

$M_2 = (2 \times 39) + 32 + (4 \times 16) = 174$ g mol^{-1},

$i = 3$, $V = 2$L, $T = 25°C = 25 + 273 = 298$ K

$$\pi = i CRT = 3 \times \frac{25 \times 10^{-3}}{174 \times 2} \times 0.0821 \times 298 = 5.27 \times 10^{-3} \text{ atm}$$

100. (i) The value of van't Hoff factor for ethanoic acid in benzene is close to 0.5 as two molecules of ethanoic acid associate to form a dimer in benzene solution.

$2CH_3COOH \rightleftharpoons (CH_3COOH)_2$

$$i = \frac{\text{Number of solute particles in solution}}{\text{Theoretical number of solute particles}}$$

$$= \frac{1}{2} = 0.5$$

(ii) It has been given that K_2SO_4 is completely dissociated. When K_2SO_4 is dissolved in water, K^+ and SO_4^{2-} ions are produced as shown:

$$K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}$$

Total number of ions produced = 3

$\therefore$ $i = 3$

Given,

$w = 2.32 \times 10^{-2}$ g; $V = 2$ L; $R = 0.082$ L atm K^{-1} mol^{-1}

$T = 25°C = (25 + 273)$ K $= 298$ K

Molar mass of $K_2SO_4 = (2 \times 39) + (1 \times 32) + (4 \times 16)$
$= 174$ g mol^{-1}

Applying the following relation,

$$\pi = i \frac{n}{V} RT$$

$$= i \times \frac{w}{M} \times \frac{1}{V} RT$$

$$= 3 \times \frac{2.32 \times 10^{-2}}{174} \times \frac{1}{2} \times 0.082 \times 298$$

$$= 4.8 \times 10^{-3} \text{ atm}$$

(iii) $\Delta T_f = iK_f m$

$$\Rightarrow \quad 0.512 = \frac{i \times 5.12 \times 25.6 \times 1000}{32 \times 1000}$$

$$\Rightarrow \quad i = \frac{0.512 \times 32 \times 1000}{5.12 \times 25.6 \times 1000}$$

$$i = \frac{1}{8} = 0.125$$

As 'i' is less than 1, therefore S is associated, *i.e.*, 8 moles of S are associated as shown $8S \leftrightarrow S_8$.
Therefore, the molecular formula of sulphur is S_8.

CBSE Sample Questions

1. (c) : Molarity is a mean to express concentration of solution. It is not a colligative property. **(0.77)**

2. (b): According to Le-Chatelier principle, solubility of gases in liquids decreases with rise in temperature because dissolution is an exothermic and reversible process. **(0.77)**

3. (b): Aquatic species are more comfortable in cold water rather than in warm water because the amount of dissolved oxygen in water decreases with rise in the water's temperature. **(1)**

4. (a) Henry's law : The partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution. **(1)**

$p = K_H x$

The pressure underwater is high, so the solubility of gases in blood increases. When the diver comes to surface, the pressure decreases and so does the solubility, causing bubbles of nitrogen in blood. To avoid this situation and maintain the same partial pressure of nitrogen underwater too, the dilution is done. **(1)**

(b) Using equation $p = K_H \times x$

Mole fraction of argon in water, $x = p/K_H = 6/40 \times 10^3$

$= 1.5 \times 10^{-4}$ **(1)**

5. (b): Raoult's law **(0.77)**

6. (c) : Let y_B be mole fraction of benzene in vapour phase.
y_T = Mole fraction of toluene in vapour phase.

$$y_{Benzene} = \frac{p_{Benzene}}{p_{Total}} ; y_{Toluene} = \frac{p_{Toluene}}{p_{Total}}$$

$p_{Benzene} = p^\circ_{Benzene}(x_{Benzene})$, $p_{Toluene} = p^\circ_{Toluene}(x_{Toluene})$

Since, $p^\circ_{Benzene} > p^\circ_{Toluene}$, $p_{Benzene} > p_{Toluene}$

Hence, $y_{Benzene} > y_{Toluene}$ **(1)**

7. (b): Nitric acid and water form maximum boiling azeotrope because they show large deviation from Raoult's law due to hydrogen bonding. **(1)**

8. (a): Fluid inside blood cells is isotonic with 0.9% NaCl solution. Hence, it will shrink when placed in water containing more than 0.9% (mass/volume) NaCl solution. **(0.77)**

9. (a): $\Delta T_f = T_f^\circ - T_f = 0 - (-14) = 14°C$, $\Delta T_f = K_f m$

$$\Delta T_f = K_f \times \frac{n_2 \times 1000}{w_1}$$

$$14 = 1.86 \times \frac{n_2 \times 1000}{1000} \Rightarrow n_2 = 7.5 \text{ mol} \quad \textbf{(0.77)}$$

10. (c) **(0.77)**

11. (c): Cryoscopic constant varies with type of solvent hence is not a universal constant. **(1)**

12. Given : $K_b = 0.52$ K kg mol^{-1}, boiling point of glucose, $\Delta T_b = 101.04°C$
As $\Delta T_b = T_b - T_b^\circ = 101.04°C - 100°C = 1.04°C$
$\Delta T_b = K_b m$

$$m = \frac{\Delta T_b}{K_b} = \frac{1.04}{0.52} = 2 \quad \textbf{(1)}$$

According to Raoult's law,
Relative lowering of vapour pressure = x_B
where x_B is mole fraction of solute.
Moles of glucose, $n_2 = 2$

Moles of water, $n_1 = \frac{1000}{18} = 55.56$

$\therefore$ Relative lowering of vapour pressure = $\frac{n_2}{n_2 + n_1}$ **(1/2)**

$$= \frac{2}{2 + 55.56} = \frac{2}{57.56} = 0.034 \quad \textbf{(1/2)}$$

13. The melting point of ice is the freezing point of water. We can use the depression in freezing point property in this case.
(a) In 3rd reading for 0.5 g, there has to be an increase in depression of freezing point and therefore, decrease in freezing point *i.e.*, decrease in melting point, when amount of salt is increased but the trend is not followed in this case. **(1)**
(b) Two sets of reading help to avoid error in data collection and give more objective data. **(1)**

(c) ΔT_f (glucose) = $1 \times K_f \times \frac{0.6 \times 1000}{180 \times 10}$

$$\Delta T_f (NaCl) = 2 \times K_f \times \frac{0.6 \times 1000}{58.5 \times 10}$$

$$\Rightarrow \quad 3.8 = 2 \times K_f \times \frac{0.6 \times 1000}{58.5 \times 10} \quad \textbf{(1)}$$

Dividing (i) by (ii)

$$\frac{\Delta T_f \text{ (glucose)}}{3.8} = \frac{58.5}{2 \times 180}$$

$$\Rightarrow \quad \Delta T_f = 0.62$$
$$\therefore \quad T_f = -0.62\,°C \quad \textbf{(1)}$$

OR

Depression in freezing point is directly proportional to molality (mass of solute when the amount of solvent remains same).
0.3 g of salt causes depression of 1.9 °C.
0.6 g of salt causes depression of 3.8 °C.
1.2 g of salt causes depression of 3.8 × 2 = 7.6 °C. **(2)**

Electrochemistry

(2025)

Q.1 Standard electrode potential for Sn^{4+}/Sn^{2+} couple is +0.15 V and that for the Cr^{3+}/Cr couple is -0.74 V. The two couples in their standard states are connected to make a cell. The cell potential will be

(1 Mark) (CBSE 2025 - 56/1/1)

A. +0.89 V

B. +0.18 V

C. +1.83 V

D. +1.19 V

Q.2 During electrolysis of dilute H_2SO^4, using platinum electrodes, the gas evolved at the anode is:

(1 Mark) (CBSE 2025 - 56/7/1)

A. O_2 gas

B. H_2 gas

C. SO_3 gas

D. SO_2 gas

Q.3 Match the type of cell given in Column I with their use given in Column II.

(1 Mark) (CBSE 2025 - 56/5/1)

Column I	**Column II**
i. Lead storage cell	a. Wall clock
ii. Mercury cell	b. Apollo Space Programme
iii. Dry cell	c. Wrist watch

iv. Fuel cell	d. Inverter

A. i-b, ii-a, iii-d, iv-c

B. i-d, ii-c, iii-a, iv-b

C. i-a, ii-b, iii-c, iv-d

D. i-c, ii-d, iii-b, iv-a

Q.4 Assertion (A) : For measuring resistance of an ionic solution an AC source is used.
Reason (R) : Concentration of ionic solution will change if DC source is used.

(1 Mark) (CBSE 2025 - 56/5/1)

A. Assertion (A) is false, but Reason (R) is true.

B. Assertion (A) is true, but Reason (R) is false.

C. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

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

Q.5 The charge required for the reduction of 1 mol of MnO^{-}_{4} to MnO2 is

(1 Mark) (CBSE 2025 - 56/2/1)

A. 5F

B. 1F

C. 3F

D. 6F

Q.6 Assertion (A) : Cu cannot liberate H_2 on reaction with dilute mineral acids.
Reason (R): Cu has positive electrode potential.

(1 Mark) (CBSE 2025 - 56/2/1)

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

B. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

C. Assertion (A) is false, but Reason (R) is true.

D. Assertion (A) is true, but Reason (R) is false.

Q.7 In an electrochemical cell, the following reaction takes place :

$$2Cu^{+}(aq) + Zn(s) \rightarrow 2Cu(s) + Zn^{2+}(aq)$$
$$E^{\circ}_{cell} = 1 \cdot 28\ V$$

As the reaction progresses, what will happen to the overall voltage of the cell?

(1 Mark) (CBSE 2025 - 56/4/1)

A. It will increase as $[Zn^{2+}]$ increases.

B. Voltage will remain constant.

C. It will decrease as $[Zn^{2+}]$ increases.

D. It will increase as [Cu+] increases.

Q.8 What amount of electric charge is required for the reduction of 1 mole of MnO^{-}_{4} into Mn^{2+} ?

(1 Mark) (CBSE 2025 - 56/4/1)

A. 5 F

B. 1 F

C. 4 F

D. 6 F

Q.9 Assertion (A) : Electrolysis of aqueous NaCl gives H_2 at cathode and Cl_2 at anode.

Reason (R): Chlorine has higher oxidation potential than H_2O

(1 Mark) (CBSE 2025 - 56/4/1)

A. Assertion (A) is false, but Reason (R) is true.

B. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

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

D. Assertion (A) is true, but Reason (R) is false.

Q.10 Which of the following cell converts the energy of combustion of fuel into electrical energy?

(1 Mark) (CBSE 2025 - 56/6/1)

A. Dry cell

B. Fuel cell

C. Lead storage cell

D. Mercury cell

Q.11

Concentration of KCl solution in mol/L	Conductivity at $298 \cdot 15\ \mathrm{K}$ in $\mathrm{S\,cm^{-1}}$	Molar Conductivity at $298 \cdot 15\ \mathrm{K}$ in $\mathrm{S\,cm^2\,mol^{-1}}$
1.000	0.1113	111.3
0.100	0.0129	129.0
0.010	0.00141	141.0

Based on the data given above, give plausible reason for the variation of conductivity and molar conductivity with concentration.

(2 Mark) (CBSE 2025 - 56/5/1)

Q.12 Define fuel cell. Give two advantages of fuel cell over ordinary cell.

(2 Mark) (CBSE 2025 - 56/4/1)

Q.13 (a) State the following :
(i) Kohlrausch law of independent migration of ions and
(ii) Faraday's first law of electrolysis.

(b) Using $E°_{values}$ of X and Y given below, predict which is better for coating the surface of iron to prevent corrosion and why?

Given
$E^{\circ}_{X^{2+}/X} = -2.36\ V$
$E^{\circ}_{Y^{2+}/Y} = -0.14\ V,$
$E^{\circ}_{Fe^{2+}/Fe} = -0.44\ V$

(3 Mark) (CBSE 2025 - 56/1/1)

Q.14 Write the name of the cell which is generally used in inverters. Write the reactions taking place at anode and cathode of this cell, when it is in use.

(3 Mark) (CBSE 2025 - 56/7/1)

Q.15 Explain why electrolysis of an aqueous solution of NaCl gives H_2 gas at cathode and Cl_2 gas at anode? Write overall reaction.

$\left(\text{Given } : E^{\circ}_{Na^+/Na} = -2.71\ V, E^{\circ}_{H_2O/H_2} = -0.83\ V,\ E^{\circ}_{Cl_2/2Cl^-} = +1.36\ V, \right.$
$\left. E^{\circ}_{H^+/O_2/H_2O} = +1.23\ V \right)$

(3 Mark) (CBSE 2025 - 56/7/1)

Q.16 The electrical resistance of a column of 0.05 M NaOH solution of area 0.8 cm^2 and length 40 cm is 5×10^3ohm. Calculate its resistivity, conductivity and molar conductivity.

(3 Mark) (CBSE 2025 - 56/2/1)

Q.17 Calculate the cell voltage of the voltaic cell which is set up by joining following half-cells at 25°C :

$Al/Al^{3+}(0 \cdot 001M)$ and $Ni/Ni^{2+}(0 \cdot 1M)$
Given : $E^{o}_{Ni^{2+}/Ni} = -0.25\ V, \quad E^{o}_{Al^{3+}/Al} = -1.66\ V$

(3 Mark) (CBSE 2025 - 56/4/1)

Q.18 Give reasons for the following :

(a) The pH of aqueous NaCl increases when it is electrolysed.

(b) Unlike dry cell, mercury cell has a constant cell potential through its lifetime.

(c) Conductivity of solution decreases with dilution.

(3 Mark) (CBSE 2025 - 56/6/1)

Q.19 (a) Write the cell reaction and calculate the e.m.f. of the following cell at 298 K :

$$\mathrm{Sn(s)\left|Sn^{2+}(0.004M)\right|\left|H^{+}(0.02M)\right|H_2(g)(1Bar)\mid Pt(s)}$$

$$\left(\text{Given : } \mathrm{E^{\circ}_{Sn^{2+}/Sn}} = -0.14\ \mathrm{V}, \mathrm{E^{\circ}}_{\mathrm{H^{+}|H_2}}(g), \mathrm{Pt} = 0.00\ \mathrm{V}\right)$$

(b) Account for the following ;

(i) On the basis of E° values, O_2 gas should be liberated at anode but it is Cl_2 gas which is liberated in the electrolysis of aqueous NaCl.

(ii) Conductivity of CH_3COOH decreases on dilution.

(5 Mark) (CBSE 2025 - 56/1/1)

Q.20 (a) Write the anode and cathode reactions and the overall cell reaction occurring in a lead storage battery during its use.

(b) Calculate the potential for half-cell containing 0.01 M $K_2Cr_2O_7(aq)$, 0.01M$Cr^{3+}(aq)$ and 1.0×10^{-4}M$H^{+}(aq)$.

The half cell reaction is:
$\mathrm{Cr_2O_7^{2-}(aq) + 14H^{+}(aq) + 6e^{-} \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)}$ and the standard electrode potential is given as $\mathrm{E^{\circ}} = 1.33\ \mathrm{V}$.
[Given : $\log 10 = 1$]

(5 Mark) (CBSE 2025 - 56/1/1)

Q.21 (a) (i) Calculate the emf of the following cell at 25°C:

$$\mathrm{Zn(s)\left|Zn^{2+}(0.1M)\right\|H^{+}(0.01M)\left|H_2(g)(1\ bar),Pt(s)\right.}$$

$$\left[\text{Given : } E^{\circ}_{Zn^{2+}/Zn} = -0.76\ V, E^{\circ}_{2H^{+}/H_2} = 0.00\ V, \log 10 = 1\right]$$

(ii) State Faraday's second law of electrolysis. How much electricity is required in terms of Faraday for the reduction of 1 mol of

$Cr_2O_7^{2-}$
to
Cr^{3+}
?

(5 Mark) (CBSE 2025 - 56/7/1)

Q.22 (b) Answer the following questions :

(i) The conductivity of 0.20 M solution of KCl is 2.48×10^{-2} S Cm^{-1}. Calculate its molar conductivity and degree of dissociation (α).

[Given :

$$\lambda^{\circ}_{(K^{+})} = 73.5\ S\ cm^2\ mol^{-1}$$

$$\lambda^{\circ}_{(Cl^{-})} = 76.5\ S\ cm^2\ mol^{-1}\Big]$$

(ii) Calculate
$\Delta_r G^{\circ}$
of the following cell :

$$Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$$

[Given :

$$E^{\circ}_{Mg^{2+}/Mg} = -2 \cdot 37\ V, \quad E^{\circ}_{Cu^{2+}/Cu} = +0 \cdot 34\ V$$

$$1\ F = 96500 C\ mol^{-1}\Big]$$

(iii) What type of cell is mercury cell ? Why is it more advantageous than dry cell?

(5 Mark) (CBSE 2025 - 56/7/1)

Q.23 (i) For a galvanic cell, the following half reactions are given. Decide, which will remain as reduction reaction and which will be reversed to become an oxidation reaction. Give reason for your answer.

$$Cr^{3+} + 3e^- \rightarrow Cr(s); E^\circ = -0 \cdot 74\ V$$
$$Fe^{2+} + 2e^- \rightarrow Fe(s); E^\circ = -0 \cdot 44\ V$$

(ii) Represent the cell in which the following reaction takes place:

$$Mg(s) + 2Ag^+(0 \cdot 001M) \rightarrow Mg^{2+}(0 \cdot 100M) + 2Ag(s$$

Calculate
E_{cell}
if
$E^\circ_{cell} = 3 \cdot 17\ V. (\log 10 = 1)$

(5 Mark) (CBSE 2025 - 56/5/1)

Q.24

(i) State Kohlrausch's law. Give any two applications of it.
(ii) $\wedge^\circ_m NH_4Cl$, $\wedge^\circ_m NaOH$ and $\wedge^\circ_m NaCl$ are $129 \cdot 8, 217 \cdot 4$, and $108.9\ S\ cm^2\ mol^{-1}$ respectively. Molar conductivity of $1 \times 10^{-2} M$ solution of NH_4OH is $9.33\ S\ cm^2\ mol^{-1}$. Calculate the degree of dissociation (α) of NH_4OH solution at this concentration.

(5 Mark) (CBSE 2025 - 56/5/1)

Q.25

(a) Calculate the standard Gibbs energy
$(\Delta_r G^\circ)$
of the following reaction at
$25^\circ C$
:

$$Au(s) + Ca^{2+}(1M) \rightarrow Au^{3+}(1M) + Ca(s)$$
$$E^\circ_{Au^{3+}/Au} = +1.5\ V, E^\circ_{Ca^{2+}/Ca} = -2.87\ V$$

Predict whether the reaction will be spontaneous or not at 25°C.

$[1\ \mathrm{F} = 96500\mathrm{C\ mol^{-1}}]$

(b) Tarnished silver contains Ag_2S.
Can this tarnish be removed by placing tarnished silverware in an aluminium pan containing an inert electrolytic solution such as NaCl ? The standard electrode potential for half reaction :

$$\mathrm{Ag_2\ S(\ s) + 2e^- \longrightarrow 2Ag(s) + S^{2-}}$$
is -0.71 V and for
$$\mathrm{Al^{3+} + 3e^- \longrightarrow 2Al(\ s)\ is\ -1.66\ V}$$

(5 Mark) (CBSE 2025 - 56/2/1)

Q.26 (a) Define the following :

(i) Cell potential
(ii) Fuel cell

(b) Calculate emf of the following cell at 25°C:

$$\mathrm{Zn(\ s)\left|Zn^{2+}_{(0.1M)}\right|\left|Cd^{2+}_{(0.01M)}\right|Cd(\ s)}$$
$$\mathrm{Given : E^\circ_{Cd^{2+}/Cd} = -0.40\ V}$$
$$\mathrm{E^\circ_{Zn^{2+}/Zn} = -0.76\ V}$$
$$[\log 10 = 1]$$

(5 Mark) (CBSE 2025 - 56/2/1)

Q.27 (i) Calculate E_{cell} of a galvanic cell in which the following reaction takes place at 25°C:

$$\mathrm{Zn(\ s) + Pb^{2+}(0\cdot 02M) \longrightarrow Zn^{2+}(0\cdot 1M) + Pb(\ s)}$$
$$[\ \mathrm{Given\ : E^\circ_{Zn}{}^{2+}/Zn = -0\cdot 76\ V, E^\circ_{Pb}{}^{2+}/Pb = -0\cdot 13\ V;}$$
$$\log 2 = 0\cdot 3010, \log 4 = 0\cdot 6021, \log 5 = 0\cdot 6990]$$

(ii) State Faraday's first law of electrolysis. How much electricity, in terms of Faraday, is required to reduce one mol of

MnO_4^-
to
Mn^{2+}
ion?

(5 Mark) (CBSE 2025 - 56/6/1)

Q.28 (i) The resistance of a conductivity cell containing 0.001 M KCl solution at 298 K is 1000 ohm. What is the cell constant if conductivity of 0.001 M KCl solution at 298 K is 0.125×10^{-3} S cm^{-1} ?

(ii) Calculate the $E_{Mg^{2+}/Mg}$ potential for the following half cell at 25°C :

$Mg/Mg^{2+}\left(1 \times 10^{-4}M\right)$; $E_{Mg^{2+}/Mg} = +2 \cdot 36$ V
[Given : $\log 10 = 1$]

(iii) What is the effect of temperature on the electrical conductance of metallic conductor?

(5 Mark) (CBSE 2025 - 56/6/1)

Answer

Q.1 A

Q.2 A

Q.3 B

Q.4 C

Q.5 C

Q.6 B

Q.7 C

Q.8 A

Q.9 D

Q.10 B

Q.11 Conductivity decreases with decrease in concentration
Due to decrease in number of current carrying ions per unit volume.
Molar conductivity increases with decrease in concentration
Due to decrease in inter-ionic attraction or increase in dissociation or increase in number of ions.

Q.12 Galvanic cell which converts the energy of combustion of fuels directly into electrical energy.
Advantages 1. High efficiency
2. Pollution free (or any other two correct advantages)

Q.13 (a) (i) The limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolyte.

(ii) The amount of chemical reaction which occurs at any electrode during electrolysis by a current is proportional to the quantity of electricity passed through the electrolyte.

(b) 'X' is better, as X has more negative electrode potential than Fe/X has more oxidation potential than Fe.

Q.14

(a) Lead storage battery

Anode: $\mathrm{Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(\,s) + 2e^-}$

Cathode: $\mathrm{PbO_2(\,s) + {SO_4}^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(\,s) + 2H_2O(1)}$

Q.15 (b)Because at cathode the reaction with higher value of E° is preferred and therefore, the reduction of H_2O to H_2 gas is preferred whereas at anode water should get oxidised in preference to $Cl^-(aq)$, however, on account of overpotential of oxygen, oxidation of Cl^- to Cl_2 gas is preferred.

$$\mathrm{NaCl(aq) + H_2O(l) \rightarrow Na^+(aq) + OH^-(aq) + 1/2H_2(\,g) + 1/2Cl_2(\,g)}$$

Q.16

$$
\begin{aligned}
\rho &= \frac{RA}{l} \\
&= \frac{5 \times 10^3 \times 0.8}{40} \\
&= \mathbf{100\Omega\ cm} \\
\kappa &= \frac{1}{\rho} \\
&= \frac{1}{100} \\
&= 10^{-2}\ \mathrm{S\ cm} - 1 \\
\Lambda_m &= \frac{\kappa \times 1000}{\mathbf{C}} \\
&= \frac{10^{-2} \times 1000}{0.05} \\
&= 2 \times 10^2\ \mathrm{S\ cm^2\ mol^{-1}}
\end{aligned}
$$

Q.17

$$
\begin{aligned}
&2\mathrm{Al} + 3\mathrm{Ni}^{2+} \rightarrow 2\mathrm{Al}^{3+} + 3\mathrm{Ni} \\
&\mathrm{E}^\circ \text{ cell } = \mathrm{E}^\circ \mathrm{Ni}^{2+}/\mathrm{Ni} - \mathrm{E}^\circ{}_{\mathrm{Al}^{3+}}/\mathrm{Al} \quad ; \mathrm{E}^\circ \text{ cell } = -0.25 - (-1.66) = 1.41\ \mathrm{V} \\
&\mathrm{n} = 6 \\
&\mathrm{E_{cell}} = \mathrm{E}^\circ{}_{\text{cell}} \frac{-2.303\mathrm{RT}}{\mathrm{nF}} \log \frac{\left[\mathrm{Al}^{3+}\right]^2}{\left[\mathrm{Ni}^{2+}\right]^3} \\
&\mathrm{E_{cell}} = 1.41 - \frac{0.059}{6} \log \frac{[0.001]^2}{[0.1]^3} \\
&\mathrm{E_{cell}} = 1.41 - \frac{0.059}{6} \log \frac{[10]^{-6}}{[10]^{-3}} \\
&\mathrm{E_{cell}} = 1.41 - \frac{0.059}{6} \log 10^{-3} \\
&\mathrm{E_{cell}} = 1.41 - (-0.0295) \\
&\mathrm{E_{cell}} = 1.41 + 0.0295 \\
&\mathrm{E_{cell}} = 1.439\ \mathrm{V} / 1.44\ \mathrm{V} \quad \text{(Deduct 1/2 mark for no or incorrect unit)}
\end{aligned}
$$

Q.18 a) Because of the formation of NaOH/ Due to the formation of OH^-ions.
b) Because the overall reaction does not involve any ion in solution whose concentration can change during its life time.
c) Because the number of ions per unit volume that carry current in a solution decreases.

Q.19

((a) The cell reaction is

$$\mathrm{Sn}(\mathrm{s}) + 2\mathrm{H}^+(\mathrm{aq}) \rightarrow \mathrm{Sn}^{2+}(\mathrm{aq}) + \mathrm{H}_2(\mathrm{g})$$

$$\mathrm{E_{Cell}} = (E^o{}_c - E^o{}_a) - \frac{0.059}{2}\log\frac{[Sn^{2+}]}{[H^+].^2}$$

$$= [(0) - (-0 \cdot 14)] - \frac{0.059}{2}\log\frac{0.004}{(0.02).^2}$$
$$= 0.14 - 0.0295\log 10$$
$$= 0.1105\ \mathrm{V}$$

(b) (i) overpotential of O_2

(ii) Number of ions carrying current per unit volume decreases on dilution

Q.20 a) At anode:

$$\mathrm{Pb} + \mathrm{SO_4}^{-2} \rightarrow \mathrm{PbSO_4} + 2\mathrm{e}-$$

At cathode:

$$\mathrm{PbO_2} + \mathrm{SO_4^{-2}} + 4\mathrm{H^+} + 2\mathrm{e}- \rightarrow \mathrm{PbSO_4} + 2\mathrm{H_2O}$$

Overall reaction:

$$\mathrm{Pb} + \mathrm{PbO_2} + 2\mathrm{SO_4^{-2}} + 4\mathrm{H^+} \rightarrow 2\mathrm{PbSO_4} + 2\mathrm{H_2O}$$

(b)

$$\mathrm{E_{Cell}} = \mathrm{E^{\circ}_{Cell}} = \frac{\mathbf{0.059}}{\mathbf{n}} \log \left[\frac{\left[Cr^{3+}\right]^2}{[\mathbf{Cr\,2O^{2-}}][H+]^{14}} \right]$$

$$\begin{aligned}
\text{Ecell} &= 1.33 - \frac{0.059}{6} \log \left(10^{-2}\right)^2 / \left(10^{-2}\right)\left(1 \times 10^{-4}\right)^{14} \\
&= 1.33 - \frac{0.059}{6}(54) \log 10 \\
&= 1.33 - 0.059 \times 9 \\
&= 1.33 - 0.531 \\
&= 0.799 \text{ V}
\end{aligned}$$

Q.21 (a) (i)

$$\begin{aligned}
\mathrm{E_{Cell}} &= (E^o{}_c - E^o{}_a) - \tfrac{0.059}{2} \log \tfrac{[Zn^{2+}]}{[H^+].^2} \\
&= [(0) - (-0 \cdot 76)] - \frac{0.059}{2} \log \frac{0.1}{(0.01) \cdot ^2} \\
&= 0.76 - 0.0295 \log 10^3 \\
&= 0.76 - 0.0885 \\
&= 0.6715 \text{ V} \quad \text{or } 0.67 \text{ V}
\end{aligned}$$

(Deduct ½ mark for no or incorrect unit)

(ii) The amounts of different substances liberated by the same quantity of electricity passing through the electrolytic solution are proportional to their chemical equivalent weights.

Q.22

$$\begin{aligned}
\Lambda_m &= \frac{K}{C} \times 1000 \\
\Lambda_m &= \frac{2.48 \times 10^{-2}}{0.2} \times 1000 \\
&= 124 \mathrm{Scm^2\ mol^{-1}}
\end{aligned}$$

$$\Lambda^0_m = \lambda^+_{\mathrm{K^0}} + \lambda^-_{\mathrm{Cl^-}}$$

$$= 73.5 + 76.5$$
$$= 150S\ \text{cm}^2\ \text{mol}^{-1}$$

$$\alpha = \frac{\Lambda_m}{\Lambda_m^\circ}$$
$$= \frac{\mathbf{124}}{\mathbf{150}}$$
$$= 0.827$$

(ii)

$$\mathrm{E^0{}_{cell}} = \mathrm{E^0{}_{cathode}} - \mathrm{E^0\ anode}$$
$$= 0.34 - (-2.37)$$
$$= 2.71\ \text{V}$$

$$\Delta_r G^0 = -\mathrm{nFE^0\ cell}$$
$$= -2 \times 96500 \times 2.71$$
$$= -523030\,\mathrm{Jmol^{-1}} \text{ or } -523.03\,\mathrm{kJmol^{-1}}$$

(iii) Primary cell

Maintains constant potential throughout its usage/ longer lifespan

Q.23 (i) (II) will remain as reduction reaction / (II)

(I) will be reversed to become an oxidation reaction

Due to low reduction potential of Cr

(ii) Cell representation

$$\mathrm{Mg(s)/Mg^{2+}(aq, 0.100M)\|Ag^{+}(aq, 0.001M)/Ag(s)}$$

$$n = 2$$

$$\begin{aligned}
\text{Ecell} &= \text{E}^\circ \text{ cell} - \frac{2.303\text{RT}}{\text{nF}} \log \frac{\left[\text{Mg}^{2+}\right]}{\left[\text{Ag}^{+}\right]^2} \\
&= 3.17 - \frac{0.059}{2} \log \frac{0.100}{(0.001)^2} \\
&= 3.17 - \frac{0.059}{2} \log 10^5 \\
&= 3.17 - 0.0295 \times 5 \\
&= 3.17 - 0.1475 \\
&= 3.0225 \text{ V or } 3.02 \text{ V}
\end{aligned}$$

Q.24 (i) Limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolyte.

To determine -1. Limiting molar conductivity of an electrolyte.

2.Dissociation constant of a weak electrolyte

(or any other two suitable applications)

$$\begin{aligned}
\text{i)}\Lambda^\circ\text{mNH4OH} &= \Lambda^\circ\text{mNH4Cl} + \Lambda^\circ\text{mNaOH} - \Lambda^\circ\text{mNaCl} \\
&= 129.8 + 217.4 - 108.9 \\
&= 238.3 \text{Scm}^2 \text{ mol}^{-1}
\end{aligned}$$

$$\alpha = \frac{\Lambda m^c}{\Lambda^\circ m}$$

$$= \frac{9.33}{238.3}$$

$$= 0.039/3.9\%$$

Q.25

$$
\begin{aligned}
\text{(a) } \mathrm{E^\circ_{cell}} &= \mathrm{E^\circ_{cathode}} - \mathrm{E^\circ_{anode}} \\
&= -2.87 - 1.5 \text{ V} \\
&= -4.37 \text{ V} \\
\Delta \mathrm{G^0} &= -\mathrm{nFE^\circ C_{ell}} \\
&= -6 \times 96500 \times (-4.37) \\
&= 2530.230 \text{ kJ/mol}
\end{aligned}
$$

Reaction is non-spontaneous.

(b) Yes, the tarnish can be removed.

Aluminium has more negative standard electrode potential than silver so will reduce silver sulphide to silver, tarnish will be removed.

$$
\begin{aligned}
&3\mathrm{Ag^+} + \mathrm{Al} \longrightarrow 3\mathrm{Ag} + \mathrm{Al^{3+}} \\
&\mathrm{E^\circ C_{ell}} = \mathrm{E^\circ_{cathode}} - \mathrm{E^\circ_{anode}} \\
&\qquad = -0.71 - (-1.66)\mathrm{V} \\
&\qquad = 0.95 \text{ V}
\end{aligned}
$$

This indicates that the reaction is feasible and tarnish can be removed.

Q.26 (a) (i) Potential difference between two electrodes of a galvanic cell.

(ii) The galvanic cell in which combustion energy of fuels is directly converted into electrical energy.

(b)

$$
\begin{aligned}
&\mathrm{n} = 2 \\
&\mathrm{E^\circ_{cell}} = \mathrm{E^\circ_{cathode}} - \mathrm{E^\circ \text{ anode}} \\
&\qquad = -0.40 - (-0.76)\mathrm{V} \\
&\qquad = 0.36 \text{ V} \\
&\mathrm{E_{Cell}} = \mathrm{E^\circ_{celi}} - \frac{\mathbf{0.059}}{\mathbf{2}} \log \left[\frac{\boldsymbol{Zn^{2+}}}{\boldsymbol{cd^{2+}}} \right]
\end{aligned}
$$

$$= [\mathbf{0.36}] - \frac{\mathbf{0.059}}{\mathbf{2}} \log \frac{\mathbf{0.1}}{\mathbf{0.01}}$$
$$= (\mathbf{0 \cdot 36 - 0 \cdot 0295})$$
$$= \mathbf{0.3305\ V}$$

(Deduct ½ mark for no or incorrect unit)

Q.27 (i)

$$\mathrm{E_{Cell}} = (E^o{}_c - E^o{}_a) - \frac{0.059}{2} \log \left[\frac{Zn^{2+}}{Pb^{2+}} \right]$$
$$= [(-0 \cdot 13) - (-0 \cdot 76)] - \frac{0.059}{2} \log \frac{0.1}{0.02}$$
$$= 0.63 - 0.0295 \log 5$$
$$= 0.63 - 0.0295 \times 0.699$$
$$= 0.63 - 0.02$$
$$= 0.61\ \mathrm{V}$$
(Deduct 1/2 mark for no or incorrect unit)

(ii) The amount of chemical reaction which occurs at any electrode during electrolysis by a current is proportional to the quantity of electricity passed through the electrolyte.

Q.28 (i)

$$\mathrm{k} = \mathrm{G}^*/\mathrm{R}$$
$$\mathrm{G}^* = \mathrm{k} \times \mathrm{R} = 0.125 \times 10^{-3} \times 1000$$
$$= 0.125\ \mathrm{cm}^{-1}$$

(ii)

$$\mathrm{E}^{2+}_{\mathrm{Mg}^{2+}}/\mathrm{Mg} = \mathrm{E}^0\mathrm{Mg}^{2+}/\mathrm{Mg} - \frac{0.059}{2} \log \frac{1}{[\mathrm{Mg}^{2+}]}$$
$$= 2.36\ \mathrm{V} - \frac{0.059}{2} \log \frac{1}{10^{-4}}$$
$$= 2.36 - 0.0295 \times 4 \log 10$$
$$= 2.242\ \mathrm{V}$$

(iii) It decreases with increase in temperature

(2024)

Q.1 Which of the following cell was used in Apollo space programme?

(1 Mark) (CBSE 2024 - 56/5/1)

A. Mercury cell

B. $H_2 - O_2$ fuel cell

C. Ni-Cd cell

D. Dry cell

Q.2 Dilution affects both conductivity as well as molar conductivity. Effect of dilution on both is as follows:

(1 Mark) (CBSE 2024 - 56/5/1)

A. conductivity decreases whereas molar conductivity increases on dilution.

B. both increase with dilution.

C. conductivity increases whereas molar conductivity decreases on dilution.

D. both decrease with dilution.

Q.3 During the electrolysis of aqueous NaCl , the cathodic reaction is :

(1 Mark) (CBSE 2024 - 56/3/1)

A. Oxidation of H_2O

B. Reduction of Na^+ion

C. Reduction of H_2O

D. Oxidation of Cl^-ion

Q.4 The molar ionic conductivities of Ca^{2+} and Cl^- are 119.0 and 76.3 S cm^2mol^{-1} respectively. The value of limiting molar conductivity of $CaCl_2$ will be :

(1 Mark) (CBSE 2024 - 56/4/1)

A. 271.6 S cm^2 mol^{-1}

B. 43.3 S cm^2 mol^{-1}

C. 314.3 S cm^2 mol^{-1}

D. 195.3 S cm^2 mol^{-1}

Q.5 Assertion (A) : For a Daniell cell, $Zn/Zn^{2+}(1M)\ ||Cu^{2+}(1M)/Cu$ with E° cell = 1.1 V=1.1 V, if the external opposing potential is more than 1.1 V, the electrons flow from Cu to Zn.
Reason (R) : Cell acts like a galvanic cell.

(1 Mark) (CBSE 2024 - 56/4/1)

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

B. Assertion (A) is true, but Reason (R) is false.

C. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

D. Assertion (A) is false, but Reason (R) is true.

Q.6 During electrolysis of aqueous solution of NaCl :

(1 Mark) (CBSE 2024 - 56/2/1)

A. Na is formed at cathode

B. $Cl_2(g)$ is liberated at cathode

C. O2(g) is liberated at anode

D. $H_2(g)$ is liberated at cathode

Q.7 State:
(a) Kohlrausch law of independent migration of ions.
(b) Faraday's first law of electrolysis.

(2 Mark) (CBSE 2024 - 56/5/1)

Q.8 Resistance of a conductivity cell filled with 0.2 mol L^{-1}KCl solution is 200Ω. If the resistance of the same cell when filled with 0.05 mol L^{-1}KCl solution is 620Ω, calculate the conductivity and molar conductivity of 0.05 mol L^{-1}KCl solution. The conductivity of 0.2 mol L^{-1}KCl solution is 0.0248 S cm^{-1}.

(2 Mark) (CBSE 2024 - 56/5/1)

Q.9 Calculate the potential of Iron electrode in which the concentration of Fe^{2+} ion is 0.01 M.

(2 Mark) (CBSE 2024 - 56/1/1)

$\left(E^0 Fe^{2+}/Fe = -0.45 \text{ V at } 298 \text{ K}\right)$
[Given : $\log 10 = 1$]

Q.10

Calculate the emf of the following cell :
$Ni(s) + 2Ag^+(0.01M) \longrightarrow Ni^{2+}(0.1M) + 2Ag(s)$
Given that $E^\circ_{cell} = 1.05 \text{ V}, \log 10 = 1$

(3 Mark) (CBSE 2024 - 56/5/1)

Q.11 When a certain conductivity cell was filled with 0.05 M KCl solution, it has a resistance of 100 ohm at 25°C. When the same cell was filled with 0.02M$AgNO_3$ solution, the resistance was 90 ohm. Calculate the conductivity and molar conductivity of $AgNO_3$ solution.

(Given : Conductivity of 0.05 M KCl solution = 1.35×10^{-2}ohm^{-1} cm^{-1})

(3 Mark) (CBSE 2024 - 56/1/1)

Q.12

The conductivity of
$0 \cdot 2M$
solution of KCl is
$2 \cdot 48 \times 10^{-2} \text{ S cm}^{-1}$
. Calculate its molar conductivity and degree of dissociation
(α)

Given:

$$\lambda^{\circ}_{K^+} = 73 \cdot 5 \text{ S cm}^2 \text{ mol}^{-1}$$
$$\lambda^{\circ}_{Cl^-} = 76 \cdot 5 \text{ S cm}^2 \text{ mol}^{-1}$$

(3 Mark) (CBSE 2024 - 56/3/1)

Q.13

Calculate emf of the following cell at $25^{\circ}C$:
$Sn/Sn^{2+}(0.001M)||H^+(0.01M) \mid H_{2(g)}(1 \text{ bar})| Pt_{(s)}$
Given : $E^{\circ}\left(Sn^{2+}/Sn\right) = -0.14 \text{ V}, E^{\circ}H^+/H_2 = 0.00 \text{ V} (\log 10 = 1)$

(3 Mark) (CBSE 2024 - 56/4/1)

Q.14

Calculate emf of the following cell :
$Zn(s) \left|Zn^{2+}(0 \cdot 1M)\right| \left|Sn^{2+}(0 \cdot 001M)\right| Sn(s)$
Given : $E^0_{Zn^{2+}/Zn} = -0.76 \text{ V}, \quad E^0_{Sn^{2+}/Sn} = -0.14 \text{ V}$
$[\log 10 = 1]$

(3 Mark) (CBSE 2024 - 56/2/1)

Q.15 Batteries and fuel cells are very useful forms of galvanic cell. Any battery or cell that we use as a source of electrical energy is basically a galvanic cell. However, for a battery to be of practical use it should be reasonably light, compact and its voltage should not vary appreciably during its use. There are mainly two types of batteries - primary batteries and secondary batteries.

In the primary batteries, the reaction occurs only once and after use over a period of time the battery becomes dead and cannot be reused again, whereas the secondary batteries are rechargeable.

Production of electricity by thermal plants is not a very efficient method and is a major source of pollution. To solve this problem, galvanic cells are designed in such a way that energy of combustion of fuels is directly converted into

electrical energy, and these are known as fuel cells. One such fuel cell was used in the Apollo space programme.

(a) How do primary batteries differ from secondary batteries?
(b) The cell potential of Mercury cell is 1.35 V, and remains constant during its life. Give reason.
(c) Write the reactions involved in the recharging of the lead storage battery.

Question 2: (c) Write two advantages of fuel cells over other galvanic cells.

(4 Mark) (CBSE 2024 - 56/1/1)

Q.16 In a galvanic cell, chemical energy of a redox reaction is converted into electrical energy, whereas in an electrolytic cell the redox reaction occurs on passing electricity. The simplest galvanic cell is in which Zn rod is placed in a solution of $ZnSO_4$ and Cu rod is placed in a solution of $CuSO_4$.

The two rods are connected by a metallic wire through a voltmeter. The two solutions are joined by a salt bridge. The difference between the two electrode potentials of the two electrodes is known as electromotive force. In the process of electrolysis, the decomposition of a substance takes place by passing an electric current. One mole of electric charge when passed through a cell will discharge half a mole of a divalent metal ion such as Cu^{2+}. This was first formulated by Faraday in the form of laws of electrolysis.

(a) What is the function of a salt bridge in a galvanic cell ?
(b) When does galvanic cell behave like an electrolytic cell ?

(c) Can copper sulphate solution be stored in a pot made of zinc ? Explain with the help of the value of E° cell.

$$\left(\mathrm{E}^{\circ}\mathrm{Cu}^{2+}/\mathrm{Cu} = 0.34\ \mathrm{V}\right)$$
$$\left(\mathrm{E}^{\circ}\mathrm{Zn}^{2+}/\mathrm{Zn} = -0.76\ \mathrm{V}\right)$$

(4 Mark) (CBSE 2024 - 56/4/1)

Q.17 (a) (i) Calculate emf of the following cell at 25°C :

$$Zn(s)\left|Zn^{2+}(0\cdot001M)\right|\left|Cd^{2+}(0\cdot1M)\right|Cd(s)$$

Given : $E^{o}_{Zn^{2+}/Zn} = -0\cdot76\ V, E^{o}_{Cd^{2+}/Cd} = -0\cdot40\ V \quad [\log 10 = 1]$

(ii) State Faraday's second law of electrolysis. How will the pH of aqueous NaCl solution be affected when it is electrolysed ?

(5 Mark) (CBSE 2024 - 56/3/1)

Q.18

(b) (i) Calculate the
$\Delta_r G^o$
and
$\log K_c$
for the following cell reaction :

$$Fe(s) + Ag^{+}(aq) \rightleftharpoons Fe^{2+}(aq) + Ag(s)$$

Given : $E^{o}_{Fe^{2+}/Fe} = -0\cdot44\ V, \quad E^{o}_{Ag^{+}/Ag} = +0\cdot80\ V$

$1\ F = 96500 C\ mol^{-1}$

(ii) Write any two advantages of the fuel cells over primary and secondary batteries?

(iii) How many Faradays are required for the oxidation of 1 mole of H_2O to O_2 ?

(5 Mark) (CBSE 2024 - 56/3/1)

Q.19 (a) (i) The resistance of 0.05MCH_3COOH solution is found to be 100 ohm. If the cell constant is 0.0354 cm^{-1}, calculate the molar conductivity of the acetic acid solution.

(ii) State Faraday's first law of electrolysis. How much charge in Faraday is required for the reduction of 1 mol of MnO^{-}_{4} to Mn^{2+}?

(5 Mark) (CBSE 2024 - 56/2/1)

Q.20 (b) (i) The conductivity of 0.0025 mol L^{-1} acetic acid is 5.25×10^{-5} S cm^{-1}. Calculate its degree of dissociation if Λ^{o}_{m} for acetic acid is 390 S cm^2 mol^{-1}.

(ii) Write anode, cathode and overall reaction of lead storage battery.

(5 Mark) (CBSE 2024 - 56/2/1)

Answer

Q.1 B

Q.2 A

Q.3 C

Q.4 A

Q.5 B

Q.6 D

Q.7

a) Limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolyte / $\Lambda_m^\circ = v_+\lambda_+^\circ + v_-\lambda_-^\circ$ Here, $\lambda^\circ+$ and $\lambda^\circ-$ are the limiting molar conductivities of the cation and anion respectively.

b) The amount of chemical reaction which occurs at any electrode during electrolysis by a current is proportional to the quantity of electricity passed through the electrolyte. / m=ZIt where $\mathrm{m} =$ mass of the substance deposited , $\mathrm{Z} =$ electrochemical equivalent, $\mathrm{I} =$ current, $\mathrm{t} =$ time.

Q.8

$$\text{Cell constant } = G^* = \text{ conductivity } \times \text{ resistance } = 0.0248\ \mathrm{S/cm} \times 200\ \mathrm{ohm}$$
$$= 4.96\ \mathrm{cm}^{-1}$$

Conductivity of $0.05\ \mathrm{mol\ L^{-1}KCl}$ solution = cell constant / resistance

$$= *G/R = 4.96/620 = 0.008\ \mathrm{S\ cm^{-1}}$$

Molar conductivity $= \Lambda_\mathrm{m} = \frac{k \times 1000}{c}$

$$= 0.008 \times 1000/0.05 = 160\ \mathrm{S\ cm^2\ mol^{-1}}$$

Q.9

$$\mathrm{E}_{\mathrm{Fe}^{2+}/\mathrm{Fe}} = \mathrm{E}_{\mathrm{Fe}^{2+}/\mathrm{Fe}^{-\frac{0.059}{2}\log\frac{1}{[\mathrm{Fe}^{2+}]}}}$$

$$= -0.45\ \mathrm{V} - \frac{0.059}{2}\log\frac{1}{0.01}$$

$$= -0.45\ \mathrm{V} - 0.059\ \mathrm{V}$$

$$= -0.509\ \mathrm{V}$$

Q.10

$$\mathrm{E}^0{}_{\mathrm{cell}} = 1.05\ \mathrm{V}$$

$$\mathrm{E}_{\mathrm{cell}} = 1.05 - \frac{0.059}{2}\log\frac{[\mathrm{Ni}]^{2+}}{[\mathrm{Ag}+]^2}$$

$$= 1.05 - 0.059/2\log\frac{(0.1)}{(0.01)^2}$$

$$= 1.05 - 0.0825$$

$$= 0.9615\ \mathrm{V}(\text{ Deduct } 1/2 \text{ mark for incorrect unit or no unit })$$

Q.11

Cell constant
$(\mathrm{G}^*) =$
Conductivity
$\times$
Resistance

$$= 1.35 \times 10^{-2} \times 100$$

$$= 1.35\ \mathrm{cm}^{-1}$$

Cell constant
$(\mathrm{G}^*) =$
Conductivity
$\times$
Resistance

$$1.35\ \mathrm{cm}^{-1} = \mathrm{k} \times 90$$

$$1.35/90 = \mathrm{k}$$

$$\mathrm{k} = 0.015\mathrm{Scm}^{-1}$$

Molar conductivity
$(\Lambda_m) = k \times 1000/C$

$$= \frac{0.015 \times 1000}{0.02}$$
$$= 750 Scm^2/mol$$

(Deduct
$1/2$
mark for no unit or incorrect unit)

Q.12

$$\Lambda_m = k/C$$
$$\Lambda_m = \frac{kx1000}{M}$$
$$= \frac{1000\ cm^3/L \times 2.48 \times 10^{-2} Scm^{-1}}{0.2\ mol\ L^{-1}}$$
$$= 124\ S\ cm^2\ mol^{-1}$$

$$\Lambda_m^\circ = \lambda_+^\circ + \lambda_-^\circ$$
$$= (73.5 + 76.5) Scm^2\ mol^{-1}$$
$$= 150\ S\ cm^2\ mol^{-1}$$
$$\alpha = \Lambda_m/\Lambda_m^\circ$$
$$= \frac{124\ S\ cm^2\ mol^{-1}}{150\ S\ cm^2\ mol^{-1}}$$
$$= 0.826\ (approx.)$$

Q.13

$$\mathrm{E_{cell}} = \mathrm{E^{o}_{cell}} - \frac{0.059}{2}\log\frac{\left[\mathrm{Sn^{2+}}\right]}{\left[\mathrm{H^{+}}\right]^{2}}$$

$$\mathrm{E^{o}_{cell}} = 0 - (-0.14\ \mathrm{V}) = 0.14\ \mathrm{V}$$

$$\mathrm{E_{cell}} = 0 \cdot 14 - \frac{0.059}{2}\log\frac{(0.001)}{(0.01)^{2}}$$

$$= 0 \cdot 14 - \frac{0.059}{2}\log 10$$

$$= 0 \cdot 14 - 0 \cdot 0295 = 0 \cdot 1105\ \mathrm{V} \text{ or } 0.11\ \mathrm{V}$$

(Deduct ½ marks for incorrect or no unit)

(Or by any other suitable method)

Q.14

$$\mathrm{E_{Cell}} = (E^{o}{}_{c} - E^{o}{}_{a}) - \frac{0.059}{2}\log\left[\frac{Zn^{2+}}{Sn^{2+}}\right]$$

$$= [(-0 \cdot 14) - (-0 \cdot 76)] - \frac{0.059}{2}\log\frac{0.1}{0.001}$$

$$= +0.62 - \frac{0.059}{2} \times 2$$

$$= (0 \cdot 62 - 0 \cdot 059)\mathrm{V}$$

$$= 0.561\ \mathrm{V}$$

Q.15 (a) Primary batteries are not rechargeable while secondary batteries are rechargeable.

(Or any other correct difference)

(b) Overall reaction does not involve any ion in solution whose concentration can change during its lifetime.

Cathode:

$$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4{}^{2-}(aq)$$

Anode:

$$PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + SO_4{}^{2-}(aq) + 4H^+(aq) + 2e^-$$

Q.15 Ans:2 (c) (i) More efficiency (ii) Pollution free

Q.16 (a) It allows flow of ions and the circuit is completed / it maintains the electrical neutrality. (or any other correct reason).

(b) When

$$E_{ext} > E_{cell}$$

(C)

$$E^\circ{}_{cell} = E^\circ Cu^{2+}/Cu - E^\circ Zn^{2+}/Zn$$
$$= 0 \cdot 34 - (-0 \cdot 76) = 1 \cdot 10\ V$$

As $E^\circ{}_{cell}$ = + ve, the reaction takes place, so copper sulphate cannot be stored ina zinc pot.

Q.17

(a)(i)

$$E^\circ \text{ cell } = E^\circ \text{ cathode } - E^\circ \text{ anode}$$
$$= -0.40 - (-0.76)V$$
$$= 0.36\ V$$

$$E_{cell} = E^\circ$$

Cell

$$-\frac{0.059}{2}\log\frac{[Zn^{2+}]}{[Cd^{2+}]}$$

$$= 0.36 \frac{-0.059}{2} \log \frac{[0.001]}{[0.1]}$$
$$= 0.36 \frac{-0.059}{2} \log 10^{-2}$$
$$= 0.36 + 0.059$$
$$= 0.419 \text{ V}$$

(ii) When same amount of electricity is passed through the electrolytic solutions connected in series, weight of substance deposited or liberated at each electrode is directly proportional to its chemical equivalent weights.

pH of solution will increase

Q.18 (b)(i)

$$E^\circ \text{cell} = E^\circ \text{cathode} - E^\circ \text{ anode}$$
$$= 0.80 \text{ V} - (-0.44 \text{ V})$$
$$= 1.24 \text{ V}$$

$$\Delta \text{G}^\circ = -\text{nFE}^\circ \text{ cell}$$
$$= -2 \times 96500 \times 1 \cdot 24 \text{ J mol}^{-1}$$
$$= -239320 \text{ J mol}^{-1}$$

$$\log \text{k}_\text{c} = \frac{\text{nE}^\circ_\text{cell}}{0.059}$$
$$= \frac{2 \times 1.24 \text{ V}}{0.059}$$

$$= 42 \cdot 0$$

(ii) More efficiency and Pollution free (Any other two correct advantages)

(iii) 2F/

$$2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$$

$$1 \text{ mole } = 2e^- \therefore 2 \text{ F}$$

Q.19 (a)(i)

$$K = \frac{1}{R}\left(\frac{L}{A}\right)_{\text{or}}$$

$$k = G^*/R$$

$$\text{k} = \frac{1}{100}(0.0354)$$

$$= 3.54 \times 10^{-4}\Omega^{-1}\text{ cm}^{-1}$$

$$\Lambda_m = \frac{K}{M} \times 1000$$

$$= \frac{3.54 \times 10^{-4}}{0.05} \times 1000$$

$$= 7.08\Omega^{-1}\text{ cm}^2\text{ mol}^{-1}$$

or

$$7.08\text{Scm}^2\text{ mol}^{-1}$$

(Deduct ½ mark for no or incorrect unit)

(ii) The amount of chemical reaction which occurs at any electrode during electrolysis by a current is proportional to the quantity of electricity passed through the electrolyte. / m=ZIt where m = mass of the substance deposited, Z = electrochemical equivalent, I = current, t = time.

Q.20

(b)(i)

$$\Lambda_m = \frac{K}{M} \times 1000$$

$$\Lambda_m = \frac{5.25 \times 10^{-5}}{0.0025} \times 1000$$

$$= 21 \text{ S cm}^2 \text{ mol}^{-1}$$

$$\alpha = \frac{\Lambda_m}{\Lambda_m^\circ}$$

$$= \frac{21 \text{ S cm}^2 \text{ mol}^{-1}}{390 \text{ S cm}^2 \text{ mol}^{-1}}$$

$$= 0.053$$

(ii)Anode:

$$\text{Pb} + \text{SO}_4 2- \longrightarrow \text{PbSO}_4 + 2\text{e}-$$

Cathode:

$$\text{PbO}_2 + {\text{SO}_4}^{2-} + 4\text{H}^+ + 2\text{e} \longrightarrow \text{PbSO}_4 + 2\text{H}_2\text{O}$$

Overall :

$$\text{Pb} + \text{PbO}_2 + 2\text{H}_2\text{SO}_4 \longrightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O}$$

Previous Years' CBSE Board Questions

2.1 Electrochemical Cells

MCQ

1. An electrochemical cell behaves like an electrolytic cell when
   (a) $E_{cell} = E_{external}$ (b) $E_{cell} = 0$
   (c) $E_{external} > E_{cell}$ (d) $E_{external} < E_{cell}$
   (2020) R

SA I (2 marks)

2. Give two points of differences between electrochemical and electrolytic cells.
   (2/5, 2020) R
3. Define electrochemical cell. What happens if external potential applied becomes greater than E°_{cell} of electrochemical cell?
   (AI 2019, 2/5, AI 2016) U

2.2 Galvanic Cells

MCQ

4. The correct cell to represent the following reaction is
   $$Zn + 2Ag^+ \longrightarrow Zn^{2+} + 2Ag$$
   (a) $2Ag \mid Ag^+ \parallel Zn \mid Zn^{2+}$ (b) $Ag^+ \mid Ag \parallel Zn^{2+} \mid Zn$
   (c) $Ag \mid Ag^+ \parallel Zn \mid Zn^{2+}$ (d) $Zn \mid Zn^{2+} \parallel Ag^+ \mid Ag$
   (2023)
5. If the standard electrode potential of an electrode is greater than zero, then we can infer that its
   (a) reduced form is more stable compared to hydrogen gas
   (b) oxidised form is more stable compared to hydrogen gas
   (c) reduced and oxidised forms are equally stable.
   (d) reduced form is less stable than the hydrogen gas. *(2020)* U

2.3 Nernst Equation

MCQ

6. ΔG and E°_{cell} for a spontaneous reaction will be
   (a) positive, negative (b) negative, negative
   (c) negative, positive (d) positive, positive.
   (2023)
7. $Ag^+_{(aq)} + e^- \longrightarrow Ag_{(s)}$; $E^\circ = +0.80$ V
   $Fe^{2+}_{(aq)} + 2e^- \longrightarrow Fe_{(s)}$; $E^\circ = -0.44$ V
   Find the E°_{cell} for :
   $Fe_{(s)} + 2Ag^+_{(aq)} \longrightarrow Fe^{2+}_{(aq)} + 2Ag_{(s)}$
   (a) 1.6 V (b) −1.16 V (c) 2.04 V (d) 1.24 V
   (2023)
8. Consider the following standard electrode potential values
   $Sn^{2+}_{(aq)} + 2e^- \rightarrow Sn_{(s)}$ $E^\circ = -0.14$ V
   $Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$ $E^\circ = +0.77$ V
   What is the cell reaction and potential for the spontaneous reaction that occurs?
   (a) $2Fe^{2+}_{(aq)} + Sn^{2+}_{(aq)} \rightarrow 2Fe^{3+}_{(aq)} + Sn_{(s)}$; $E^\circ = -0.91$ V
   (b) $2Fe^{3+}_{(aq)} + Sn_{(s)} \rightarrow 2Fe^{2+}_{(aq)} + Sn^{2+}_{(aq)}$; $E^\circ = +0.91$ V
   (c) $2Fe^{2+}_{(aq)} + Sn^{2+}_{(aq)} \rightarrow 2Fe^{3+}_{(aq)} + Sn_{(s)}$; $E^\circ = +0.91$ V
   (d) $2Fe^{3+}_{(aq)} + Sn_{(s)} \rightarrow 2Fe^{2+}_{(aq)} + Sn^{2+}_{(aq)}$; $E^\circ = +1.68$ V
   (2023)

SA I (2 marks)

9. Calculate the emf of the following cell at 298 K:
   $Fe_{(s)} \mid Fe^{2+}(0.01\ M) \parallel H^+_{(1M)} \mid H_{2(g)}$ (1 bar), $Pt_{(s)}$
   Given $E^\circ_{cell} = 0.44$ V. *(2023)*
10. Calculate $\Delta_r G^\circ$ for the cell reaction at 25°C:
    $Zn \mid Zn^{2+} \parallel Cd^{2+} \mid Cd$
    Given that : $E^\circ_{Zn^{2+}/Zn} = -0.76$ V,
    $E^\circ_{Cd^{2+}/Cd} = 0/.40$ V, 1 F = 96500 C mol^{-1} *(2023)*
11. Write the Nernst equation for the following cell reaction:
    $Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$
    How will the E_{cell} be affected when concentration of
    (i) Cu^{2+} ions is increased and
    (ii) Zn^{2+} ions is increased? *(Term II, 2021-22)*
12. For an electrochemical cell
    $Mg_{(s)} + Ag^+_{(aq)} \longrightarrow Ag_{(s)} + Mg^{2+}_{(aq)}$,
    give the cell representation. Also write the Nernst equation for the above cell at 25°C. *(2020)*
13. Calculate the emf of the following cell at 25°C :
    $Al_{(s)} \mid Al^{3+}(0{\cdot}001\ M) \parallel Ni^{2+}(0.1\ M) \mid Ni_{(s)}$
    Given : $E^\circ_{(Ni^{2+}/Ni)} = -0{\cdot}25$ V
    $E^\circ_{(Al^{3+}/Al)} = -1{\cdot}66$ V
    [log 2 = 0·3010, log 3 = 0·4771] *(2019)* Ev
14. Calculate $\Delta_r G^\circ$ for the reaction :
    $Mg_{(s)} + Cu^{2+}_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + Cu_{(s)}$
    Given $E^\circ_{cell} = +2.71$ V, 1 F = 96500 C mol^{-1}
    (2/3,AI 2014) Ap
15. Equilibrium constant (K_c) for the given cell reaction is 10. Calculate E°_{cell}.
    $A_{(s)} + B^{2+}_{(aq)} \rightleftharpoons A^{2+}_{(aq)} + B_{(s)}$ *(2/3,Foreign 2014)*

SA II (3 marks)

16. Write the Nernst equation and calculate the emf of the following cell at 298 K :

$Zn \mid Zn^{2+}(0.001\ M) \parallel H^+(0.01\ M) \mid H_{2(g)}(1\ bar) \mid Pt_{(s)}$
Given : $E^\circ_{Zn^{2+}/Zn} = -0.76\ V, E^\circ_{H^+/H_2} = 0.00\ V$, [log 10 = 1]
(Term II, 2021-22, Foreign 2015) Cr

17. Calculate $\Delta_r G^\circ$ and log K_c for the following cell :
$Ni_{(s)} + 2Ag^+_{(aq)} \rightarrow Ni^{2+}_{(aq)} + 2Ag_{(s)}$
Given that $E^\circ_{cell} = 1.05\ V$, $1F = 96{,}500\ C\ mol^{-1}$
(Term II, 2021-22)

OR

Calculate the maximum work and logK_c for the given reaction at 298 K :
$Ni_{(s)} + 2Ag^+_{(aq)} \rightleftharpoons Ni^{2+}_{(aq)} + 2Ag_{(s)}$
Given : $E^\circ_{Ni^{2+}/Ni} = -0.25\ V, E^\circ_{Ag^+/Ag} = +0.80\ V$
$1F = 96500\ C\ mol^{-1}$ *(2020)*

OR

For the cell reaction,
$Ni_{(s)} \mid Ni^{2+}_{(aq)} \mid\mid Ag^+_{(aq)} \mid Ag_{(s)}$
Calculate the equilibrium constant at 25°C. How much maximum work would be obtained by operation of this cell?
$E^\circ_{(Ni^{2+}/Ni)} = -0.25\ V$ and $E^\circ_{Ag^+/Ag} = 0.80V$
(3/5, Delhi 2015C)

18. Calculate the e.m.f. of the following cell at 298K :
$Fe_{(s)} \mid Fe^{2+}(0.001\ M) \mid\mid H^+(0.01\ M) \mid H_{2(g)}(1\ bar) \mid Pt_{(s)}$
Given that $E^\circ_{cell} = +0.44\ V$
[log 2 = 0.3010, log 3 = 0.4771, log 10 = 1]
(Term II, 2021-22) Ev

OR

Calculate emf of the following cell at 25°C:
$Fe \mid Fe^{2+}(0.001\ M) \mid\mid H^+(0.01\ M) \mid H_{2(g)}(1\ bar) \mid Pt_{(s)}$
$E^\circ_{(Fe^{2+}/Fe)} = -0.44\ V, E^\circ_{(H^+/H_2)} = 0.00\ V$ *(Delhi 2015)*

19. Calculate ΔG° for the reaction,
$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$
Given : E° for $Zn^{2+}/Zn = -0.76\ V$ and
E° for $Cu^{2+}/Cu = +0.34\ V$
$R = 8.314\ J\ K^{-1}\ mol^{-1}$, $1\ F = 96500\ C\ mol^{-1}$.
(3/5, 2020)

20. Calculate e.m.f of the following cell :
$Zn_{(s)} \mid Zn^{2+}(0.1\ M) \parallel Ag^+(0.01\ M) \mid Ag_{(s)}$
Given : $E^\circ_{Zn^{2+}/Zn} = -0.76\ V, E^\circ_{Ag^+/Ag} = +0.80\ V$
[Given : log 10 = 1] *(3/5, 2020)*

21. Calculate $\Delta_r G^\circ$ and log K_c for the following reaction.
$Cd^{2+}_{(aq)} + Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + Cd_{(s)}$
Given : $E^\circ_{Cd^{2+}/Cd} = -0.403\ V; E^\circ_{Zn^{2+}/Zn} = -0.763\ V$
(AI 2019) Ap

22. Zinc rod is dipped in 0·01 M solution of zinc sulphate when temperature is 298 K. Calculate the electrode potential of zinc.
(Given : $E^\circ_{Zn^{2+}/Zn} = = -0{\cdot}76\ V$; log 10 = 1) *(2019C)* Ev

23. Write the cell reaction and calculate the e.m.f. of the following cell at 298 K.
$Sn_{(s)} \mid Sn^{2+}(0.004\ M) \parallel H^+(0.020\ M) \mid H_{2(g)}(1\ bar) \mid Pt_{(s)}$
(Given : $E^\circ_{Sn^{2+}/Sn} = -0.14\ V$) *(3/5, 2018)* U

24. For the reaction,
$2AgCl_{(s)} + H_{2(g)}(1\ atm) \rightarrow 2Ag_{(s)} + 2H^+(0.1\ M) + 2Cl^-(0.1\ M)$
$\Delta G^\circ = -43600\ J$ at 25 °C.
Calculate the e.m.f. of the cell. (log $10^{-n} = -n$)
(3/5, 2018)

25. Calculate e.m.f. of the following cell at 298 K.
$2Cr_{(s)} + 3Fe^{2+}(0.1M) \rightarrow 2Cr^{3+}(0.01M) + 3Fe_{(s)}$
Given : $E^\circ_{(Cr^{3+}/Cr)} = -0.74\ V, E^\circ_{(Fe^{2+}/Fe)} = -0.44\ V$
(Delhi 2016)

26. Calculate E°_{cell} for the following reaction at 298 K.
$2Al_{(s)} + 3Cu^{2+}(0.01M) \rightarrow 2Al^{3+}(0.01M) + 3Cu_{(s)}$
Given : $E_{cell} = 1.98\ V$ *(3/5,AI 2016)*

27. Calculate the standard cell potential of the galvanic cell in which the following reaction takes place :
$Fe^{2+}_{(aq)} + Ag^+_{(aq)} \rightarrow Fe^{3+}_{(aq)} + Ag_{(s)}$
Calculate the $\Delta_r G^\circ$ and equilibrium constant of the reaction.
$\left(E^\circ_{Ag^+/Ag} = 0.80\ V; E^\circ_{Fe^{3+}/Fe^{2+}} = 0.77\ V\right)$
(3/5, Delhi 2015C) U

28. Calculate the emf of following cell at 298 K :
$Mg_{(s)} \mid Mg^{2+}(0.1\ M) \mid\mid Cu^{2+}(0.01\ M) \mid Cu_{(s)}$
[Given : $E^\circ_{cell} = +2.71\ V, 1\ F = 96500\ C\ mol^{-1}$]
(3/5, Delhi 2014)

29. Estimate the minimum potential difference needed to reduce Al_2O_3 at 500°C. The Gibbs energy change for the decomposition reaction,
$\frac{2}{3}Al_2O_3 \rightarrow \frac{4}{3}Al + O_2$ is 960 kJ. ($F = 96500\ C\ mol^{-1}$)
(3/5,Delhi 2014C)

LA (5 marks)

30. E°_{cell} for the given redox reaction is 2.71 V.
$Mg_{(s)} + Cu^{2+}(0.01M) \rightarrow Mg^{2+}(0.001M) + Cu_{(s)}$
Calculate E_{cell} for the reaction. Write the direction of flow of current when an external opposite potential applied is
(i) less than 2.71 V and
(ii) greater than 2.71 V *(Delhi 2019)*

31. Calculate e.m.f and ΔG for the following cell
$Mg_{(s)} \mid Mg^{2+}(0.001\ M) \mid\mid Cu^{2+}(0.0001\ M) \mid Cu_{(s)}$
$E^\circ_{(Mg^{2+}/Mg)} = -2{\cdot}37\ V, E^\circ_{(Cu^{2+}/Cu)} = +0.34\ V$
(NCERT, AI 2015)

2.4 Conductance of Electrolytic Solutions

MCQ

32. The unit of molar conductivity is
(a) $S\ cm^{-2}\ mol^{-1}$ (b) $S\ cm^2\ mol^{-1}$
(c) $S^{-1}\ cm^2\ mol^{-1}$ (d) $S\ cm^2\ mol$ *(2023)*

33. **Assertion (A)** : Conductivity of an electrolyte increases with decrease in concentration.
Reason (R) : Number of ions per unit volume decreases on dilution.

(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is correct, but Reason (R) is wrong statement.
(d) Assertion (A) is wrong, but Reason (R) is correct statement. *(2020)* An

VSA (1 mark)

34. Give reason :
Conductivity of CH_3COOH decreases on dilution. *(1/5, 2018)* U

35. Define limiting molar conductivity. Why conductivity of an electrolyte solution decreases with the decrease in concentration? *(1/2, Delhi 2015)*

OR

Define the following term :
Limiting molar conductivity *(1/5, Delhi 2014)*

36. State Kohlrausch's law of independent migration of ions. Write its one application. *(1/2, Foreign 2015)*

OR

Define the following term :
Kohlrausch's law of independent migration of ions. *(1/5, Delhi 2015C)* R

37. Define the following term :
Molar conductivity (Λ_m) *(1/5, Delhi 2015C)*

SA I (2 marks)

38. On diluting two electrolytes 'A' and 'B', then Λ_m of 'A' increases 25 times while that of 'B' increases by 1.5 times. Which of the two electrolytes is strong? Justify your answer graphically. *(2023)*

39. (i) State Kohlrausch's law of independent migration of ions.
(ii) Calculate the degree of dissociation (α) of CH_3COOH if Λ_m and Λ°_m of CH_3COOH are 48 $S\,cm^2\,mol^{-1}$ and 400 $S\,cm^2\,mol^{-1}$ respectively. *(Term II, 2021-22)*

40. The conductivity of 0.001 M acetic acid is $7.8 \times 10^{-5}\ S\,cm^{-1}$. Calculate its degree of dissociation if Λ°_m for acetic acid is 390 $S\,cm^2\,mol^{-1}$. *(Term II, 2021-22)* Ap

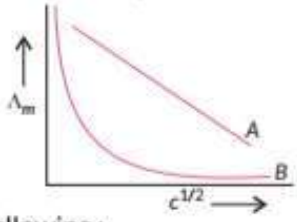
41. In a plot of Λ_m against the square root of concentration ($C^{1/2}$) for strong and weak electrolyte, the value of limiting molar conductivity of a weak electrolyte cannot be obtained graphically. Suggest a way to obtain this value. Also state the related law, if any. *(Term II, 2021-22)* EV

42. Answer the following questions (Any two) :
(a) Define molar conductivity (Λ_m).
(b) Write the unit of Λ_m.
(c) How does Λ_m vary with concentration? *(Term II,2021-22 C)*

43. Answer the following questions (Any two) :
(a) Why is alternating current used instead of direct current for measuring resistance of an electrolytic solution ?
(b) State Kohlrausch's law of independent migration of ion.
(c) Depict the Galvanic cell in which the following reaction takes place :
$Mg_{(s)} + Cu^{2+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + Cu_{(s)}$ *(Term II, 2021-22C)*

44. X and Y are two electrolytes. On dilution molar conductivity of 'X' increases 2.5 times while that Y increases 25 times. Which of the two is a weak electrolyte and why? *(2/5, 2020)* Ap

45. In the plot of molar conductivity (Λ_m) vs square root of concentration ($c^{1/2}$),following curves are obtained for two electrolytes A and B



Answer the following :
(i) Predict the nature of electrolytes A and B.
(ii) What happens on extrapolation of Λ_m to concentration approaching zero for electrolytes A and B? *(2/5, Delhi 2019)* Ev

46. Explain with a graph, the variation of molar conductivity of a strong electrolyte with dilution. *(2019)*

47. Calculate the degree of dissociation (α) of acetic acid if its molar conductivity (Λ_m) is 39.05 $S\,cm^2\,mol^{-1}$.
(Given : $\lambda^\circ(H^+) = 349.68\ S\,cm^2mol^{-1}$ and $\lambda^\circ(CH_3COO^-) = 40.9\ S\,cm^2\,mol^{-1}$) *(Delhi 2017)*

48. Define the term degree of dissociation. Write an expression that relates the molar conductivity of a weak electrolyte to its degree of dissociation. *(2/5, Delhi 2015C)* Cr

49. Define conductivity and molar conductivity for the solution of an electrolyte. Discuss their variation with concentration. *(NCERT, 2/5, AI 2015C)*

50. State Kohlrausch law of independent migration of ions. Why does the conductivity of a solution decrease with dilution? *(AI 2014)*

51. Define the terms conductivity and molar conductivity for the solution of an electrolyte. Comment on their variation with temperature. *(Delhi, AI 2014C)* U

52. The resistance of 0.01 M NaCl solution at 25°C is 200 Ω. The cell constant of the conductivity cell used is unity. Calculate the molar conductivity of the solution. *(2/3, AI 2014C)*

SA II (3 marks)

53. (a) The standard Gibbs energy ($\Delta_r G^\circ$) for the following cell reaction is -300 kJ mol^{-1} :
$Zn_{(s)} + 2Ag^+_{(aq)} \rightarrow Zn^{2+}_{(aq)} + 2Ag_{(s)}$

Calculate E°_{cell} for the reaction.
(Given: 1F = 96500 C mol^{-1})

(b) Calculate λ°_m for $MgCl_2$ if λ° values for Mg^{2+} ion and Cl^- ion are 106 S cm^2 mol^{-1} and 76.3 S cm^2 mol^{-1} respectively. *(Term I, 2021-22)*

54. The conductivity of 0.001 mol L^{-1} solution of CH_3COOH is 3.905×10^{-5} S cm^{-1}. Calculate its molar conductivity and degree of dissociation (α).
[Given : $\lambda^\circ(H^+) = 349.6$ S cm^2 mol^{-1} and $\lambda^\circ(CH_3COO^-) = 40.9$ S cm^2 mol^{-1}]
(Term II, 2021-22C, 3/5, AI 2016)

55. Conductivity of 2×10^{-3} M methanoic acid is 8×10^{-5} S cm^{-1}. Calculate its molar conductivity and degree of dissociation if Λ°_m for methanoic acid is 404 S cm^2 mol^{-1}. *(2020)*

56. Out of the following pairs, predict with reason which pair will allow greater conduction of electricity.
(i) Silver wire at 30°C or silver wire at 60 °C.
(ii) 0.1 M CH_3COOH solution or 1 M CH_3COOH solution.
(iii) KCl solution at 20 °C or KCl solution at 50 °C.
(3/5, 2020)

57. The electrical resistance of a column of 0.05 M KOH solution of length 50 cm and area of cross-section 0.625 cm^2 is 5×10^3 ohm. Calculate its resistivity, conductivity and molar conductivity. *(3/5, 2020)*

58. (a) Following reaction takes place in the cell :
$Zn_{(s)} + Ag_2O_{(s)} + H_2O_{(l)} \rightarrow Zn^{2+}_{(aq)} + 2Ag_{(s)} + 2OH^-_{(aq)}$
Calculate $\Delta_r G^\circ$ of the reaction..
[Given : $E^\circ_{(Zn^{2+}/Zn)} = -0.76$ V,
$E^\circ_{(Ag^+/Ag)} = 0.80$ V, 1 F = 96,500 C mol^{-1}]

(b) How can you determine limiting molar conductivity, (Λ°_m) for strong electrolyte and weak electrolyte? *(2019)*

59. The conductivity of 0.20 mol L^{-1} solution of KCl is 2.48×10^{-2} S cm^{-1}. Calculate its molar conductivity and degree of dissociation (α).
Given : λ° (K^+) = 73.5 S cm^2 mol^{-1} and λ° (Cl^-) = 76.5 S cm^2 mol^{-1}. *(AI 2015)*

60. Resistance of a conductivity cell filled with 0.1 mol L^{-1} KCl solution is 100 Ω. If the resistance of the same cell when filled with 0.02 mol L^{-1} KCl solution is 520 Ω, calculate the conductivity and molar conductivity of 0.02 mol L^{-1} KCl solution. The conductivity of 0.1 mol L^{-1} KCl solution is 1.29×10^{-2} Ω^{-1} cm^{-1}.
(3/5, AI 2014) Ap

LA (4/5 marks)

61. Rahul set up an experiment to find resistance of aqueous KCl solution for different concentrations at 298 K using a conductivity cell connected to a Wheatstone bridge. He fed the Wheatstone bridge with a.c. power in the audio frequency range 550 to 5000 cycles per second. Once the resistance was calculated from null point he also calculated the conductivity κ and molar conductivity Λ_m and recorded his readings in tabular form.

S.No.	Conc. (M)	κ (S cm^{-1})	Λ_m (S cm^2 mol^{-1})
1.	1.00	111.3×10^{-3}	111.3
2.	0.10	12.9×10^{-3}	129.0
3.	0.01	1.41×10^{-3}	141.0

Answer the following questions:

(a) Why does conductivity increase though the conductivity decrease with dilution?

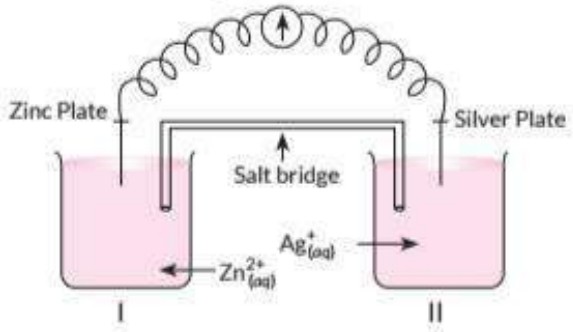
(b) If Λ°_m of KCl is 150.0 S cm^2 mol^{-1}, calculate the degree of dissociation of 0.01 M KCl.

(c) If Rahul had used HCl instead to KCl then would you expect the Λ_m values to be more or less than those per KCl for a given concentration. Justify. *(2023)*

62. **Read the passage given below and answer the questions that follow :**

Oxidation-reduction reactions are commonly known as redox reactions. They involve transfer of electrons from one species to another. In a spontaneous reaction, energy is released which can be used to do useful work. The reaction is split into two half reactions. Two different containers are used and a wire is used to drive the electrons from one side to the other and a voltaic/galvanic cell is created. It is an electrochemical cell that uses spontaneous redox reactions to generate electricity. A salt bridge also connects to the half cells. The reading of the voltmeter gives the cell voltage or cell potential or electromotive force. If E°_{cell} is positive the reaction is spontaneous and if it is negative the reaction is non-spontaneous and is referred to as electrolytic cell. Electrolysis refers to the decomposition of a substance by an electric current. One mole of electric charge when passed through a cell will discharge half a mole of a divalent metal ion such as Cu^{2+}. This was first formulated by Faraday in the form of laws of electrolysis.

The conductance of material is the property of materials due to which a material allows the flow of ions through itself and thus conducts electricity. Conductivity is represented by *k* and it depends upon nature and concentration of electrolyte, temperature etc. A more common term molar conductivity of a solution at a given concentration is conductance of the volume of solution containing one mole of electrolyte kept between two electrodes with the unit area of cross-section and distance of unit length. Limiting molar conductivity of weak electrolytes cannot be obtained graphically.



(a) Is silver plate the anode or cathode ?
(b) What will happen if the salt bridge is removed ?
(c) When does electrochemical cell behave like an electrolytic cell ?
(d) (i) What will happen to the concentration of Zn^{2+} and Ag^{+} when $E_{cell} = 0$.
(ii) Why does conductivity of a solution decreases with dilution ?

OR

(d) The molar conductivity of a 1.5 M solution of an electrolyte is found to be 138.9 S cm^2 mol^{-1}. Calculate the conductivity of this solution.
(Term II, 2021-22)

63. (i) The electrical resistance of a column of 0·02 M NaOH solution of diameter 1·40 cm and length 44 cm is 5·00 x 10^3 ohm. Calculate its resistivity, conductivity and molar conductivity.
(ii) Depict the galvanic cell in which the reaction takes place :
$Ni_{(s)} + 2Ag^{+}_{(aq)} \rightarrow Ni^{2+}_{(aq)} + 2Ag_{(s)}$
Further show :
(i) Which of the electrodes is positively charged ?
(ii) The carriers of the current in the outer circuit.
(2021C) An

64. (a) Represent the cell in which the following reaction takes place :
$2Al_{(s)} + 3Ni^{2+}$ (0·1 M) $\rightarrow 2Al^{3+}$ (0·01 M) $+ 3Ni_{(s)}$
Calculate its emf if $E^{\circ}_{cell} = 1·41$ V.
(b) How does molar conductivity vary with increase in concentration for strong electrolyte and weak electrolyte ? How can you obtain limiting molar conductivity (Λ°_m) for weak electrolyte ? *(2019)*

2.5 Electrolytic Cells and Electrolysis

MCQ

65. Four half reactions I to IV are shown below:
I. $2Cl^{-} \rightarrow Cl_2 + 2e^{-}$
II. $4OH^{-} \rightarrow O_2 + 2H_2O + 2e^{-}$
III. $Na^{+} + e^{-} \rightarrow Na$
IV. $2H^{+} + 2e^{-} \rightarrow H_2$
Which two of these reactions are most likely to occur when concentrated brine is electrolysed?
(a) I and III (b) I and IV
(c) II and III (d) II and IV *(2023)*

VSA (1 mark)

66. How much charge in terms of Faraday is required to reduce one mol of MnO_4^{-} to Mn^{2+}? *(2020)* Ev

67. How many coulombs are required for the oxidation of 1 mol of H_2O to O_2? *(One word, 2020)*

68. Give reason :
On the basis of E° values, O_2 gas should be liberated at anode but it is Cl_2 gas which is liberated in the electrolysis of aqueous NaCl. *(1/5, 2018)* U

69. Following reactions occur at cathode during the electrolysis of aqueous silver chloride solution :
$Ag^{+}_{(aq)} + e^{-} \rightarrow Ag_{(s)}$, $E^{\circ} = +0.80$ V
$H^{+}_{(aq)} + e^{-} \rightarrow \frac{1}{2}H_{2(g)}$, $E^{\circ} = 0.00$ V
On the basis of their standard reduction electrode potential (E°) values, which reaction is feasible at the cathode and why? *(AI 2017C, 1/2, Delhi 2015)*

70. How much charge is required for the reduction of 1 mol of Zn^{2+} to Zn? *(Delhi 2015)*

71. Following reactions occur at cathode during the electrolysis of aqueous copper (II) chloride solution :
$Cu^{2+}_{(aq)} + 2e^{-} \rightarrow Cu_{(s)}$; $E^{\circ} = +0.34$ V
$H^{+}_{(aq)} + e^{-} \rightarrow \frac{1}{2}H_{2(g)}$; $E^{\circ} = 0.00$ V
On the basis of their standard reduction electrode potential (E°) values, which reaction is feasible at the cathode and why? *(1/2, Foreign 2015)* Ev

72. State the Faraday's first law of electrolysis.
(Delhi 2015C) R

SA I (2 marks)

73. (i) What should be the signs (positive/negative) for E°_{cell} and ΔG° for a spontaneous redox reaction occurring under standard conditions?
(ii) State Faraday's first law of electrolysis. *(2023)*

74. Predict the products of electrolysis of an aqueous solution of $CuCl_2$ with platinum electrodes.
(Given : $E^{\circ}_{Cu^{2+}/Cu} = +0.34$ V,
$E^{\circ}_{(1/2Cl_2/Cl^{-})} = +1.36$ V
$E^{\circ}_{H^{+}/H_{2(g)}, Pt} = 0.00$ V, $E^{\circ}_{(1/2O_2/H_2O)} = +1.23$ V)
(2/5, 2020)

75. Predict the products of electrolysis in each of the following :
(a) An aqueous solution of $CuSO_4$ with Pt electrode
(b) An aqueous solution of $AgNO_3$ with Pt electrode
(2020C)

76. How many seconds does it require to reduce 3 moles of Fe^{3+} to Fe^{2+} with 2 A current?
(Given : 1 F = 96500 C mol^{-1}) *(2020C)*

77. Following reactions may occur at cathode and anode during electrolysis of aqueous sodium chloride. What products will be held at anode and cathode? Use given E° values to justify your answer.
Cathode : $Na^{+}_{(aq)} + e^{-} \rightarrow Na_{(s)}$ $E^{\circ} = -2·71$ V
$H^{+}_{(aq)} + e^{-} \rightarrow \frac{1}{2}H_{2(g)}$ $E^{\circ} = 0·00$ V
Anode : $Cl^{-}_{(aq)} \rightarrow \frac{1}{2}Cl_{2(g)} + e^{-}$ $E^{\circ} = +1·36$ V
$2H_2O_{(aq)} \rightarrow O_{2(g)} + 4H^{+} + 4e^{-}$ $E^{\circ} = +1·23$ V
(2019) Ap

78. Calculate the mass of Ag deposited at cathode when a current of 2 ampere was passed through a solution of $AgNO_3$ for 15 minutes.

(Given : Molar mass of Ag = 108 g mol^{-1}, 1 F = 96500 C mol^{-1}) *(2/3, Delhi 2017)*

79. State Faraday's first law of electrolysis. How much charge in terms of Faraday is required for the reduction of 1 mol of Cu^{2+} to Cu? *(2/5, Delhi 2014)*

80. A solution of $Ni(NO_3)_2$ is electrolysed between platinum electrodes using a current of 5.0 ampere for 20 minutes. What mass of nickel will be deposited at the cathode?
(Given : At. mass of Ni = 58.7 g mol^{-1}, 1F = 96500 C mol^{-1}) *(Foreign 2014)*

81. Predict the products of electrolysis in each of the following :
(i) An aqueous solution of $AgNO_3$ with platinum electrodes.
(ii) An aqueous solution of H_2SO_4 with platinum electrodes. *(2/5, Delhi 2014C)*

SA II (3 marks)

82. When a steady current of 2A was passed through two electrolytic cells *A* and *B* containing electrolytes $ZnSO_4$ and $CuSO_4$ connected in series, 2 g of Cu were deposited at the cathode of cell *B*. How long did the current flow ?
What mass of Zn was deposited at cathode of cell *A*?
[Atomic mass : Cu = 63.5 g mol^{-1}, Zn = 65 g mol^{-1}; 1F = 96500 C mol^{-1}] *(2020)* Ev

83. A steady current of 2 amperes was passed through two electrolytic cells *X* and *Y* connected in series containing electrolytes $FeSO_4$ and $ZnSO_4$ until 2.8 g of Fe deposited at the cathode of cell *X*. How long did the current flow? Calculate the mass of Zn deposited at the cathode of cell *Y*.
(Molar mass : Fe = 56 g mol^{-1}, Zn = 65.3 g mol^{-1}, 1 F = 96500 C mol^{-1}) *(3/5, Delhi 2019)*

84. Chromium metal is electroplated using an acidic solution containing CrO_3 according to the following equation :
$CrO_{3(aq)} + 6H^+ + 6e^- \rightarrow Cr_{(s)} + 3H_2O$
Calculate how many grams of chromium will be electroplated by 24,000 coulombs. How long will it take to electroplate 1.5 g chromium using 12.5 A current?
[Atomic mass of Cr = 52 g mol^{-1}, 1 F = 96500 C mol^{-1}] *(AI 2019)*

85. (a) The cell in which the following reaction occurs :
$2Fe^{3+}_{(aq)} + 2I^-_{(aq)} \rightarrow 2Fe^{2+}_{(aq)} + I_{2(s)}$
has E°_{cell} = 0.236 V at 298 K. Calculate the standard Gibbs energy of the cell reaction.
(Given : 1 F = 96,500 C mol^{-1}) *(NCERT Intext)*
(b) How many electrons flow through a metallic wire if a current of 0.5 A is passed for 2 hours?
(Given : 1 F = 96,500 C mol^{-1}) *(AI 2017)*

LA (5 marks)

86. (i) State Kohlrausch's law of independent migration of ions. Write an expression for the limiting molar conductivity of acetic acid according to Kohlrausch's law.
(ii) Calculate the maximum work and log K_c for the given reaction at 298 K :
$Ni_{(s)} + 2Ag^+_{(aq)} \rightleftharpoons Ni^{2+}_{(aq)} + 2Ag_{(s)}$
Given : $E^\circ_{Ni^{2+}/Ni} = -0.25$ V, $E^\circ_{Ag^+/Ag} = +0.80$ V
1 F = 96500 C mol^{-1} *(2023)*

2.6 Batteries

VSA (1 mark)

87. Define : Secondary batteries *(1/5, Delhi 2015C)* R

SA I (2 marks)

88. Write the name of the cell which is generally used in hearing aids. Write the reactions taking place at the anode and the cathode of this cell. *(AI 2017)* R

89. Write the name of the cell which is generally used in inverters. Write the reactions taking place at the anode and the cathode of this cell. *(AI 2017)*

90. Write the name of the cell which is generally used in transistors. Write the reactions taking place at the anode and the cathode of this cell. *(AI 2017)*

91. What type of battery is mercury cell? Why is it more advantageous than dry cell? *(2/5, AI 2015)* U

LA (5 marks)

92. (a) The conductivity of 0·001 mol L^{-1} acetic acid is 4.95×10^{-5} S cm^{-1}. Calculate the dissociation constant if Λ°_m for acetic acid is 390.5 S cm^2 mol^{-1}.
(b) Write Nernst equation for the reaction at 25°C :
$2Al_{(s)} + 3Cu^{2+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3Cu_{(s)}$
(c) What are secondary batteries? Give an example. *(2019)*

2.7 Fuel Cells

MCQ

93. Which of the following cell was used in Apollo space programme?
(a) Mercury cell (b) Daniell cell
(c) $H_2 - O_2$ Fuel cell (d) Dry cell *(2023)*

VSA (1 mark)

94. Name the cell use in hearing aids and watches. *(2020)* R

95. Name the type of cell which was used in Apollo space programme. *(2020, 1/3, AI 2014)*

96. Define : Fuel cell *(Delhi 2017, 1/5, Delhi 2015C, 2014)*

SA I (2 marks)

97. Give two advantages of fuel cells. *(2/5, 2020)*

98. Define fuel cell and write its two advantages. *(2/5, 2018)* R

99. From the given cells :
Lead storage cell, Mercury cell, Fuel cell and Dry cell
Answer the following :
(i) Which cell is used in hearing aids?
(ii) Which cell was used in Apollo space programme?
(iii) Which cell is used in automobiles and inverters?
(iv) Which cell does not have long life?
(Delhi 2016) R

100. Write two advantages of H_2-O_2 fuel cell over ordinary cell. *(2/3, Foreign 2014)*

2.8 Corrosion

VSA (1 mark)

101. Using the E° values of *A* and *B* predict which is better for coating the surface of iron $\left[E^\circ_{(Fe^{2+}/Fe)} = -0.44\ V\right]$ to prevent corrosion and why?
$E^\circ_{(A^{2+}/A)} = -2.37\ V$; $E^\circ_{(B^{2+}/B)} = -0.14\ V$
(AI 2016) An

CBSE Sample Questions

2.3 Nernst Equation

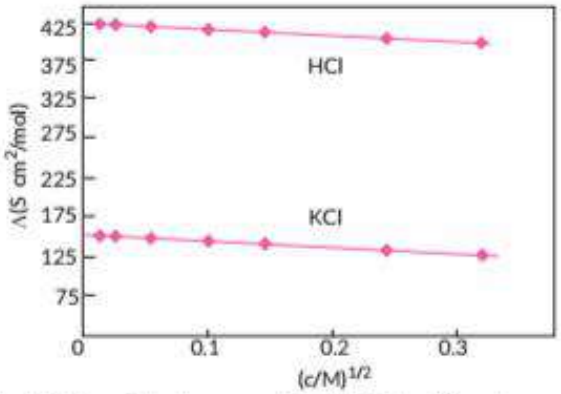
SA II (3 marks)

1. Represent the cell in which the following reaction takes place. The value of E° for the cell is 1.260 V. What is the value of E_{cell}?
$2Al_{(s)} + 3Cd^{2+}\ (0.1\ M) \rightarrow 3Cd_{(s)} + 2Al^{3+}\ (0.01\ M)$
(Term II, 2021-22)

2.4 Conductance of Electrolytic Solutions

MCQ

2. The molar conductivity of CH_3COOH at infinite dilution is 390 S cm^2/mol. Using the graph and given information, the molar conductivity of CH_3COOK will be



(a) 100 S cm^2/mol (b) 115 S cm^2/mol
(c) 150 S cm^2/mol (d) 125 S cm^2/mol
(Term-II, 2021-22)

3. Which of the following option will be the limiting molar conductivity of CH_3COOH if the limiting molar conductivity of CH_3COONa is 91 S cm^2 mol^{-1}? Limiting molar conductivity for individual ions are given in the following table.

S.No.	Ions	Limiting molar conductivity / S cm^2 mol^{-1}
1.	H^+	349.6
2.	Na^+	50.1
3.	K^+	73.5
4.	OH^-	199.1

(a) 350 S cm^2 mol^{-1} (b) 375.3 S cm^2 mol^{-1}
(c) 390.5 S cm^2 mol^{-1} (d) 340.4 S cm^2 mol^{-1}
(2020-21) An

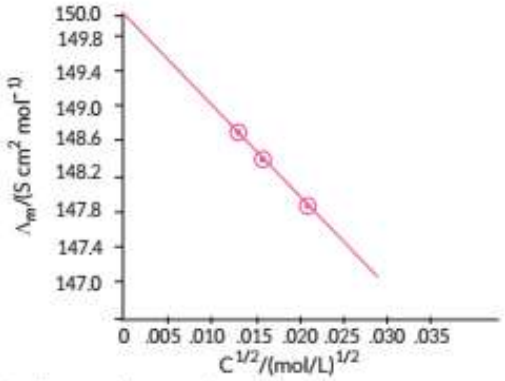
SA I (2 marks)

4. Solutions of two electrolytes 'A' and 'B' are diluted. The Λ_m of 'B' increases 1.5 times while that of *A* increases 25 times. Which of the two is a strong electrolyte? Justify your answer. Graphically show the behaviour of 'A' and 'B'. *(Term II, 2021-22)*

LA (5 marks)

5. (i) State Kohlrausch law.
(ii) Calculate the emf of the following cell at 298 K :
$Al_{(s)}|Al^{3+}\ (0.15\ M)\ ||\ Cu^{2+}\ (0.025\ M)\ |\ Cu_{(s)}$
(Given $E^\circ_{(Al^{3+}/Al)} = -1.66$ V, $E^\circ_{(Cu^{2+}/Cu)} = 0.34$ V, log 0.15 = −0.8239, log 0.025 = −1.6020)
(2020-21)

6. (i) On the basis of E° values identify which amongst the following is the strongest oxidising agent?
$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-$; $E^\circ = +1.36$ V,
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$; $E^\circ = +1.51$ V
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$;
$E^\circ = +1.33$ V
(ii) The following figure represents variation of (Λ_m) *vs* $\sqrt{C}$ for an electrolyte. Here, Λ_m is the molar conductivity and *C* is the concentration of the electrolyte.



(a) Define molar conductivity.
(b) Identify the nature of electrolyte on the basis of the above plot. Justify your answer.
(c) Determine the value of Λ_m° for the electrolyte.
(d) Show how to calculate the value of A for the electrolyte using the above graph. *(2020-21)*

2.5 Electrolytic Cells and Electrolysis

LA (5 marks)

7. (a) Molar conductivity of substance 'A' is 5.9×10^3 S/m and 'B' is 1×10^{-16} S/m. Which of the two is most likely to be copper metal and why?
(b) What is the quantity of electricity in Coulombs required to produce 4.8 g of Mg from molten $MgCl_2$? How much Ca will be produced if the same amount of electricity was passed through molten $CaCl_2$? (Atomic mass of Mg = 24 u, atomic mass of Ca = 40 u).
(c) What is the standard free energy change for the following reaction at room temperature? Is the reaction spontaneous?
$Sn_{(s)} + 2Cu^{2+}_{(aq)} \rightarrow Sn^{2+}_{(aq)} + 2Cu^{+}_{(s)}$ *(2022-23)*

2.6 Batteries

LA (5 marks)

8. (a) Why does the cell voltage of a mercury cell remain constant during its lifetime?
(b) Write the reaction occurring at anode and cathode and the products of electrolysis of aq KCl.
(c) What is the pH of HCl solution when the hydrogen gas electrode shows a potential of -0.59 V at standard temperature and pressure? *(2022-23)*

2.8 Corrosion

SA I (2 marks)

9. Corrosion is an electrochemical phenomenon. The oxygen in moist air reacts as follows:
$O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$.
Write down the possible reactions for corrosion of zinc occurring at anode, cathode, and overall reaction to form a white layer of zinc hydroxide. *(2022-23)*

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. (c) : If external potential applied becomes greater than E_{cell} of electrochemical cell then the cell behaves as an electrolytic cell and the direction of flow of current is reversed.

2.

S.No.	Electrochemical cell	Electrolytic cell
1.	It is a device to convert chemical energy into electrical energy, *i.e.*, electrical energy is produced as a result of the redox reaction.	It is a device to convert electrical energy into chemical energy, *i.e.*, electrical energy is supplied to the electrolytic solution to bring about the redox reaction.
2.	It is based upon the redox reaction which is spontaneous *i.e.*, ΔG = –ve	In it redox reaction is non-spontaneous and takes place only when electrical energy is supplied *i.e.*, ΔG = +ve.

Commonly Made Mistake

- **Electrochemical cell** : Convert chemical energy into electrical energy.
- **Electrolytic cell** : Convert electrical energy into chemical energy.

3. The device which converts the chemical energy liberated during the chemical reaction to electrical energy is called electrochemical cell.
If external potential applied becomes greater than E°_{cell} of electrochemical cell then the cell behaves as an electrolytic cell and the direction of flow of current is reversed.

4. (d) : The cell can be represented as :
$Zn \mid Zn^{2+} \parallel Ag^+ \mid Ag$

5. (a) : If standard electrode potential of an electrode is greater than zero, then we can infer that its reduced form is more stable as compared to hydrogen gas.

6. (c) : For a spontaneous reaction, Gibb's free energy change ΔG must be negative, so E°_{cell} should be positive.
$\Delta G = -nFE^\circ_{cell}$

7. (d) : $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$
$= +0.80 - (-0.44) = +1.24$ V

8. (b) : $Sn_{(s)} \longrightarrow Sn^{2+}_{(aq)} + 2e^-$ ...(i)

$Fe^{3+}_{(aq)} + e^- \longrightarrow Fe^{2+}_{(aq)}$ ...(ii)

On multiplying equation (ii) by 2 and adding equation (i) and (ii), we get

$Sn_{(s)} + 2\,Fe^{3+}_{(aq)} \longrightarrow 2Fe^{2+}_{(aq)} + Sn^{2+}_{(aq)}$

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$
$= 0.77 - (-0.14)$
$= +0.91\ V$

$\because$ E°_{cell} is positive, so ΔG is -ve, hence spontaneous reaction.

9. $Fe \longrightarrow Fe^{2+} + 2e^-$
$2H^+ + 2e^- \longrightarrow H_2$
$Fe + 2H^+ \longrightarrow Fe^{2+} + H_2$

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{2}\log\frac{[Fe^{2+}]}{[H^+]^2}$$

$$= 0.44 - \frac{0\cdot0591}{2}\log\left(\frac{0.01}{1}\right)$$

$$= 0.44 + \frac{0\cdot0591}{2} \times 2$$

$E_{cell} = 0.4991\ V$

10. $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$
$= 0.40 - (-0.76)$
$= 1.16\ V$
$\Delta G^\circ = -nFE^\circ_{cell}$
$\Delta G^\circ = -2 \times 96500 \times 1.16$
$= -2,23,880\ J\ mol^{-1}$
$= -223.880\ kJ\ mol^{-1}$

11. $$E_{cell} = E^\circ_{cell} - \frac{0.059}{2}\log\frac{[Zn^{2+}]}{[Cu^{2+}]}$$

or $$E_{cell} = E^\circ_{cell} + \frac{0.059}{2}\log\frac{[Cu^{2+}]}{[Zn^{2+}]}$$

(i) When concentration of Cu^{2+} ions is increased, E_{cell} will increase.

(ii) When concentration of Zn^{2+} ions is increased, E_{cell} will decrease.

12. The cell can be written as
$Mg\,|\,Mg^{2+}\,||\,Ag^+\,|\,Ag$
According to Nernst equation,

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF}\ln\frac{[Mg^{2+}]}{[Ag^+]^2}$$

$$E_{cell} = E^\circ_{cell} - \frac{0.059}{2}\log\frac{[Mg^{2+}]}{[Ag^+]^2},\ \text{At}\ 25^\circ C$$

Key Points

- Metal|Metal ion (conc.) || Metal ion (conc.)|Metal
  Salt bridge
  By convention the electrode on which oxidation takes place is written on the L.H.S and other electrode on which reduction takes place is written on the R.H.S

13. $2Al_{(s)} + 3Ni^{2+}_{(aq.)} \longrightarrow 2Al^{3+}_{(aq.)} + 3Ni_{(s)}$
$E^\circ_{cell} = E^\circ_{Ni^{2+}/Ni} - E^\circ_{Al^{3+}/Al}$
$= -0.25 - (-1.66) = 1.41\ V$

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{n}\log\frac{[Al^{3+}]^2}{[Ni^{2+}]^3}$$

$$= 1.41 - \frac{0.0591}{6}\log\frac{(0.001)^2}{(0.1)^3}$$

$$= 1.41 - \frac{0.0591}{6}\log 10^{-3}$$

$$= 1.41 + \frac{0.0591}{6} \times 3 \times 1 = 1.439\ V$$

14. Given : $E^\circ_{cell} = 2.71\ V$
For the reaction, $Mg_{(s)} + Cu^{2+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + Cu_{(s)}$
$n = 2, \Delta_r G^\circ = ?$

Using formula, $\Delta_r G^\circ = -nFE^\circ_{cell}$

$\Delta_r G^\circ = -2 \times 96500\ C\ mol^{-1} \times 2.71\ V$
or $\Delta_r G^\circ = -523030\ J\ mol^{-1} = -523.03\ kJ\ mol^{-1}$

15. $A_{(s)} + B^{2+}_{(aq)} \rightleftharpoons A^{2+}_{(aq)} + B_{(s)}$
Here, $n = 2$
Using formula,

$$E^\circ_{cell} = \frac{0.059}{n}\log K_c$$

$$E^\circ_{cell} = \frac{0.059}{2}\log 10$$

$E^\circ_{cell} = 0.0295\ V$

16. For a general electrochemical reaction,
$aA + bB \longrightarrow cC + dD$
Nernst equation can be written as:

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF}\ln\frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Given cell :
$Zn|Zn^{2+}\,(0.001\ M)||H^+(0.01\ M)|\,H_{2(g)}\,(1\ bar)\,|\,Pt_{(s)}$
Cell reaction :
$Zn + 2H^+ \longrightarrow Zn^{2+} + H_2$

$E^\circ_{cell} = E^\circ_{H^+/H_2} - E^\circ_{Zn^{2+}/Zn} = 0.00\ V - (-0.76\ V) = 0.76\ V$

$$E_{cell} = 0.76\ V - \frac{0.0591}{2}\log\frac{(0.001)}{(0.01)^2}$$

$= 0.76 - (0.0295) \times (1) = 0.76 - 0.0295 = 0.73\ V$

17. **At anode :** $Ni \rightarrow Ni^{2+} + 2e^-$
At cathode : $[Ag^+ + e^- \rightarrow Ag] \times 2$
Cell reaction : $Ni + 2Ag^+ \rightarrow Ni^{2+} + 2Ag$
$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$
$= E^\circ_{Ag^+/Ag} - E^\circ_{Ni^{2+}/Ni} = 0.80\ V - (-0.25)$
$E^\circ_{cell} = 1.05\ V$

$$E^\circ_{cell} = \frac{0.0591}{n}\log K_c$$

$$\log K_c = \frac{E^\circ_{cell} \times n}{0.0591} = \frac{1.05 \times 2}{0.0591}$$

$\log K_c = 35.53$
$K_c = \text{antilog}\ 35.53 = 3.38 \times 10^{35}$
$\Delta G^\circ = -nFE^\circ = -2 \times 96500 \times 1.05 = -202650\ J\ mol^{-1}$
$= -202.65\ kJ\ mol^{-1}$

The maximum work that can be obtained = 202.65 kJ.

Answer Tips

- When a spontaneous chemical reaction occurs, the decrease in the free energy, $-\Delta G$, corresponds to the maximum possible quantity of useful work, W_{max}.

18. The cell reaction is

$Fe_{(s)} + 2H^+_{(aq)} \rightarrow Fe^{2+}_{(aq)} + H_{2(g)}$

$E^\circ_{cell} = 0.0 - (-0.44) = 0.44\ V$

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{2}\log\frac{[Fe^{2+}]}{[H^+]^2}$$

$$= 0.44 - \frac{0.0591}{2}\log\left(\frac{0.001}{(0.01)^2}\right)$$

$= 0.44 - 0.02955 = 0.41045\ V$

19. $Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$

Here, $n = 2$

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = 0.34 - (-0.76) = 1.1\ V$

$1\ F = 96500\ C\ mol^{-1}$

$\Delta_r G^\circ = -nFE^\circ_{cell} = -2 \times 1.1 \times 96500 = -212300\ J\ mol^{-1}$

$= -212.3\ kJ\ mol^{-1}$

20. **At anode :** $Zn \rightarrow Zn^{2+} + 2e^-$

At cathode : $2Ag^+ + 2e^- \rightarrow 2Ag$

Overall reaction : $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = E^\circ_{Ag^+/Ag} - E^\circ_{Zn^{2+}/Zn}$

$= 0.80 - (-0.76) = 1.56\ V$

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{2}\log\frac{[Zn^{2+}]}{[Ag^+]^2}$$

$$= 1.56 - \frac{0.059}{2}\log\frac{0.1}{(0.01)^2} = 1.47\ V$$

21. $E^\circ_{cell} = E^\circ_{right} - E^\circ_{left} = -0.403 - (-0.763) = 0.36\ V$

$\Delta_r G^\circ = -nFE^\circ_{cell} = -2 \times 96500 \times 0.36$

$= -69480\ J\ mol^{-1} = -69.48\ kJ\ mol^{-1}$

Using formula, $\log K_c = \frac{nE^\circ_{cell}}{0.059} = \frac{2 \times 0.36}{0.059} = 12.20$

$K_c = \text{antilog } 12.20 = 1.58 \times 10^{12}$

22. $$E = E^\circ - \frac{0.0591}{n}\log\frac{[M]}{[M^{n+}]}$$

$$= E^\circ - \frac{0.0591}{n}\log\frac{1}{[M^{n+}]}$$

$$= -0.76 - \frac{0.0591}{2}\log\frac{1}{0.01}$$

$$= -0.76 - \frac{0.0591}{2} \times 2$$

$= -0.819\ V$

Key Points

- For pure solids or liquids or gases at one atmospheric pressure, the molar concentration (here [M]) is taken as unity.

23. The electrode reactions are

At anode : $Sn_{(s)} \rightarrow Sn^{2+}\ (0.004\ M) + 2e^-$

At cathode : $2H^+\ (0.02\ M) + 2e^- \rightarrow H_2\ (1\ bar)$

Net reaction :

$Sn_{(s)} + 2H^+(0.02\ M) \rightarrow Sn^{2+}(0.004\ M) + H_2\ (1\ bar)$

The Nernst equation of this cell at 25 °C

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{2}\log\frac{[Sn^{2+}](p_{H_2})}{[H^+]^2}$$

$E^\circ_{cell} = E^\circ_{H^+|H_2} - E^\circ_{Sn^{2+}|Sn} = 0.000\ V - (-0.14\ V) = +0.14\ V$

or, $$E_{cell} = E^\circ_{cell} - 0.0296 \log\frac{0.004 \times 1}{(0.02)^2}$$

$$= E^\circ_{cell} - 0.0296 \log\left(\frac{0.004}{0.0004}\right)$$

$$= E^\circ_{cell} - 0.0296\ (\log 10)$$

$= E^\circ_{cell} - 0.0296 \times 1 = E^\circ_{cell} - 0.0296$

$E_{cell} = 0.14 - 0.0296 = 0.1104\ V$

Key Points

- Remember : $E^\circ_{H^+|H_2} = 0$

24. $\Delta G^\circ = -nFE^\circ_{cell}$

$$E^\circ_{cell} = -\frac{\Delta G^\circ}{nF} = -\frac{(-43600)}{2 \times 96500} = 0.226\ V$$

$2AgCl_{(s)} + H_{2(g)}\ (1\ atm) \rightarrow 2Ag_{(s)} + 2H^+(0.1\ M) + 2Cl^-(0.1\ M)$

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{n}\log\frac{[Product]}{[Reactant]}$$

$$= 0.226 - \frac{0.0591}{2}\log\frac{(0.1)^2}{(1)}$$

$$= 0.226 - \frac{0.0591}{2}\log(10^{-2}) = 0.226 - \frac{0.0591}{2}(-2)$$

$= 0.226 + 0.0591 = 0.2851\ V$

Answer Tips

- As Cl^- is not participating in the redox reaction so Cl^- ion concentration should be ignored.

25. $E^\circ_{cell} = E^\circ_{right} - E^\circ_{left} = -0.44 - (-0.74) = 0.30\ V$

$2\ Cr + 3Fe^{2+}\ (0.1\ M) \rightarrow 2Cr^{3+}\ (0.01\ M) + 3Fe$

$$E_{cell} = 0.30 - \frac{0.0591}{6}\log\frac{(0.01)^2}{(0.1)^3} = 0.30 + 0.01 = 0.31\ V$$

Answer Tips

- E°_{cell} = Oxidation potential at anode – oxidation potential at cathode

$= E^\circ_{ox(Anode)} - E^\circ_{ox(Cathode)}$

26. Given cell,

$2Al_{(s)} + 3Cu^{2+}\ (0.01\ M) \rightarrow 2Al^{3+}(0.01\ M) + 3Cu_{(s)}$

$E_{cell} = 1.98\ V,\ E^\circ_{cell} = ?$

Using Nernst equation at 298 K

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{6}\log\frac{[Al^{3+}]^2}{[Cu^{2+}]^3}$$

$$1.98\ V = E^\circ_{cell} - \frac{0.0591}{6}\log\frac{[10^{-2}]^2}{[10^{-2}]^3}$$

$$1.98\ V = E^\circ_{cell} - \frac{0.0591}{6}\log 10^2$$

$$1.98\ V = E^\circ_{cell} - \frac{0.0591}{6}\times 2$$

$$\therefore \quad E^\circ_{cell} = 1.98 + \frac{0.0591}{3} = 2\ V$$

27. $E^\circ_{cell} = +0.80\ V - 0.77\ V = +0.03\ V$

$\Delta_r G^\circ = -nFE^\circ_{cell} = -1 \times 96500 \times 0.03$

$= -2895\ J\ mol^{-1} = -2.895\ kJ\ mol^{-1}$

$\Delta G^\circ = -2.303\ RT \log K_c$

$-2895 = -2.303 \times 8.314 \times 298 \times \log K_c$

or $\log K_c = 0.5074$

$K_c = \text{Antilog}\ (0.5074) = 3.22$

28. The cell reaction can be represented as :

$Mg_{(s)} + Cu^{2+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + Cu_{(s)}$

Given: $E^\circ_{cell} = +2.71\ V, T = 298\ K$

According to the Nernst equation :

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{n}\log\frac{[Mg^{2+}_{(aq)}]}{[Cu^{2+}_{(aq)}]}$$

$$= 2.71 - \frac{0.0591}{2}\log\frac{0.1}{0.01} = 2.6804\ V$$

29. $Al_2O_3\,(2Al^{3+} + 3O^{2-}) \rightarrow 2Al + \frac{3}{2}O_2,\ n = 6e^-$

$$\therefore \frac{2}{3}Al_2O_3 \rightarrow \frac{4}{3}Al + O_2,\ n = \frac{2}{3}\times 6e^- = 4e^-$$

$\Delta G = 960\ kJ = 960000\ J$

Now, $\Delta G = -nFE_{cell}$

$$E_{cell} = -\frac{\Delta G}{nF} = \frac{-960000}{4\times 96500} = -2.487\ V$$

Minimum potential difference needed to reduce Al_2O_3 is $-2.487\ V$.

30. $$E_{cell} = E^\circ_{cell} - \frac{0.0591}{n}\log\frac{[Mg^{2+}]}{[Cu^{2+}]}$$

$$= 2.71 - \frac{0.0591}{2}\log\frac{0.001}{0.01} = 2.73955\ V$$

(i) If external opposing potential is less than 2.71 V then current will flow from Cu to Mg.

(ii) If external opposing potential is greater than 2.71 V then current will flow in opposite direction *i.e.* from Mg to Cu.

31. $Mg_{(s)}\,|\,Mg^{2+}(0.001\ M)\,||\,Cu^{2+}(0.0001\ M)\,|\,Cu_{(s)}$

Reactions :

Anode : $Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + 2e^-$

Cathode : $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

Net cell reaction : $Mg_{(s)} + Cu^{2+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + Cu_{(s)}$

$\therefore \quad n = 2$

Using Nernst equation :

$$E_{cell} = E^\circ_{cell} - \frac{2.303RT}{nF}\log\frac{[Mg^{2+}]}{[Cu^{2+}]}$$

For the given cell

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = E^\circ_{Cu^{2+}/Cu} - E^\circ_{Mg^{2+}/Mg}$

$= 0.34\ V - (-2.37\ V) = 2.71\ V$

Given $[Mg^{2+}] = 0.001\ M, [Cu^{2+}] = 0.0001\ M$

Putting in Nernst equation at 298 K

$$E_{cell} = 2.71 - \frac{0.059}{2}\log\frac{0.001}{0.0001}$$

$E_{cell} = 2.71 - 0.0295 \log 10 = 2.68\ V$

$\Delta_r G = -nFE_{cell} = -2\times 96500\ C\ mol^{-1}\times 2.68$

$= -517240\ J\ mol^{-1} = -517.24\ kJ\ mol^{-1}$

32. **(b):** Unit of molar conductivity:

$$\Lambda_m = \frac{\kappa(\Omega^{-1}cm^{-1})\times 1000(cm^3L^{-1})}{\text{Molarity}\ (mol\,L^{-1})}$$

$= \Omega^{-1}cm^2\ mol^{-1}$ or $S\ cm^2\ mol^{-1}$.

33. **(d)**

Key Points

- Conductivity always decrease with decrease in concentration both for weak and strong electrolytes.

34. Conductivity of CH_3COOH (weak electrolyte) decreases with dilution because the number of current carrying particles *i.e.*, ions present per cm^3 of the solution becomes less and less on dilution.

35. The limiting molar conductivity of an electrolyte is defined as its molar conductivity when the concentration of the electrolyte in the solution approaches zero.

Conductivity of an electrolyte decreases with dilution because the number of current carrying particles *i.e.*, ions present per cm_3 of the solution becomes less and less on dilution.

36. **Kohlrausch's law of independent migration of ions :** It states that limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolyte.

If $\lambda^\circ_{Na^+}$ and $\lambda^\circ_{Cl^-}$ are limiting molar conductivities of the sodium and chloride ions respectively then the limiting molar conductivity for sodium chloride is given by

$$\Lambda^\circ_{m\,(NaCl)} = \lambda^\circ_{Na^+} + \lambda^\circ_{Cl^-}$$

Kohlrausch's law helps in the calculation of degree of dissociation of weak electrolyte like acetic acid.

The degree of dissociation α is given by

$$\alpha = \frac{\Lambda_m}{\Lambda^\circ_m}$$

where, Λ_m is the molar conductivity and Λ°_m is the limiting molar conductivity.

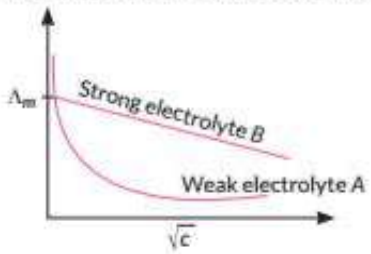
37. **Molar Conductivity** : Molar conductivity of a solution at a volume V is the conductance of all the ions produced from one mole of the electrolyte dissolved in $V\ cm^3$ of the solution when the electrodes are one cm apart and the area of the electrodes is so large that the whole solution is contained between them.

$\Lambda_m = \kappa V$

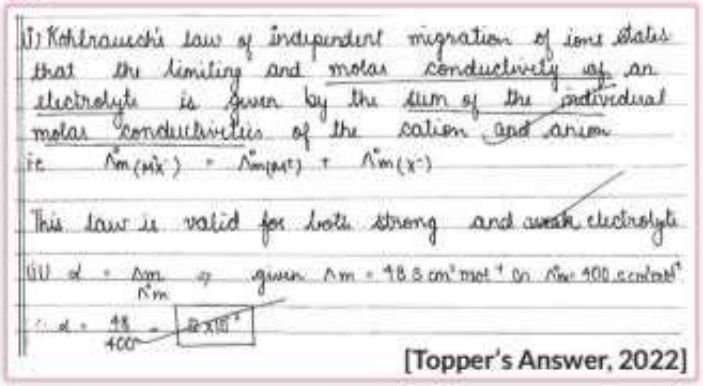
Its units are $S\ cm^2\ mol^{-1}$.

38. The molar conductivity (Λ_m) of strong electrolyte increases slowly with dilution as there is no increase in number of ions on dilution because they are already completely dissociated whereas Λ_m for weak electrolyte

increases very rapidly on dilution as the number of ions increase due to increase in dissociation. Hence, *B* is a strong electrolyte and *A* is a weak electrolyte.



39.


(i) Kohlrausch's law of independent migration of ions states that the limiting and molar conductivity of an electrolyte is given by the sum of the individual molar conductivities of the cation and anion
ie $\Lambda^\circ_{m(MX)} = \Lambda^\circ_{m(M^+)} + \Lambda^\circ_{m(X^-)}$
This law is valid for both strong and weak electrolyte
(ii) $\alpha = \frac{\Lambda_m}{\Lambda^\circ_m}$ given $\Lambda_m = 48.8\ cm^2 mol^{-1}$ & $\Lambda^\circ_m = 400\ cm^2 mol^{-1}$
$\therefore \alpha = \frac{48}{400} = 0.12$

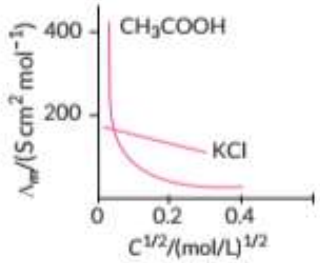
[Topper's Answer, 2022]

40. Given that, $\kappa = 7.8 \times 10^{-5}\ S\ cm^{-1}$, $M = 0.001\ M$
$\Lambda^\circ_m = 390\ S\ cm^2\ mol^{-1}$
We know that,

$$\Lambda_m = \frac{\kappa \times 1000}{M} = \frac{7.8 \times 10^{-5} \times 1000}{0.001} = 78\ S\ cm^2\ mol^{-1}$$

$$\alpha = \frac{\Lambda_m}{\Lambda^\circ_m} = \frac{78}{390} = 0.2$$

41. Weak electrolytes like acetic acid have lower degree of dissociation at higher concentrations and hence for such electrolytes, the change in Λ_m with dilution is due to increase in the degree of dissociation. This results in increase in the number of ions in the total volume. In case of weak electrolyte, Λ_m increases steeply on dilution at lower concentrations and does not reach a constant value even at infinite dilution. Therefore Λ°_m cannot be obtained by extrapolation of Λ_m to zero concentration.



Λ°_m for such case is obtained by using Kohlrausch law of independent migration of ions. The law states that limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolytes, *i.e.*, $\Lambda^\circ_m = \upsilon_+ \lambda^\circ_+ + \upsilon_- \lambda^\circ_-$

42. (a) Molar conductivity of a solution at a volume *V* is the conductance of all the ions produced from one mole of the electrolyte dissolved in *V* cm^3 of the solution when the electrodes are one cm apart and the area of the electrodes is so large that the whole solution is contained between them.

$\Lambda_m = \kappa V$

(b) Units are S cm^2 mol^{-1}.

(c) Molar conductivity increases with decrease in concentration because the total volume, *V* of solution containing one mole of electrolyte also increases.

43. (a) Direct current will cause electrolysis of solution, so more ions will be produced. Hence, we use alternating current instead of direct current.

(b) Kohlrausch's law of independent migration of ions : It states that limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolyte.

If $\lambda^\circ_{Na^+}$ and $\lambda^\circ_{Cl^-}$ are limiting molar conductivities of the sodium and chloride ions respectively then the limiting molar conductivity for sodium chloride is given by

$$\Lambda^\circ_{m\,(NaCl)} = \lambda^\circ_{Na^+} + \lambda^\circ_{Cl^-}$$

(c) The cell can be represented as :
$Mg \mid Mg^{2+} \parallel Cu^{2+} \mid Cu$

44. *Y* is a weak electrolyte. As the concentration of the weak electrolyte is reduced, more of it ionises. Hence, a weak electrolyte shows a very large increase in concentration with dilution. A strong electrolyte shows only small increase in conductance with dilution, because a strong electrolyte is completely dissociated in solution so the number of ions remain constant.

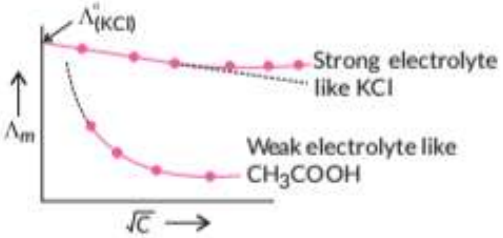
45. (i) Electrolyte *A* is a strong electrolyte while electrolyte *B* is a weak electrolyte.

(ii) For electrolyte *A*, the plot becomes linear near high dilution and thus can be extrapolated to zero concentration to get the molar conductivity at infinite dilution.

For weak electrolyte *B*, Λ_m increases steeply on dilution and extrapolation to zero concentration is not possible. Hence, molar conductivity at infinite dilution cannot be determined.

46. For a strong electrolyte it is shown by Debye-Huckel Onsager equation as follows :

$$\Lambda_m = \Lambda^\circ_m - A\sqrt{C}$$



Here, Λ°_m = Molar conductivity at infinite dilution (Limiting molar conductivity)
Λ_m = Molar conductivity at *V*-dilution
A = Constant which depends upon nature of solvent and temperature
c = Concentration
Plot of Λ_m against $C^{1/2}$ is a straight line with intercept equal to Λ°_m and slope equal to '–*A*'.
Thus, Λ_m decreases linearly with $\sqrt{C}$, when $C = 0$,

$\Lambda_m = \Lambda^\circ_m$ and Λ°_m can be determined experimentally.

47. Degree of dissociation (α) = $\frac{\Lambda_m}{\Lambda^\circ_m}$

$$\alpha = \frac{39.05\ S\ cm^2 mol^{-1}}{(349.68+40.9)\ S\ cm^2 mol^{-1}} = 0.1$$

48. The fraction of the total number of molecules present in solution as ions is known as degree of dissociation.
Molar conductivity (λ_m) = $\alpha\lambda^\circ_m$
where λ°_m is the molar conductivity at infinite dilution.

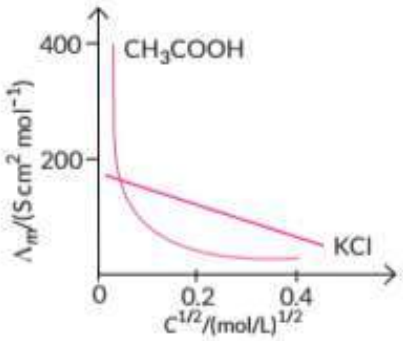
49. The reciprocal of resistivity is known as specific conductance or simply conductivity. It is denoted by κ (kappa).

$$\kappa = \frac{1}{\rho} \text{ or } \kappa = G \times \frac{l}{A}$$

Hence, conductivity of a solution is defined as the conductance of a conductor of 1 cm length and having 1 cm^2 as the area of cross section. Alternatively, it may be defined as conductance of one centimetre cube of the solution of the electrolyte. Molar conductivity of a solution at a dilution V is the conductance of all the ions produced from 1 mole of the electrolyte dissolved in V cm^3 of the solution. It is represented by Λ_m.

$\Lambda_m = \kappa V$

Variation of conductivity and molar conductivity with concentration : Conductivity always decreases with decrease in concentration, for both weak and strong electrolytes. Because the number of ions per unit volume that carry the current in a solution decreases on dilution.



Molar conductivity increases with decrease in concentration because the total volume, V of solution containing one mole of electrolyte also increases. It has been found that decrease in κ on dilution of a solution is more than compensated by increase in its volume.

Commonly Made Mistake

- For strong electrolyte conductivity decrease with decrease in concentration while molar conductivity increase with increase in concentration.

50. **Kohlrausch's law of independent migration of ions :** It states that limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolyte.
If $\lambda^\circ_{Na^+}$ and $\lambda^\circ_{Cl^-}$ are limiting molar conductivities of the sodium and chloride ions respectively then the limiting molar conductivity for sodium chloride is given by

$\Lambda^\circ_{m\,(NaCl)} = \lambda^\circ_{Na^+} + \lambda^\circ_{Cl^-}$

Conductivity of an electrolyte decreases with dilution because the number of current carrying particles *i.e.*, ions present per cm^3 of the solution becomes less and less on dilution.

51. The reciprocal of resistivity is known as specific conductance or simply conductivity. It is denoted by κ (kappa).

$$\kappa = \frac{1}{\rho} \text{ or } \kappa = G \times \frac{l}{A}$$

Hence, conductivity of a solution is defined as the conductance of a conductor of 1 cm length and having 1 sq. cm as the area of cross section. Alternatively, it may be defined as conductance of one centimetre cube of the solution of the electrolyte. Molar conductivity of a solution at a dilution V is the conductance of all the ions produced from 1 mole of the electrolyte dissolved in V cm^3 of the solution. It is represented by Λ_m.

$\Lambda_m = \kappa V$

Variation of conductivity and molar conductivity with temperature : Both increase with increase in temperature as degree of ionisation increases.

52. Conductivity (κ) = $\frac{1}{R} \times G^* = \frac{1}{200} \times 1$

$= 5 \times 10^{-3}\ \Omega^{-1}\ cm^{-1}$

Molar conductivity (Λ_m)

$$= \frac{\kappa \times 1000}{M} = \frac{5 \times 10^{-3} \times 1000}{0.01} = 500\ \Omega^{-1}\ cm^2\ mol^{-1}$$

53. (a) $\Delta G^\circ = nFE^\circ_{cell}$

$$E^\circ_{cell} = \frac{-\Delta G^\circ}{nF} = \frac{300 \times 1000\ J\ mol^{-1}}{2 \times 96500\ C\ mol^{-1}} = 1.55\ V$$

(b) $\Lambda^\circ_m (MgCl_2) = \lambda^\circ_m (Mg^{2+}) + 2\lambda^\circ_m (Cl^-)$

$= 106\ S\ cm^2\ mol^{-1} + 2 \times 76.3\ S\ cm^2\ mol^{-1}$

$= 258.6\ S\ cm^2\ mol^{-1}$

54. Using formula, $\Lambda_m = \frac{\kappa \times 1000}{C}$

Given, $\kappa = 3.905 \times 10^{-5}\ S\ cm^{-1}$

$C = 0.001\ mol\ L^{-1}$

$$\therefore \Lambda_m = \frac{3.905 \times 10^{-5} \times 1000}{0.001} = 39.05\ S\ cm^2\ mol^{-1}$$

The degree of dissociation, $\alpha = \frac{\Lambda_m}{\Lambda^\circ_m} = \frac{39.05}{390.5} = 0.1$

$[\because \Lambda^\circ_m = 349.6 + 40.9 = 390.5\ S\ cm^2\ mol^{-1}]$

55. Given : Conductivity, $\kappa = 8 \times 10^{-5}\ S\ cm^{-1}$

Molarity, $C = 0.002\ M = 0.002\ mol\ L^{-1}$

Using formula, $\Lambda^c_m = \frac{1000 \times \kappa}{C}$

$$\Lambda^c_m = \frac{1000 \times 8 \times 10^{-5}}{0.002} = 40\ S\ cm^2\ mol^{-1}$$

$$\alpha = \frac{\Lambda^c_m}{\Lambda^\circ_m} = \frac{40}{404} = 0.099$$

56. (i) Silver wire at 30 °C allows greater conduction of electricity than 60 °C because with increase in temperature metallic conduction decreases due to vibration of kernels.
(ii) 0.1 M acetic acid solution allows greater conduction of electricity because with dilution degree of dissociation increases and hence, number of ions increases.
(iii) KCl solution at 50° C will have greater conductance. This is because ionic mobilities increases with increase in temperature.

Commonly Made Mistake

- In solid metals, conduction decreases with increase in temperature while in solution conductivity increases with increase in temperature.

57. Given : $a = 0.625\ cm^2$, $l = 50\ cm$
$R = 5 \times 10^3$ ohm, $M = 0.05$ M

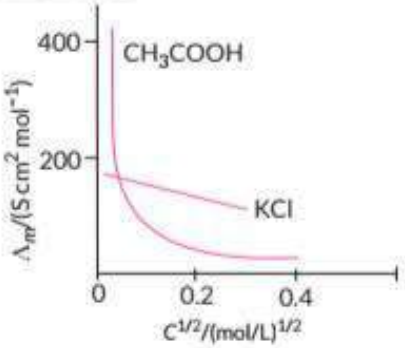
$$\text{Resistivity, } \rho = R \times \frac{A}{l} = 5 \times 10^3 \times \frac{0.625}{50} \text{ ohm cm}$$
$$= 62.5 \text{ ohm cm}$$

$$\text{Conductivity, } \kappa = \frac{1}{\rho} = \frac{1}{62.5} = 0.016 \text{ ohm}^{-1} \text{ cm}^{-1}$$

$$\text{Molar conductivity, } \Lambda_m = \frac{\kappa \times 1000}{M}$$
$$= \frac{0.016 \times 1000}{0.05} = 320 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$$

58. (a) $E^\circ_{cell} = E^\circ_{Ag^+/Ag} - E^\circ_{Zn^{2+}/Zn}$
$= 0.80 + 0.76 = 1.56$ V
$\Delta_r G^\circ = -nFE^\circ$
$\Delta_r G^\circ = -2 \times 96500 \times 1.56$
$= 301080\ J\ mol^{-1} = 301.080\ kJ\ mol^{-1}$

(b) For strong electrolytes the plot between Λ_m and $\sqrt{C}$ is a straight line with intercept equal to Λ°_m and slope equal to $-A$. Λ°_m for these can be obtained by extrapolation of Λ_m to zero concentration.



Λ°_m for weak electrolyte cannot be obtained by entrapolaration of graph at zero concentration. Λ°_m for such case is obtained by using Kohlrausch law of independent migration of ions. The law states that limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolytes, *i.e.*, $\Lambda^\circ_m = \upsilon_+ \lambda^\circ_+ + \upsilon_- \lambda^\circ_-$

59. Given : Conductivity, $\kappa = 0.0248\ S\ cm^{-1}$
Molarity, $C = 0.20$ M $= 0.20\ mol\ L^{-1}$

$$\text{Using formula, } \Lambda^c_m = \frac{1000 \times \kappa}{C}$$

$$\Lambda^c_m = \frac{1000 \times 0.0248}{0.20} = 124\ S\ cm^2\ mol^{-1}$$

$$\alpha = \frac{\Lambda^c_m}{\Lambda^\circ_m} = \frac{124}{73.5+76.5} = 0.82$$

60. Resistance of 0.1 M KCl solution $R = 100\ \Omega$
Conductivity $\kappa = 1.29\ S\ m^{-1}$
Cell constant $G^* = \kappa \times R = 1.29 \times 100 = 129\ m^{-1}$
Resistance of 0.02 M KCl solution, $R = 520\ \Omega$

$$\text{Conductivity, } \kappa = \frac{\text{cell constant}}{R} = \frac{129\ m^{-1}}{520\ \Omega} = 0.248\ S\ m^{-1}$$

Concentration, $C = 0.02\ mol\ L^{-1}$
$= 1000 \times 0.02\ mol\ m^{-3} = 20\ mol\ m^{-3}$

$$\text{Molar conductivity, } \Lambda_m = \frac{\kappa}{C} = \frac{0.248\ S\ m^{-1}}{20\ mol\ m^{-3}}$$
$$= 0.0124\ S\ m^2\ mol^{-1}$$

61. (a) Conductivity of an electrolyte decreases with dilution because the number of current carrying particles *i.e.*, ions present per cm^3 of the solution becomes less and less on dilution.
Molar conductivity increases with decrease in concentration because the total volume, V of solution containing one mole of electrolyte also increases.

(b) Degree of dissociation, $\alpha = \frac{\Lambda_m}{\Lambda^\circ_m}$

Given, $\Lambda^\circ_m = 150.0\ S\ cm^2\ mol^{-1}$
$\Lambda_m = 141.0\ S\ cm^2\ mol^{-1}$

$$\therefore \quad \alpha = \frac{141}{150} = 0.94 \text{ or } 94\%$$

(c) H^+ ion is smaller than K^+ ion. Since, smaller the cation, higher the molar conductivity, hence for the same concentration of HCl and KCl, molar conductivity of HCl is higher than that of KCl.

62. (a) The half cell reactions are :
At anode : $Zn \longrightarrow Zn^{2+} + 2e^-$
At cathode : $2Ag^+ + 2e^- \longrightarrow 2Ag$
So, silver plate is acting as cathode where reduction is taking place.
(b) The function of salt bridge in an electrochemical cell is to maintain electrical neutrality in solutions and prevent voltage drop. If the salt bridge is removed voltage will drop to zero and no current will flow.
(c) If external potential applied becomes greater than E°_{cell} of electrochemical cell then it behaves as an electrolytic cell and the direction of flow of current is reversed.
(d) (i) When E_{cell} is equal to zero, there will be a condition of equilibrium in the cell. So, the concentrations of Zn^{2+} and Ag^+ will become constant.
(ii) Conductivity of the solution decreases with dilution because the number of ions per unit volume that carry the current in solution decreases with dilution.

OR

(d) Given that, $\lambda_m = 138.9\ S\ cm^2\ mol^{-1}$,
Concentration = 1.5 M, κ = ?

$$\lambda_m = \frac{\kappa \times 1000}{M} \quad \Rightarrow \quad \kappa = \frac{\lambda_m \times M}{1000}$$

$k = \frac{138.9\ Scm^2\ mol^{-1} \times 1.5M}{1000} = 0.208\ Scm^{-1}$

63. (i) $C = 0.02\ M$

$r = \frac{d}{2} = \frac{1.40}{2}\ cm = 0.70\ cm$

$l = 44\ cm, \quad R = 5.00 \times 10^3\ \Omega$

As we know that,

$R = \rho\frac{l}{A} \Rightarrow 5.00 \times 10^3 = \rho \times \frac{44}{\pi(0.70)^2}$

$\rho = \frac{5.00 \times 10^3 \times 3.14 \times (0.70)^2 \times 10^{-2}}{44}$

$= 174.8\ \Omega cm$

Conductivity, $\kappa = \frac{1}{\rho} = \frac{1}{174.8} = 5.72 \times 10^{-3}\ \Omega^{-1}cm^{-1}$

Molar conductivity,

$\Lambda_m = \kappa \times \frac{1000}{\text{Molarity}} = \frac{5.72 \times 1000 \times 10^{-3}}{0.02} = 2,86\ Scm^2\ mol^{-1}$

(ii) $Ni|Ni^{2+}||Ag^+|Ag$

(i) Silver electrode is positively charged.

(ii) Electrons are the carriers of the current in the outer circuit.

64. (a) $2Al + 3Ni^{2+}(0.1\ M) \rightarrow 2Al^{3+}(0.01\ M) + 3Ni$

$E^\circ_{cell} = 1.41\ V$

The cell can be represent as :

$Al\ |\ Al^{3+}(0.01\ M)\ ||\ Ni^{2+}(0.1\ M)\ |\ Ni$

$E_{cell} = E^\circ_{cell} - \frac{0.0591}{n}\log\frac{[Al^{3+}]^2}{[Ni^{2+}]^3}$

$= 1.41 - \frac{0.0591}{n}\log\frac{(0.01)^2}{(0.1)^3}$

$= 1.41 - \frac{0.0591}{6}\log 10^{-1}$

$= 1.41 + \frac{0.0591}{6} = 1.419\ V$

(b) For weak electrolytes molar conductivity decrease with increase in concentration. As on low concentration (or on dilution) ionisation increases for weak electrolytes hence molar conductivity increases on dilution.

While the molar conductivity of strong electrolytes increases with increase in concentration as number of ions increases on increasing concentration.

For strong electrolyte, $\Lambda_m = \Lambda^\circ_m - A\sqrt{C}$

Thus Λ_m increase with increase in concentration.

Limiting molar conductivity for weak electrolytes is obtained by using kohlrauhch law of independent migration of ions. The law states that limiting molar conductivity of on electrolyte can be represent as the sum of the individual contributions of an anion and cation of the electrolyte i.e.,

$\Lambda^\circ_m = \nu_+ \lambda^\circ_+ + \nu_- \lambda^\circ_-$

65. (b): When concentrated brine *i.e.* aqueous solution of NaCl is electrolysed, products are chlorine at anode and hydrogen at cathode.

At cathode:

$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$

At anode :

$2Cl^-_{(aq.)} \rightarrow Cl_{2(g)} + 2e^-$

66. $\overset{+7}{MnO_4^-} + 5e^- \longrightarrow Mn^{2+}$

As $5e^-$ are needed to reduce 1 mol of MnO_4^- to Mn^{2+} thus chnage required is 5 Faraday.

Answer Tips

- For calculating charge required calculate number of electrons need for the change.

67. $\overset{-2}{H_2O} \longrightarrow H_2 + \frac{1}{2}\overset{0}{O_2}$,

charge required to oxidised 1 mol of H_2O is 2F

$= 2 \times 96500 = 193000\ C$

68. The reaction at anode with lower value of E° is preferred *i.e.*, O_2 gas should be liberated but on account of overpotential of oxygen, reaction preferred at anode is

$Cl^-_{(aq)} \rightarrow \frac{1}{2}Cl_{2(g)} + e^-$

i.e., Cl_2 gas is liberated at anode in the electrolysis of aq. NaCl.

69. The species that get reduced at cathode is the one having higher value of standard reduction potential. Hence, the reaction that will occur at cathode is $Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$.

70. $\underset{1\ mol}{Zn^{2+}_{(aq)}} + \underset{2\ mol}{2e^-} \longrightarrow Zn_{(s)}$

One mole of Zn^{2+} requires 2 moles of electrons for reduction *i.e.*

$Q = 2 \times F = 2 \times 96500 = 193000\ C$

71. The species that get reduced at cathode is the one which have higher value of standard reduction potential. Hence, the reaction that will occur at cathode is

$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

72. **Faraday's first law of electrolysis** : During electrolysis the amount of any substance deposited or liberated at an electrode is directly proportional to the quantity of electricity passed through the electrolyte *i.e.*,

$w \propto Q \quad \text{or} \quad w \propto I \times t \qquad [\because Q = I \times t]$

$w = Z \times I \times t$

where, Z is a constant of proportionality known as electrochemical equivalent of the substance deposited.

73. (i) $\Delta G^\circ = -nFE^\circ_{cell}$ (nF = amount of charge passed)

If ΔG is negative, *i.e.* E° is positive then the reaction will be spontaneous.

(ii) According to Faraday's first law of electrolysis, "weight of ions deposited on an electrode of an electrolytic cell is directly proportional to the quantity of electricity passed" *i.e.*,

$w \propto Q$ or $w = ZQ = ZIt$

where, Q = quantity of electricity (in coulombs)

I = current (in amperes), t = time (in second)

Z = electrochemical equivalent of material deposited on the electrode.

74. In aqueous solution, $CuCl_2$ ionises into

$CuCl_2 \rightarrow Cu^{2+} + 2Cl^-$

At cathode : $Cu^{2+} + 2e^- \rightarrow Cu$

At anode : $2Cl^- \rightarrow Cl_2 + 2e^-$

At the cathode, the copper ion will be deposited because it has a higher reduction potential than the water molecule. At the anode, the lower electrode potential value will be preferred but due to over potential of oxygen, chloride ion gets oxidized at the anode.

75. (a) $CuSO_{4(aq)} \rightarrow Cu^{2+}_{(aq)} + SO^{2-}_{4(aq)}$

At cathode: $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

At anode : $H_2O_{(l)} \rightarrow \frac{1}{2}O_{2(g)} + 2H^+_{(aq)} + 2e^-$

(b) At the cathode the following reduction reactions compete to take place :

$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$; $E^\circ = 0.80$ V

$H^+_{(aq)} + e^- \rightarrow \frac{1}{2}H_{2(g)}$; $E^\circ = 0.00$ V

The reaction with a higher value of E° takes place at the cathode. Therefore, the deposition of silver will take place. Since, Pt electrodes are inert, the anode is not attacked by NO_3^- ions. Therefore, OH^- or NO_3^- ions can be oxidized at the anode. But OH^- ions having a lower discharge potential get preference and decompose to liberate O_2.

$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$

76. $\underset{1\text{ mole}}{Fe^{3+}} + \underset{1e^-}{1e^-} \rightarrow Fe^{2+}$

1 mole of Fe^{3+} requires 1 mole of electrons for reduction.

3 moles of Fe^{3+} requires 3 moles of electrons for reduction.

i.e., $Q = 3 \times F$

$Q = 3 \times 96500$

$I = 2A$

$I = \frac{Q}{t}$

$t = \frac{Q}{I} = \frac{289500}{2} = 144750$ s

77. The species that get reduced at cathode is the one having higher value of standard reduction potential.

Hence, the reaction that will occur at cathode is

$H^+_{(aq)} + e^- \rightarrow \frac{1}{2}H_{2(g)}$; $E^\circ = 0{\cdot}00$ V

The species that get oxidised at anode is the one having lower value of E°. Thus

$2H_2O \longrightarrow O_{2(g)} + 4H^+ + 4e^-$

should take place but on account of overpotential of oxygen reaction preferred at anode is

$Cl^-_{(aq)} \rightarrow \frac{1}{2}Cl_{2(g)} + e^-$; $E^\circ = +1{\cdot}36$ V

78. Given : $I = 2$ A, $t = 15$ min $= 15 \times 60$ s $= 900$ s, $w = ?$

$Q = I \times t = 2 \times 900 = 1800$ C

Reaction for deposition of Ag is as follows :

$\underset{1\times 96500\text{ C}}{\overset{1\text{ F}}{Ag^+ + 1e^-}} \rightarrow \underset{108\text{ g}}{\overset{1\text{ mol}}{Ag}}$

Thus, 1×96500 C of electricity is required to deposit 108 g of Ag.

$\therefore$ 1800 C of electricity would deposit

$= \frac{108 \times 1800}{1 \times 96500} = 2.014$ g of Ag

79. **Faraday's first law of electrolysis :** During electrolysis the amount of any substance deposited or liberated at an electrode is directly proportional to the quantity of electricity passed through the electrolyte *i.e.*,

$w \propto Q$ or $w \propto I \times t$ [$\because Q = I \times t$]

$w = Z \times I \times t$

where, Z is a constant of proportionality known as electrochemical equivalent of the substance deposited.

The electrode reaction is $Cu^{2+} + 2e^- \rightarrow Cu$

$\therefore$ Quantity of charge required for reduction of 1 mol of $Cu^{2+} = 2F = 2 \times 96500 = 193000$ C

80. Given : Current $I = 5$ A; $t = 20 \times 60$ s, $w = ?$

$Q = I \times t = 5 \times 20 \times 60 = 6000$ C

Reaction for deposition of Ni,

$\underset{2\times 96500\text{ C}}{\overset{2\text{ mol}}{Ni^{2+} + 2e^-}} \longrightarrow \underset{58.7\text{ g}}{\overset{1\text{ mol}}{Ni}}$

Thus, 2×96500 C of electricity produces 58.7 g Ni.

$\therefore$ 6000 C of electricity would produce

$= \frac{58.7 \times 6000}{2 \times 96500} = 1.825$ g

81. (i) At the cathode the following reduction reactions compete to take place :

$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$; $E^\circ = 0.80$ V

$H^+_{(aq)} + e^- \rightarrow \frac{1}{2}H_{2(g)}$; $E^\circ = 0.00$ V

The reaction with a higher value of E° takes place at the cathode. Therefore, the deposition of silver will take place. Since, Pt electrodes are inert, the anode is not attacked by NO_3^- ions. Therefore, OH^- or NO_3^- ions can be oxidized at the anode. But OH^- ions having a lower discharge potential get preference and decompose to liberate O_2.

$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$

(ii) At the cathode, the following reduction reaction occurs to produce H_2 gas.

$H^+_{(aq)} + e^- \rightarrow \frac{1}{2}H_{2(g)}$

At the anode, the following processes are possible :

$2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$; $E^\circ = +1.23$ V ...(i)

$2SO^{2-}_{4(aq)} \rightarrow S_2O^{2-}_{8(aq)} + 2e^-$; $E^\circ = +1.96$ V ...(ii)

For dilute sulphuric acid, reaction (i) is preferred to produce O_2 gas but for concentrated sulphuric acid, (ii) occurs.

82. According to first law of electrolysis,

$w = ZIt$

$w = \frac{\text{Eq. wt.}}{F} \times It$

$w_{Cu} = 2$ g

$I = 2$ A

$2 = \frac{31.75}{96500} \times 2 \times t \Rightarrow t = \frac{96500 \times 2}{2 \times 31.75} = 3040$ sec

Eq. w.t of $Cu^{2+} = 31.75$

According to second law of electrolysis,

$$\frac{\text{Mass of Zn deposited}}{\text{Mass of Cu deposited}} = \frac{\text{Eq. wt. of Zn}}{\text{Eq. wt. of Cu}}$$

$$\frac{w_{Zn}}{2} = \frac{32.5}{31.75}$$

$$w_{Zn} = \frac{32.5 \times 2}{31.75} = 2.047 \text{ g}$$

83. According to Faraday's first law of electrolysis,
mass of substance deposited $\propto$ quantity of electricity passed

$$\Rightarrow W = ZQ = \frac{\text{Eq. wt.}}{F} \times Q$$

$$\Rightarrow 2.8 = \frac{28}{96500} \times Q$$

$$\Rightarrow Q = \frac{2.8 \times 96500}{28} = 9650 \text{ C}$$

$$\text{Now } Q = It \Rightarrow t = \frac{Q}{I} = \frac{9650}{2} = 4825 \text{ s}$$

According to Faraday's second law of electrolysis,

$$\frac{\text{Mass of Fe deposited}}{\text{Mass of Zn deposited}} = \frac{\text{Eq.wt.of Fe}}{\text{Eq.wt.of Zn}}$$

$$\Rightarrow \frac{2.8}{\text{Mass of Zn deposited}} = \frac{28}{32.65}$$

$$\Rightarrow \text{Mass of Zn deposited} = \frac{2.8}{28} \times 32.65 = 3.265 \text{ g}$$

84. Charge = 24,000 coulombs
According to reaction, $Cr^{6+} + 6e^- \rightarrow Cr_{(s)}$
We require 6F or 6 × 96500 C to deposit 1 mole or 52 g of Cr.
For 24,000 C, the mass of Cr deposited

$$= \frac{52 \times 24{,}000}{6 \times 96500} = 2.15 \text{ g}$$

According to Faraday's first law of electrolysis,

$$\frac{w_1}{w_2} = \frac{Q_1}{Q_2} \text{ or } \frac{2.15}{1.5} = \frac{24{,}000}{12.5 \times t}$$

$w = ZIt$

$$1.5 = \frac{52}{6 \times 96500} \times 12.5 \times t \Rightarrow t = \frac{6 \times 1.5 \times 96500}{52 \times 12.5} = 1336.15 \text{ s}$$

85. (a) $2Fe^{3+} + 2e^- \longrightarrow 2Fe^{2+}$ and $2I^- \longrightarrow I_2 + 2e^-$
Hence, for the given cell reaction, $n = 2$
$\Delta_r G^\circ = -nFE^\circ_{cell} = -2 \times 96500 \times 0.236 = -45.55 \text{ kJ mol}^{-1}$
(b) Given, $I = 0.5$ A, $t = 2$ hrs.
Number of electrons = ?
Total charge (Q) = $I \times t = 0.5 \times 2 \times 60 \times 60 = 3600$ C

$$\therefore \text{ Number of electrons} = \frac{\text{Total charge}}{\text{Charge of one electron}}$$

$$= \frac{3600}{1.6 \times 10^{-19}}$$

$$= 2.25 \times 10^{22} \text{ electrons}$$

86. (i) It states that limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolyte.
Expression for the limiting molar conductivity of acetic acid is

$$\Lambda^\circ_{CH_3COOH} = \lambda^\circ_{CH_3COO^-} + \lambda^\circ_{H^+}$$

(ii) $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = E^\circ_{Ag^+/Ag} - E^\circ_{Ni^{2+}/Ni}$
$= +0.80 \text{ V} - (-0.25 \text{ V})$
$= 1.05 \text{ V}$
Maximum work = $\Delta G^\circ = -nFE^\circ_{cell}$
$= -2 \times 96500 \times 1.05$
$= -202650 \text{ J mol}^{-1}$
$= -202.65 \text{ kJ mol}^{-1}$
$\Delta G^\circ = -RT \ln K_c = -202650 \text{ J mol}^{-1}$
$8.314 \text{ J K}^{-1}\text{mol}^{-1} \times 298 \text{ K} \ln K_c = 202650 \text{ J mol}^{-1}$
$\ln K_c = 81.79$
$2.303 \log K_c = 81.79$
$\log K_c = 35.5145$

87. The batteries which can be recharged again and again are called as secondary batteries. *e.g.*, lead storage battery.

88. The mercury cell is generally used in hearing aids.
Reaction at cathode :
$HgO + H_2O + 2e^- \rightarrow Hg + 2OH^-$
Reaction at anode :
$Zn(Hg) + 2OH^- \longrightarrow ZnO + H_2O + 2e^-$

89. The cell which is generally used in inverters is secondary cell *i.e.*, lead storage battery.
At cathode : $PbO_{2(s)} + SO^{2-}_{4(aq)} + 4H^+_{(aq)} + 2e^- \longrightarrow PbSO_{4(s)} + 2H_2O_{(l)}$
At anode : $Pb_{(s)} + SO^{2-}_{4(aq)} \longrightarrow PbSO_{4(s)} + 2e^-$

90. Mercury cell is generally used in transistors.
At cathode : $HgO + H_2O + 2e^- \longrightarrow Hg(l) + 2OH^-$
At anode : $Zn(Hg) + 2OH^- \longrightarrow ZnO + H_2O + 2e^-$

91. Mercury cell is a primary battery. Hence, it can be used only once and cannot be recharged.
Advantage : The cell potential remains constant during its life time. Hence, it is useful for devices requiring constant current *e.g.*, hearing aids and watches.

92. (a) $\kappa = 4.95 \times 10^{-5} \text{ S cm}^{-1}$, $M = 0.001$ M
$\Lambda^\circ_m = 390.5 \text{ S cm}^2 \text{ mol}^{-1}$
We know that

$$\Lambda_m = \frac{\kappa \times 1000}{M} = \frac{4.95 \times 10^{-5} \times 1000}{0.001} = 49.5 \text{ S cm}^2 \text{ mol}^{-1}$$

$$\alpha = \frac{\Lambda_m}{\Lambda^\circ_m} = \frac{49.5}{390.5} = 0.1267$$

$$K_c = \frac{C\alpha^2}{1-\alpha} = \frac{0.001 \times 0.1267 \times 0.1267}{(1-0.1267)} = 1.82 \times 10^{-5}$$

(b) $$E_{cell} = E^\circ_{cell} - \frac{0.0591}{6} \log \frac{[Al^{3+}]^2}{[Cu^{2+}]^3}$$

(c) The batteries which can be recharged again and again are called as secondary batteries. *e.g.*, lead storage battery.

93. (c) : The H_2-O_2 fuel cell was used for producing electricity in Apollo space programme. The water vapours produced were condensed and added to drinking water supply for astronauts.

94. Mercury cell is used for low current devices like hearing aids and watches.

Key Points

- Mercury cell is used in waters and hearing aids because their potential remains constant throughout their life.

95. The hydrogen oxygen fuel cell was used in Apollo space programme.

96. Those galvanic cells which give us direct electrical energy by the combustion of fuels like hydrogen, methane, methanol, etc. are called fuel cells.

97. The two advantages of fuel cells are :
(i) They produce electricity with an efficiency of about 70% compared to thermal plants whose efficiency is about 40%.
(ii) They are pollution free.

98. Those galvanic cells which give us direct electrical energy by the combustion of fuels like hydrogen, methane, methanol, etc. are called fuel cells.
The two advantages of fuel cells are :
(i) They produce electricity with an efficiency of about 70% compared to thermal plants whose efficiency is about 40%.
(ii) They are pollution free.

99. (i) Mercury cell is used for low current devices like watches and hearing aids.
(ii) The hydrogen oxygen fuel cell was used in Apollo space programme.
(iii) Lead storage battery is used in automobiles and inverters.
(iv) Dry cell.

100. (i) It is pollution free.
(ii) It has high efficiency of 70 - 75% and its rate can be controlled.

101. Metals of lower electrode potential value when connected with iron protect it from oxidation and prevent corrosion. Hence, coating of metal *A* having lower electrode potential will be better than *B* which has higher $E^\circ_{(B^{2+}/B)} = (-0.14\ V)$.

CBSE Sample Questions

1. $Al\,|\,Al^{3+}(0.01\ M)\,||\,Cd^{2+}(0.1\ M)\,|\,Cd$ **(1/2)**

$2Al_{(s)} + 3Cd^{2+}(0.1\ M) \rightarrow 3Cd_{(s)} + 2Al^{3+}(0.01\ M)$

$E_{cell} = E^\circ_{cell} - \frac{0.059}{n}\log\frac{[Al^{3+}]^2}{[Cd^{2+}]^3}$ **(1/2)**

$E_{cell} = 1.26 - \frac{0.059}{6}\log\frac{(0.01)^2}{(0.1)^3}$ **(1/2)**

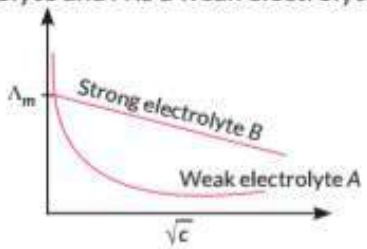
$= 1.26 - \frac{0.059}{6}(-1)$ **(1)**

$= 1.26 + 0.0098 = 1.269\ V = 1.27\ V$ **(1/2)**

2. (b): $\Lambda^\circ_{CH_3COOK} = \Lambda^\circ_{CH_3COOH} + \Lambda^\circ_{KCl} - \Lambda^\circ_{HCl}$
$= 390 + 150 - 425 = 115\ S\ cm^2/mol$ **(1)**

3. (c) : Limiting molar conductivity of CH_3COOH can be calculated as
$\Lambda^\circ_{CH_3COOH} = \lambda^\circ_{CH_3COONa} + \lambda^\circ_{H^+} - \lambda^\circ_{Na^+}$
$= 91 + 349.6 - 50.1$
$= 440.6 - 50.1 = 390.5\ S\ cm^2\ mol^{-1}$ **(1)**

4. The molar conductivity(Λ_m) of strong electrolyte increases slowly with dilution as there is no increase in number of ions on dilution because they are already completely dissociated whereas Λ_m for weak electrolyte increases very rapidly on dilution as the number of ions increase due to increase in dissociation. Hence, *B* is a strong electrolyte and *A* is a weak electrolyte. **(1)**



(1)

5. (i) **Kohlrausch's law :** It states that limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolyte. **(1)**

If $\lambda^\circ_{Na^+}$ and $\lambda^\circ_{Cl^-}$ are limiting molar conductivities of the sodium and chloride ions respectively then the limiting molar conductivity for sodium chloride is given by

$\Lambda^\circ_{m(NaCl)} = \lambda^\circ_{Na^+} + \lambda^\circ_{Cl^-}$

(ii) $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$; $E^\circ_{Cu^{2+}/Cu} = 0.34\ V$ (At cathode)

$Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e^-$; $E^\circ_{Al^{3+}/Al} = -1.66\ V$ (At anode)

$2Al_{(s)} + 3Cu^{2+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3Cu_{(s)}$ (Overall reaction) **(1/2)**

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = 0.34 - (-1.66) = 2.00\ V$ **(1/2)**

$E_{cell} = E^\circ_{cell} - \frac{0.059}{n}\log\frac{[Al^{3+}]^2}{[Cu^{2+}]^3}$ **(1)**

$= 2.00 - \frac{0.059}{6}\log\frac{(0.15)^2}{(0.025)^3}$ $(\because n = 6)$ **(1)**

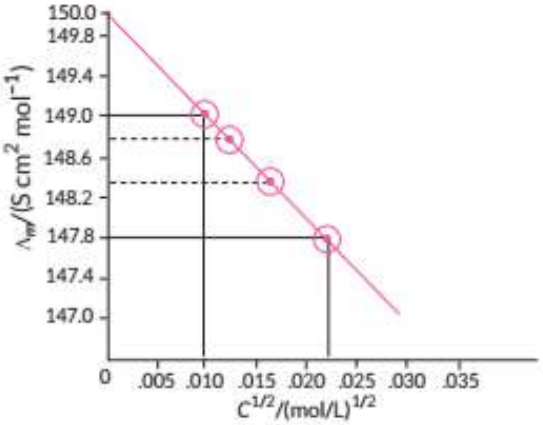
$= 2.00 - \frac{0.059}{6}(2\log 0.15 - 3\log 0.025)$

$= 2.00 - \frac{0.059}{6}(-1.6478 - (-4.806)) = 1.9689\ V$ **(1)**

6. (i) MnO_4^- is the strongest oxidising agent because it has maximum positive E° value. **(1)**
(ii) (a) Molar conductivity of a solution at a dilution *V* is the conductance of all the ions produced from one mole of the electrolyte dissolved in *V* cm^3 of the solution when the electrodes are one cm apart and the area of the electrodes is so large that the whole solution is contained between them, *i.e.*, $\Lambda_m = \kappa V_m$ **(1)**
(b) Electrolyte is a strong electrolyte. Molar conductivity (Λ_m) increases slowly with dilution. **(1)**
(c) $\Lambda_m = \Lambda^\circ_m - AC^{1/2}$ **(1)**

Λ°_m is equal to intercept on y-axis of the graph.
Therefore $\Lambda^\circ_m = 150\ S\ cm^2\ mol^{-1}$

(d)



A = – slope = – (149 – 147.8/0.010 – 0.022)

= 100 S cm^2 mol^{-1}/(mol/L^{-1})$^{1/2}$ **(1)**

7. (a) "A" is copper metal as metals have high value of conductivity. **(1)**

(b) $Mg^{2+} + 2e^- \longrightarrow Mg$

1 mole of magnesium ions gain 2 moles of electrons or 2F to form 1 mole of Mg. 24 g Mg requires 2F electricity.

4.8 g Mg requires $2 \times \frac{4.8}{24} = 0.4F = 0.4 \times 96500 = 38600C$

(1)

$Ca^{2+} + 2e^- \rightarrow Ca$

2 F electricity is required to produce 1 mole or 40 g Ca.

0.4 F electricity will produce 8 g Ca. **(1)**

(c) $F = 96500C$, $n = 2$,

$Sn^{2+}_{(aq)} + 2e^- \longrightarrow Sn_{(s)}$; $E° = -0.14$ V

$Cu^{2+}_{(aq)} + e^- \longrightarrow Cu^{+}_{(aq)}$; $E° = 0.15$ V

$E°_{cell} = E°_{Cathode} - E°_{Anode}$

$= 0.15 - (-0.14) = 0.29$ V

$\Delta G° = -nFE°_{cell} = 2 \times 96500 \times 0.29 = 55970$ J/mol **(1)**

8. (a) The cell potential remains constant during its life as the overall reaction does not involve any ion in solution whose concentration can change during its lifetime. **(1)**

(b) $KCl_{(aq)} \rightleftharpoons K^+_{(aq)} + Cl^-_{(aq)}$

Cathode: $H_2O_{(l)} + e^- \longrightarrow \frac{1}{2} H_{2(g)} + OH^-_{(aq)}$ **(1/2)**

Anode: $Cl^-_{(aq)} \longrightarrow \frac{1}{2} Cl_{2(aq)} + e^-$ **(1/2)**

Net reaction: $KCl_{(aq)} + H_2O_{(l)} \longrightarrow K^+_{(aq)} + OH^-_{(aq)} + \frac{1}{2}H_{2(g)} + \frac{1}{2} Cl_{2(g)}$ **(1)**

(c) Given, potential of hydrogen gas electrode = –0.59 V

Electrode reaction: $H^+ + e^- \longrightarrow \frac{1}{2}H_2$

Applying Nernst equation,

$E_{(H^+/H_2)} = E°_{(H^+/H_2)} - \frac{0.059}{n} \log \frac{[H_2]^{1/2}}{[H^+]}$ **(1)**

$E°_{(H^+/H_2)} = 0$ V

$E_{(H^+/H_2)} = -0.59$ V

$n = 1$

$[H_2] = 1$ bar

$-0.59 = 0 - 0.059 (- \log [H^+])$ **(1/2)**

$-0.59 = - 0.059$pH **(1/2)**

$\therefore$ pH = 10

9. Anode: $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$ **(1/2)**

Cathode: $O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$ **(1/2)**

Overall: $2Zn_{(s)} + O_{2(g)} + 2H_2O_{(l)} \rightarrow 2Zn^{2+}_{(aq)} + 4OH^-_{(aq)}$

$2Zn_{(s)} + O_{2(g)} + 2H_2O_{(l)} \rightarrow 2[Zn(OH)_2]_{(ppt.)}$ **(1)**

4 Write the Python statement for each of the following tasks using built-in functions/methods only :

(i) To remove the item whose key is "NISHA" from a dictionary named Students. For example, if the dictionary Students contains {"ANITA":90, "NISHA":76, "ASHA":92}, then after removal the dictionary should contain{"ANITA":90,"ASHA":92}

(ii) To display the number of occurrences of the substring "is" in a string named message. For example if the string message contains "This is his book", then the output will be 3.

5 A tuple named subject stores the names of different subjects. Write the Python commands to convert the given tuple to a list and thereafter delete the last element of the list.

6 Predict the output of the following code :

```
d={"IND":"DEL","SRI":"COL","CHI":"BEI"}
str1=""
for i in d:
  str1=strl+str(d[i])+"@"
  str2=str1[:-1]
print (str2)
```

7 Write the Python statement for each of the following tasks using BUILT-IN functions/methods only :

(i) To delete an element 10 from the list lst.

(ii) To replace the string "This" with "That" in the string str1.

8 A dictionary dict2 is copied into the dictionary dict1 such that the common key's value gets updated. Write the Python commands to do the task and after that empty the dictionary dict1.

9 Write difference between mutable and immutable data types? Write name of any two mutable data types.

10 i. Which operator in python has right to left associativity?

ii. Evaluate the following expression and write output: >>> 5//4**3%6+2

11 If str1= "foundation stone" and str2= "strong base", then

Write the Python statements for each of the following tasks using Built-in functions/methods only:

- To count the occurrence of the letter 'n' in str1.
- To convert the string str2 in a list and each word of the string should become the element of the list

12 Write a user defined function in Python named showGrades(S) which takes the dictionary S as an argument. The dictionary, S contains Name:(Eng,Math,Science] as key:value pairs. The function displays the corresponding grade obtained by the students according to the following grading rules :

Average of Eng,Math,Science	Grade
>=90	A
<90 but >=60	B
<60	C

Scanned with OKEN Scanner

For example : Consider the following dictionary

S={"AMIT":[92,86,64],"NAGMA":[65,42,43],"DAVID":[92,90,88]}

The output should be :

AMIT – B

NAGMA – C

DAVID – A

Scanned with OKEN Scanner

5	(a) Both A and R are true and R is the correct explanation for A

Short Answer Questions/Long Answer Questions

1 Rewrite the following Python program after removing all the syntactical errors (if any), underlining each correction:

```
def checkval
  x = input ("Enter a number")
  if x % 2 =0:
    print (x, "is even")
  elseif x<0:
    print (x, "should be positive")
  else:
    print (x, "is odd")
```

2 Mani Ayyar, a python programmer, is working on a project which requires him to define a function with name CalculateInterest( ).
He defines it as:

```
def CalculateInterest (Principal, Rate=.06, Time):    # Code
```

But this code is not working; Can you help Mani Ayyar to identify the error in the above function and with the solution?

3 Predict the possible output(s) of the following code. Also specify the maximum and minimum value that can be assigned to the variable R when K is assigned value as 2.

```
import random
Signal=['stop', 'wait', 'go']
for K in range (2,0, -1):
    R=random.randrange(K)
    print (Signal[R], end=" #")
```

a. Stop#wait#go# b. wait#stop# c. go#wait# d.go#stop#

4 Predict the output of the following code fragment

```
def display (x=2, y=3):
    x=x+y
    y+=2
    print(x,y)
display ( )
display (5,1)
display (9)
```

a) 5 5
6 3
12 5

b)12 5
6 3
5 5

c) 5 6
12 5
6 3

d) 5 5
7 7
6 6

5 Predict the output of the following code snippet:

```
def Execute(M):
  if M%3==0:
    return M*3
  else:
```


Scanned with OKEN Scanner

```
    return M+10;
def Output(B=2):
  for T in range (0, B):
    print (Execute(T),"* ", end="")
  print ( )
Output (4)
Output ( )
Output (3)
```

6. Find the output of the following program:

```
def ChangeIt(Text,C):
  T=""
  for K in range(len(Text)):
    if Text[K]>='F' and Text[K]<='L':
      T=T+Text[K]. lower ( );
    elif Text[K]=='E' or Text[K]=='e':
      T=T+C;
    elif K%2==0:
      T=T+Text[K]. upper ( )
    else:
      T=T+T[K-1]
  print(T)
OldText="pOwERALone"
ChangeIt(OldText,"%")
```

7. What possible outputs are expected to be displayed on screen at the time of execution of the program from the following code? Also specify the maximum value that can be assigned to each of the variables L and U.

```
import random
Arr= [10,30,40,50,70,90,100]
L=random.randrange(1,3)
U=random.randrange(3,6)
for i in range (L, U+1):
    print (Arr[i],"@", end="")
```

i) 40 @50 @ ii) 10 @50 @70 @90 @
iii) 40 @50 @70 @90 @ iv) 40 @100 @

8. What will be the output of the following code

```
total=0
def add(a,b):
        global total
        total=a+b
        print(total)
add (6,6)
print(total)
```

a) 12 b) 12 c) 0 d) None of these

9. What possible output(s) are expected to be displayed on screen at the time of execution of the following code? Also specify the maximum and minimum value that can be assigned to variable X.

```
import random
```


Scanned with OKEN Scanner

	L= [10,7,21] X=random.randint(1,2) for i in range(X): Y=random.randint(1, X) print(L[Y],"$", end=" ") (i)10 $ 7 $ (ii) 21 $ 7 $ (iii) 21 $ 10 $ (iv) 7 $

10	Vivek has written a code to input a number and check whether it is even or odd number. His code is having errors. Rewrite the correct code and underline the corrections made.
	Def checkNumber(N):
	status = N%2
	return
	#main-code
	num=int (input ("Enter a number to check :))
	k=checkNumber(num)
	if k = 0:
	print ("This is EVEN number")
	else:
	print ("This is ODD number")

11	Find and write the output of the following Python code:
	def changer(p,q=10):
	  p=p/q
	  q=p%q
	  print(p,"#",q)
	  return p
	a=200
	b=20
	a=changer(a,b)
	print(a,"$",b)
	a=changer(a)
	print(a,"$",b)

12	Write a function INDEX_LIST(L), where L is the list of elements passed as argument to the function. The function returns another list named 'indexList' that stores the indices of all Non-Zero Elements of L. For example: If L contains [12,4,0,11,0,56] The indexList will have – [0,1,3,5]
	ANSWERS
1	def checkval():

Scanned with OKEN Scanner

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(C) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

Assertion : If the distance between parallel plates of a capacitor is halved and dielectric constant is three times, then the capacitance becomes 6 times.
Reason : Capacity of the capacitor does not depend upon the nature of the material.

Assertion : The total charge stored in a capacitor is zero.
Reason : The field just outside the capacitor is σ/ε_0 . (σ is the charge density).

Assertion : Two equipotential surfaces cannot cut each other.
Reason : Two equipotential surfaces are parallel to each other.

Assertion : Polar molecules have permanent dipole moment.

Reason : In polar molecules, the centres of positive and negative charges coincide even when there is no external field.

Assertion : A parallel plate capacitor is connected across battery through a key. A dielectric slab of dielectric constant k is introduced between the plates. The energy stored becomes k times.

Reason : The surface density of charge on the plate remains constant.

2 marks question –

1.What is equipotential surface? Why do two equipotential surfaces never intersect?

2.Derive the relation between electric field and potential

3.What is dielectric constant? Write its significance.

4.State Coulomb's law in vector form and explain the terms used.

5.Define electric potential and derive expression for potential due to a point charge.

6.Explain the effect of dielectric on capacitance of a capacitor.

7.A parallel plate capacitor has capacitance C_0. A dielectric slab of dielectric constant K is inserted partially. Find the new capacitance.

Numericals-:

1.Two-point charges +3μC and –2μC are placed 10 cm apart in vacuum. Find the force between them.

2.Two capacitors 3μF and 6μF are connected in series. Find equivalent capacitance.

3.Find the electric field intensity at a point 30 cm away from a charge of 5 μC in vacuum.

4.Calculate the electric potential at a point 10 cm away from a charge of 2 μC.

5.charge of 2 μC is placed in an electric field of intensity 5×10^4 N/C. Find the force acting on it.

6.Two charges +3 μC and –3 μC are separated by 8 mm. Calculate electric dipole moment.

7.A parallel plate capacitor has plate area 2 m^2 and separation 2 mm. Find its capacitance

8.Two capacitors of 3 μF and 5 μF are connected in parallel. Find equivalent capacitance.

9.Find the work done in moving a charge of 2 C through a potential difference of 12 V.

10.An electric dipole of moment 4×10^{-8} C m is placed in a uniform field of 2×10^5 N/C at 30°. Find torque.

11.An electric dipole of moment 3×10^{-8} C·m is placed in a uniform electric field of 10^5 N/C at 60°.

Find:(a) Torque. (b) Potential energy

12.Two point charges q_A=3μC and q_B=−3μC are located 20 cm apart in vacuum. What is the electric field at the midpoint O of the line AB joining the two charges?

Long question -:

1.Derive the expression for electric field intensity at a point on the axial line of an electric dipole.

2.Derive the expression for electric field intensity at a point on the equatorial line of an electric dipole.

3. Using Gauss's law, derive the expression for electric field due to an infinitely long straight uniformly charged wire.

4. Using Gauss's law, derive the electric field due to a uniformly charged spherical shell.

5. Using Gauss's law, derive the electric field due to an infinite plane sheet of charge.

6. Derive the expression for capacitance of a parallel plate capacitor with air/vacuum between the plates.

7. A dielectric slab is inserted between the plates of a capacitor. Derive the new capacitance.

8. Derive the expression for energy stored in a parallel plate capacitor.

9. Derive the expression for torque acting on an electric dipole placed in a uniform electric field.