1

CHAPTER

Solutions

Level - 1

CORE SUBJECTIVE QUESTIONS

MULTIPLE CHOICE QUESTIONS (MCQs) (1 Mark)

1. **Option (D) is correct.**

Explanation:

$$\text{Vant Hoff factor (i)} = \frac{\text{No. of moles after association}}{\text{No. of moles before association}}$$

For association: $i < 1$
For dissociation: $i > 1$
For Non-electrolyte: $i = 1$

2. **Option (C) is correct.**

Explanation: Isotonic solutions have the same osmotic pressure.

3. **Option (B) is correct.**

Explanation: An azeotropic solution of two liquids has a boiling point lower than either of them when it show a positive deviation from Raoult's law.

4. **Option (D) is correct.**

Explanation: According to Raoult's law, "The relative lowering of vapour pressure is equal to mole fraction of solute

$$\frac{P_A^\circ - P_S}{P_A^\circ} = x_B \Rightarrow 0.0225 = x_B$$

5. **Option (B) is correct.**

Explanation: Given:

A 1% solution of solute 'X' is isotonic with a 6% solution of sucrose.

Molar mass of sucrose is 342 g mol^{-1}

Percentage concentration means grams of solute per 100 mL of solution.

Since, Mass of sucrose in 100 mL solution is 6 g.

$$\text{Molarity of sucrose} = \frac{6}{342 \times 0.1}$$

As isotonic solutions have the same osmotic pressure, it implies equal molar concentrations.

$$\pi_1 = \pi_2$$
$$c_1 = c_2$$
$$\frac{1}{M_B \times 0.1} = \frac{6}{342 \times 0.1}$$
$$M_B = \frac{342}{6} = 57 \text{ g mol}^{-1}$$

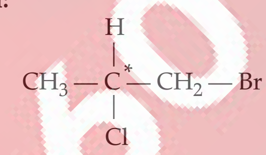
6. **Option (B) is correct.**

Explanation:

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

7. **Option (B) is correct.**

Explanation:



Because C^* is connected to four different groups.

8. **Option (A) is correct.**

Explanation: Maltose is a disaccharide made up of two glucose unit.

9. **Option (A) is correct.**

Explanation: Osmotic pressure method is specially suitable for the determination of molecular masses of macro molecules such as protein and polymer because for these substances the value of other colligative properties are too small.

10. **Option (C) is correct.**

Explanation: At high altitude, the partial pressure of oxygen is lower than at ground level. This decreased atmospheric pressure causes the body to release oxygen from blood.

11. **Option (D) is correct.**

Explanation: The value of molal elevation constant (K_b) will be unchanged because it does not rely on the molality of solution.

12. **Option (B) is correct.**

Explanation: We know

$$4A — A_4$$

$$i = 1 - \alpha + \frac{1-\alpha+\frac{\alpha}{4}}{1}$$

$$i = 1 - \frac{3\alpha}{4}$$

For 100% dissociation $\alpha = 1$

$$i = 1 - \frac{3}{4}$$

$$i = \frac{1}{4}$$

$$= 0.25$$

13. Option (B) is correct.

Explanation:

$$x_A = \frac{1}{1+2} = \frac{1}{3}$$

$$x_B = \frac{2}{1+2} = \frac{2}{3}$$

$$P_{Total} = P_{A}^{\circ} x_A + P_B^{\circ} x_B$$

$$= 45 \times \frac{1}{3} + 30 \times \frac{2}{3}$$

$$= 35 \text{ torr}$$

However, the actual pressure i.e. 40 torr is greater than the expected pressure. As a result, the solution will have a positive deviation.

14. Option (C) is correct.

Explanation: Henry constant increases with increase in the temperature.

ASSERTION-REASON QUESTIONS (1 Mark)

1. **Option (C) is correct.**

Explanation: Ethylene glycol acts as anti-freeze. Ethylene glycol has hydroxyl (—OH) groups in its structure which allow it to form hydrogen bond with water.

2. **Option (B) is correct.**

Explanation: Since NaCl dissociates into two ions, it effectively increases the number of particles in the solution leading to a greater depression in freezing point. Both assertion and reason are correct but reason does not explain the assertion correctly.

3. **Option (A) is correct.**

Explanation: On addition of non-volatic solute (NaCl) to water, NaCl solution is formed. NaCl reduces the number of solvent molecules available on the surface of the solution. As less number of solvent molecules are available to evaporate, the vapour pressure of the solution is lower than the pure water. Lower vapour pressure leads to lowering in freezing point as liquid phase is stable and additionally NaCl also interferes with the crystal lattice during ice formation. Thus the freezing point of solution decreases. Both assertion and reason are correct and reason is the correct explanation of assertion.

4. **Option (C) is correct.**

Explanation: Osmotic pressure of a solution at any temperature depend on the molar concentration not on molality.

VERY SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. (i) Solubility of gas is inversely proportional to the value of Henry's constant K_H. On increasing temperature nitrogen gas becomes less soluble because its K_H value increases.

(ii) 64.5°C

Chloroform and acetone mixture show negative deviation from Raoult's law. Therefore, they form maximum boiling azeotrope at a specific composition. The boiling point of the mixture so obtained will be higher than the individual components.

2. (i) Correct, because at higher altitudes i.e. in Srinagar the atmospheric pressure is lower. The solubility of a gas in a liquid is directly proportional to the partial pressure of the gas over the solution. Therefore, the carbon dioxide dissolved in water will be lesser at Srinagar making the soda go flat faster.

(ii) Preservation of fruits by adding sugar/salt protects against bacterial action. Through osomosis, a bacterium on canned fruit loses water, shrivels and dies.

3. The depression in freezing point when 1 mole of the non-volatile solute is dissolved in 1000 g of the solvent is called molal depression constant (k_f).

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

4. Ethanol and acetone mixture show positive deviation from Raoult's law. This is because ethanol - acetone interaction is weaker than pure ethanol and pure acetone molecular interactions.

They form minimum boiling azeotropes.

5. For isotonic solution, concentrations of the solutions is equal, as osmotic pressures are equal for isotonic solutions and concentration is directly related to it.

$$c_1 = c_2$$

$$c_1 = \frac{\frac{6}{180}}{0.1} = \frac{6}{18} \text{ mol/L}$$

$$c_2 = \frac{\frac{2.5}{M}}{0.1} = \frac{2.5}{0.1\,M} = \frac{25}{M} \text{ mol/L}$$

Since, $c_1 = c_2$

$$\frac{6}{18} = \frac{25}{M}$$

$$6\,M = 18 \times 25$$

$$6\,M = 450$$

$$M = \frac{450}{6}$$

$$= 75 \text{ g/mol}$$

6. Mass of solute = 18 g

Mass of water (solvent) = 200 g

Freezing point of mixture = 272.07 K

Freezing point of water = 273.15 K

We know,

$$\Delta T_f = k_f \times m$$

$$\Delta T_f = k_f \times \frac{W_B 1000}{M_B \times W_A}$$

$$M_B = \frac{1.86 \times 18 \times 1000}{200 \times (273.15 - 272.07)}$$

$$= \frac{1.86 \times 18 \times 1000}{200 \times 1.08}$$

$$= 0.155 \text{ kg/mol}$$

$$= 155 \text{g/mol}$$

7. Pure vapour pressure of liquid X and Y at 25° C are:

$$P_x^\circ = 120 \text{ mm Hg and}$$

$$P_y^\circ = 160 \text{ mm Hg}$$

Let the number of moles of liquid X and Y be 'n'

$$X_x = \frac{n}{n + N}$$

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

Total vapour pressure of solution will be

$$P_{Total} = P_X^o X_X + P_Y^o X_Y$$

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

$$= 60 + 80$$

$$= 140 \text{ mm Hg.}$$

8. (i) Aquatic animals are more comfortable in cold water than warm water because there is more dissolved oxygen in cold water.

(ii) Sprinkling salt on snow-covered roads in hilly areas help clean the snow because sprinkling of salt causes depression in freezing point and snow melts easily.

9. An azeotrope is a binary liquid mixture that has the same composition in both its liquid and vapour phase and boils at a constant temperature.

A maximum boiling azeotrope is formed when a solution show a negative deviation from Raoult's law. For example: A mixture of 68% nitric acid and 32% of water by mass which boils at 393.5 K.

10. Henry's law states that the partial vapour pressure of a gas is directly proportional to the mole fraction of the gas in the solution.

$p = K_H x$

Where p is partial pressure of gas.

x is mole fraction in solution, and K_H is Henry's constant.

Application: To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.

SHORT ANSWER TYPE QUESTIONS (3 Marks)

1.

$$\left(\frac{P_A^\circ - P_S^\circ}{P_A^\circ}\right) = i\left(\frac{n_B}{n_A + n_B}\right)$$

$$\left(\frac{100 - P_S^\circ}{100}\right) = 2\left(\frac{1}{50+1}\right)$$

$$\frac{100 - P_S^\circ}{100} = 2 \times \left(\frac{1}{51}\right)$$

$$100 - P_S^o = \frac{2}{51} \times 100$$

$$100 - P_S^o = \frac{200}{51}$$

$$-P_S^o = \frac{200}{51} - 100$$

$$-P_S^o = \left(\frac{200 - 5100}{51}\right)$$

$$-P_S^o = -\frac{4900}{51}$$

$$P_S^o = 96.07 \text{ mm Hg}$$

2. Let molar mass of solute $= m$

Molar mass of solvent $=$ M

Weight of solvent $=$ W

Weight of solute $= \omega$

$$\frac{P_A^0 - P_S}{P_A^0} = \frac{w \times M}{m \times W}$$

$$\frac{0.16}{32} = \frac{5 \times 18}{m \times 200}$$

$$m = \frac{5 \times 18 \times 32}{0.16 \times 200}$$

$$m = 90 \text{ g/mol}$$

$\therefore$ Molar mass of solute $= 90$ g/mol

3. Wt. of solute (w_2) = 4g

Wt. of solvent (w_1) = 100g

$i = 2$ ($MgSO_4$ dissociate to give 2 ions)

$MgSO_4 \rightleftharpoons Mg^{2+} + SO_4^{2-}$

$K_b = 0.52$ kg mol^{-1}, $M_2 = 120$ g mol^{-1}

Elevation in boiling point

$$\Delta T_b = \frac{i \times k_b \times w_2 \times 1000}{M_2 \times w_1}$$

$$\frac{2 \times 0.52 \times 4 \times 1000}{120 \times 100} = 0.346 \text{ K}$$

As boiling point of pure water is 373 K

$$T_b = \Delta T_b + T_b^\circ$$

$$T_b = 373 + 0.346$$

$$= 373.346 \text{ K}$$

4. (i)

Ideal Solution	Non-ideal solution
(1) The solutions obeys Raoult's law at all concentrations.	The solution does not obey Raoult's law.
(2) $\Delta V_{mixing} = 0$ and $\Delta H_{mixing} = 0$	$\Delta V_{mixing} = 0$ and $\Delta H_{mixing} = 0$

(ii) $$\frac{P_A^o - P_A}{P_A^o} = 1 - \frac{P_A}{23.8}$$

$$\frac{\frac{W_B}{M_B}}{\frac{W_B}{M_B}+\frac{W_A}{M_A}} = \frac{\frac{30}{60}}{\frac{846}{18}+\frac{30}{60}}$$

$$P_A = \frac{47}{47.5}\times 23.8 = 23.5 \text{ mm Hg}$$

5. Given,

Mass of acetic acid in solution = 0.3 g

Molar mass of acetic acid = 60 g mol^{-1}

Mass of benzene = 30 g = 0.03 kg

The depression in freezing point is given by,

$$\Delta T_f = i.K f.m$$

Where, ΔT_f is depression in freezing point and *m* is molality of the solution.

$$\text{Molality of the solution m} = \frac{\left(\frac{0.3}{60}\right)}{0.03} \text{ mol kg}^{-1}$$

$$= 0.1667 \text{ mol kg}^{-1}$$

Substituting given values in the above formula,

$$i = \frac{0.45}{(5.12\times 0.1667)}$$

$$= 0.527$$

As acetic acid is forming a dimer,

$$i = \frac{1-\alpha}{2}$$

α is the degree of association

$$\alpha = 2(1 - 0.527) = 0.946$$

Hence, percentage association = 0.946 × 100 = 94.6%

6. We know, $$c = \frac{n}{v} = \frac{W_B \times 1000}{M_B \times V}$$

where C = molarity of the benzoic acid solution

$$= \frac{6.1\times 1000}{122\times 100}$$

$$= 0.500 \text{ mol L}^{-1}$$

Now, using the osmotic pressure formula to calculate van't hoff factor

$$\pi = i \times c \times R \times T$$

$$i = \frac{\pi}{cRT}$$

$$= \frac{6.5}{0.500\times 0.0821\times 300}$$

$$i = \frac{6.5}{12.315} = 0.528$$

Determining the degree of association

$$i = \frac{1-\alpha}{2}$$

$$\alpha = 2(1 - i)$$

$$= 2\,(1 - 0.528)$$

$$= 0.944$$

Percentage of association = α × 100

= 0.944 × 100

= 94.4%

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. (i) Depression in the freezing point is a colligative property. In dilute solutions the depression of freezing point (ΔT_f) is directly proportional to the molal concentration of the solute in a solution.

From the graph it is interpreted that Solution 2 shows more depression in freezing point.

1 M $Al(NO)_3$ has higher *i* value (*i* = 3) than 1 M glucose (*i* = 1)

1 M $Al(NO)_3$ will have higher depression , hence solution 2 is $Al(NO)_3$ solution and solution 1 is glucose solution.

(ii) $$\pi = \frac{n_2}{V} RT$$

Given π = 2.64 atm

Let $V_1 = V$

$V_2 = 5V$ (On dilution by 5 times)

$$\frac{\pi_1}{\pi_2} = \frac{(n/V_1)}{(n/V_2)}$$

$$\frac{2.46}{\pi_2} = \frac{(n/V)}{(n/5V)}$$

$$\pi_2 = 0.492 \text{ atm}$$

Osmotic pressure is directly proportional to temperature.

The osmotic pressure of cane sugar can be decreased by decreasing the temperature.

2. (i) While giving intravenous injection to the patients, utmost care of concentration of the solution is to be taken. The solution must have same concentration as that of blood cells.

If the solution becomes more concentrated than the concentration of the blood it will lead to the shrinking of blood cells and fluid will start flowing out because of exomosis.

If solution is less concentrated than the concentration of the blood it will lead to swelling of blood cells because of the endomosis. Both situations are life-threatening.

(ii) $2C_6H_5OH \rightarrow (C_6H_5OH)_2$

Initial concentration : C 0

Final concentration : C(1–α) Cα/*n*,

where α is degree of association.

Experimentally, phenol is 73% associated.

Hence α = 0.73.

Relation between *i* (van't hoff factor) and α is given as:

$\alpha = \dfrac{(1-i)}{\left(1-\dfrac{i}{n}\right)}$, where n for phenol = 0.5 as phenol acts as dimer, association is taking place

Substituting the values:

$$0.73 = \frac{(1-i)}{(0.5)}$$

$$i = 1 - \frac{0.73}{2}$$

$$i = 0.635$$

Depression in freezing point can be calculated as:

$$\Delta T_f = iK_f m$$

$$= iK_f(w_b/M_b \times w_a)$$

$$K_f = 5.12\text{K kg/mol},$$

$$w_b = 2 \times 10^{-2} \text{ kg} = 20\text{g},$$

$$w_a = 1 \text{ kg}, M_b = 94$$

$$\Delta T_f = (0.635 \times 5.12 \times 20/94)$$

$$= 0.691\text{K}$$

3. (i) The van't Hoff factor for ethonoic acid in benzene will be less than 1. This is because ethanoic acid dimerises in benzene, which means that two molecules become one.

(ii) An ideal solution is that solution that follows Raoult's law under all standard temperature and concentration.

(iii)
$$i = 3$$

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

$$\Delta T_f = \frac{i \times k_f \times W_B \times 100}{M_B \times W_A}$$

$$2k = \frac{3 \times 1.86 \times W_B \times 100}{111 \times 500}$$

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

$$= 19.89 \text{ g.}$$

4. (i)
$$P_A^\circ = 75$$

$$P_B^\circ = 25$$

$$P_{Total} = (75 \times 0.4) + (25 \times 0.6)$$

$$= 30 + 15$$

$$= 45$$

$$P_B = P_{Total} \times x_B$$

$$x_B = \frac{25 \times 0.6}{45} = \frac{15}{45} = \frac{1}{3}$$

$$= 0.333 \text{ mm Hg.}$$

(ii) Those properties which depend on the number of solute particle not on the nature of solute are called colligative properties.

Osmotic pressure is used to find the molecular mass of macromolecule.

(iii) Isotonic solution are those having same concentration and osmotic pressure. The equimolar solutions of sodium chloride and glucose are not isotonic because sodium chloride undergoes dissociation (i = 2) in water while glucose does not.

5. (i) Mass of water (W_A) = 500 g

Boiling point of pure water at 750 mm Hg (T_b°) = 99.68°C

Boiling point of mixture (T_b) = 100°C

Molar Mass of Sucrose (M_B) = 342 g mol^{-1}

Elevation in boiling point (ΔT_b) = $T_b - T_b^\circ$

$$\Delta T_b = \frac{K_b \times W_B}{M_B \times W_A}$$

$$0.32 = \frac{0.52 \times W_B}{342 \times 500 \times 10^{-3}}$$

$$W_B = \frac{0.32 \times 500 \times 10^{-3} \times 342}{0.52}$$

$$= 105.230 \text{ g}$$

(ii) Henry's law is a gas law that states that the amount of gas dissolved in a liquid is directly proportional to its partial pressure.

Application of Henry's law include carbonated beverages. Carbon dioxide is dissolved in the drink under high pressure and when the bottle is opened the gas escapes due to the lower external pressure.

6. (i) Oxygen (O_2) will have higher value of Henry's law constant (K_H) than carbon dioxide (CO_2) because O_2 is less soluble in water than CO_2.

(ii) Blood cells are isotonic with 0.9% sodium chloride solutions. When placed in a solution with a higher concentration of sodium chloride, water flows out of the cells through osmosis and blood cell shrink.

(iii) $A_2B_3 \longrightarrow 2A^{3+} + 3B^{2-}$

$1 - 0.6 \qquad 2 \times 0.6 \qquad 3 \times 0.6$

van't Hoff factor = 1 – 0.6 + 1.2 + 1.8

= 3.4

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

$$\Delta T_b = 3.4 \times 0.52 \times 1 = 1.768$$

$$T_b = 373 + 1.768$$

$$T_b = 374.77$$

$$= 375 \text{ K}$$

7. (i) When we apply pressure more than osmotic pressure, the water molecule starts moving through solution side to the solvent side across a semi permeable membrane and this phenomenon is called reverse osmosis (R.O.)

(ii) This is because the solubility of oxygen in water increases as the temperature decreases. Aquatic species are more comfortable in cold water than in warm water because cold water has more dissolved oxygen per unit area.

(iii) Molar mass of glucose (M_B) = 180 g mol^{-1}

Molar mass of water (M_A) = 18 g mol^{-1}

No. of moles of glucose (n_B) = $\dfrac{2}{180}$ = 0.0111 mol.

No. of moles of water (n_A) = $\dfrac{100}{18}$ = 5.56

Total number of moles of solute and solvent

= 0.0111 + 5.56

$= 5.571$ mole

Mole fraction of water $= \frac{n_A}{n_A + n_B} = \frac{5.56}{5.571}$

$= 0.998$

According to Raoult's law

$P_{Solution} = x_{water} \times P_{water}$

$= 0.998 \times 32.8$

$= 32.73$ mm Hg

8. (i) Freezing point of water = 0°C

Required freezing point = –2.8 °C

Depression in freezing point = 2.8 K

Weight of water = 1 Kg

k_f for water = 1.86 K kg mol^{-1}

Depression in freezing point

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

$i = 1$ (because ethylene glycol do not dissociate)

$2.8 = 1 \times 1.86 \times m$

$m = \frac{2.8}{1.86}$

$= 1.5053$ mol/kg

Mass of ethylene glycol = no. of moles × Molar mass

$= 1.5053 \times 62$

$= 93.33$ g

(ii) When acetone is added to ethanol the acetone molecule breaks some of the hydrogen bonds between the ethanol molecules. This weakens the interactions between the molecules which causes the solution to show positive deviation from Raoult's law as intermolecular forces between acetone and ethanol are weaker as compared to the intermolecular forces between solute-solute and solvent-solvent molecules.

9. (i) The van't Hoff factor for ethanoic acid in benzene is close to 0.5 because ethanoic acid in benzene dimerises meaning two molecules become one.

(ii) When K_2SO_4 is dissolved in water, ions are produced.

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

Total number of ions produced = 3

$\therefore \quad i = 3$

$\pi = i\,cRT$

$= \frac{3 \times 2.32 \times 10^{-2} \times 0.0821 \times 298}{174 \times 2}$

$= 4.89 \times 10^{-3}$ atm

(iii) Wt. of solute (W_B) = 25.6g

Wt. of solvent (W_A) = 1000 g

$\Delta T_f = 0.512$ K

$k_f = 5.12$ K Kg mol^{-1}

We know

$$M_B = \frac{k_f \times 1000 \times W_B}{\Delta T_f \times W_A}$$

$$= \frac{5.12 \times 1000 \times 25.6}{0.512 \times 1000}$$

$M_B = 256$

Atomic mass of sulphur = 32

Molecular mass $= 32 \times x$

$32 \times x = 256$

$x = \frac{256}{32}$

$= 8$

So, the molecular formula of sulphur $= S_8$

10. (i) Because the van't Hoff factor for 1 M NaCl is 2. As it ionises into 2 in the solution, which is bigger than that of 1 M glucose solution, the boiling point is directly proportional to van't Hoff factor and molality.

(ii) Relative lowering of vapour pressure

$$\frac{P_A^\circ - P_S}{P_S} = \frac{n_B}{n_A}$$

$$\frac{P_A^\circ - 0.9P_A^\circ}{0.9P_A^\circ} = \frac{W_B}{50} \times \frac{78}{78}$$

$$W = \frac{0.1}{0.9} \times 50$$

$$= \frac{50}{9}$$

$= 5.5$ g

(iii) Weight of $MgCl_2$ W_B = 10g; Molar mass of $MgCl_2$ = 95 g mol^{-1}

Weight of solvent (water) W_A = 200;

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

$$\Delta T_b = \frac{k_b \times W_B \times 100}{M_B \times W_A}$$

$$= \frac{0.512 \times 10 \times 1000}{95 \times 200}$$

$\Delta T_b = 0.269$ K

Level - 2 ADVANCED COMPETENCY FOCUSED QUESTIONS

MULTIPLE CHOICE QUESTIONS (MCQs) (1 Mark)

1. Option (A) is correct.

Explanation: Molarity decreases with increasing the temperature where as molality does not change with temperature.

2. Option (C) is correct.

Explanation: On adding non-volatile solute in volatile solvent the freezing point decreases.

3. Option (C) is correct.

Explanation: At high altitude boiling point decreases.

4. Option (B) is correct.

Explanation:

$$\text{Molarity} = \frac{W_B \times 1000}{M_B \times V_S(\text{mL})}$$

$$0.25 = \frac{5 \times 1000}{M_B \times 500}$$

$$M_B = \frac{10}{0.25}$$

$$M_B = 40$$

Molar mass of NaOH = 23 + 16 + 1
= 40

The unknown substance likely to be NaOH.

5. **Option (C) is correct.**
Explanation: On increasing temperature molarity of solution decreases.

ASSERTION-REASON QUESTIONS (1 Mark)

1. Option (A) is correct
Explanation: Assertion is true. When a non-volatile solute is added to a volatile solvent, the number of solvent molecules at the surface decreases. Fewer solvent molecules escape into the vapour phase, so the vapour pressure of the solution decreases compared to the pure solvent. This is in accordance with Raoult's Law.
Reason is also true. A non-volatile solute does not evaporate and occupies surface area of the solution. This lowers the number of solvent molecules at the liquid surface, so fewer can escape as vapour, leading to lower vapour pressure.

2. Option (A) is correct
Explanation: Assertion is true. Boiling point elevation is a colligative property, which depends on the number of solute particles in solution, not their nature.
NaCl dissociates into two ions (Na^+ and Cl^-), whereas glucose is a non-electrolyte and does not dissociate. So, NaCl solution produces more particles, leading to a greater elevation in boiling point.
Reason is also true. Yes, NaCl dissociates completely in water as:
$$NaCl \rightarrow Na^+ + Cl^-$$
This increases the van't Hoff factor *(i)* from 1 (for glucose) to approximately 2 (for NaCl), hence increasing the colligative effect.

3. Option (A) is correct
Explanation: Assertion is true. Molality (m) is defined as:
$$\text{Molality} = \frac{\text{moles of solute}}{\text{mass of solvent in kg}}$$
Since mass does not change with temperature, molality remains constant even when temperature changes.
Reason is also true. Unlike volume, mass is not affected by temperature. That's why molality, which is based on the mass of solvent, remains temperature-independent.

4. Option (D) is correct
Explanation: Assertion is false. Osmosis is not the movement of solute molecules, but rather the movement of solvent (typically water) molecules from a region of lower solute concentration to higher solute concentration across a semi-permeable membrane, in order to equalise solute concentrations.
Reason is true. Osmosis does occur across a semi-permeable membrane, which allows the passage of solvent molecules but not solute molecules.

5. Option (A) is correct
Explanation: Assertion is true. Raoult's law states that the partial vapour pressure of each component in a solution is directly proportional to its mole fraction. This law holds true for ideal solutions, where the intermolecular interactions between different components are similar to those between like components.
Reason is also true. An ideal solution is one in which:
$\Delta H_{mix} = 0$ (no heat is absorbed or evolved when mixing the components)
$\Delta V_{mix} = 0$ (no volume change on mixing)
This is a defining property of ideal solutions.

VERY SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. Equivalent weight of $KMnO_4$ in Acidic medium
$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$
Equivalent weight of $KMnO_4 = \frac{158}{5} = 31.6 \text{ geq}^{-1}$

Equivalent weight of $KMnO_4$ in Neutral medium
$MnO_4^- + 2H_2O + 3e^- \longrightarrow MnO_2 + 4OH^-$
Equivalent weight of $KMnO_4 = \frac{158}{3} = 52.6 \text{ g eq}^{-1}$

The equivalent mass of $KMnO_4$ in acidic medium is less than neutral medium because the oxidation number of manganese changes differently in different medium.

2. The ratio of molar mass A : B:
Let the molar mass of A is M_A and B is M_B
Since the solutions are isotonic,
so $C_1RT = C_2RT$ (equal osmotic pressure)

$$\Rightarrow \quad \frac{5}{M_A} + \frac{1}{M_B} = \frac{3}{M_A} + \frac{5}{M_B}$$

$$\Rightarrow \quad \frac{2}{M_A} = \frac{4}{M_B}$$

$$\Rightarrow \quad \frac{M_A}{M_B} = \frac{1}{2}$$

The ratio of molar mass of A : B is 1 : 2.

3. Initially $P_1 = 0.6$ atm, $T_1 = 283$ K and let the volume be V_1; Finally, $P_2 = 0.3$, $T_2 = 298$ K and let the volume be V_2
Applying osmotic pressure formula

$$\Rightarrow \quad \frac{P_1 \times V_1}{P_2 \times V_2} = \frac{nRT_1}{nRT_2}$$

$$\Rightarrow \quad \frac{0.6 \times V_1}{0.3 \times V_2} = \frac{283}{298}$$

$$\Rightarrow \quad \frac{V_1}{V_2} = 0.474$$

So, $V_2 = 2.10\, V_1$

SHORT ANSWER TYPE QUESTIONS (3 Marks)

1. (i) $2CH_3COOH \rightleftharpoons (CH_3COOH)_2$

$$i = 1+\left(\frac{1}{n}-1\right)\alpha$$

Where,

i, = van't Haff factor

a = degree of association (1 for complete association)

n = number of molecules combining (2 for dimerisation)

For dimerisation $n = 2$

For complete association, $\alpha = 1$

$$i = 1+\left(\frac{1}{2}-1\right)\times 1$$

$$i = 1+\left(-\frac{1}{2}\right)$$

$$i = 1 - 0.5 = 0.5$$

(ii) Mass of protein (w) = 3.5 g

Volume (V) = 0.05 L

Osmotic pressure (π) = 0.035 atm

Temperature (T) = 310K

Gas constant (R) = 0.0821 L atm K^{-1} mol^{-1}

Molar mass of protein (M_B) = ?

We know,

$$\pi = \frac{W}{M\times V}\times R\times T$$

$$M = \frac{3.5\times 0.0821\times 310}{0.035\times 0.05}$$

$$M = 50902 \text{ g}$$

2. (i) Ratio of molecular weight of P and Q:

For solution A, $\Delta T_b = K_b \times m \times i$

$$\Rightarrow 0.4 = K_b \times \left(\frac{\text{mass of P}}{\text{molecular weight of P}}\right) \times \frac{1000}{(\text{Weight of benzene})}\times 1$$

...(equation 1)

For solution B, $\Delta T_b = K_b \times m \times i$

$$0.8 = K_b \times \left(\frac{\text{mass of Q}}{\text{molecular weight of Q}}\right) \times \frac{1000}{(\text{Weight of benzene})}\times 1 \text{ ... (equation 2)}$$

Since Mass of P = Mass of Q and K_b is the same as both are formed in benzene solution with equal weights, equations 1 and 2 gives

$$\frac{\text{Molecular weight of P}}{\text{Molecular weight of Q}} = \frac{2}{1}$$

(ii) Minimum value of the sum of molecular weights of P and Q:

Since P : Q = 2 : 1 and molecular weight of P is 200, so Q = 100

Minimum value = 200 + 100 = 300

3. (i) van't Hoff factor of acetic acid in water:

Acetic acid in water dissociates to:

$CH_3COOH + H_2O \rightarrow CH_3COO + H_3O^+$

$i = 1 + \alpha\,(n - 1)$[Where $\alpha = 1$ for 100 percent dissociation; n is no. of ions in the product]

$\Rightarrow i = 2$ (in water)

van't Hoff factor of acetic acid in Benzene:

Acetic acid in Benzene associates to:

$2[CH_3COOH] \rightarrow [CH_3COOH]_2$

For association, i is given by $i = 1 + \alpha\left(\frac{1}{n}-1\right)$

[here n is no. of moles in the reactant]

$\Rightarrow i = 0.5$ (in benzene)

(ii) Urea is an organic molecule having covalent bonds. It does not split into ions in the presence of a solvent.

4. (i) 9.8 g of H_2SO_4 is 0.1 mole. 1 mole of H_2SO_4 reacts with 2 moles of NaOH.

0.2 moles of NaOH reacts with 0.1 moles of H_2SO_4.

$$\text{Molarity of NaOH} = 0.2 \times \frac{1000}{240} = 0.83 \text{ M/litre}$$

(ii) $$\text{Moles} = \frac{\text{amount of NAOH}}{\text{molar mass}}$$

Amount of NaOH = Molar mass × moles

Amount of NaOH = 40 × 0.2 = 8 grams

(iii) 0.5 M of 1 litre NaOH solution will have 0.5 moles of NaOH. Therefore, 20 grams of NaOH needs to be present. Therefore, 12 g of NaOH needs to be added.

CASE BASED QUESTIONS (4 Mark)

1. (i) Pure ethanol cannot be prepared by fractional distillation of an ethanol water mixture because the mixture forms an azeotrope.

(ii) It is because of the hydrogen bonds that form between the chloroform and acetone molecules are stronger than the solute-solute and solvent-solvent interactions. Since the A-A and B-B interaction are weaker than A-B interaction so it will show a negative deviation.

(iii) (a) $P_A^\circ = 1.25$ atm

$P_S^\circ = 1.237$ atm

$W_A = 60$ g

$W_B = 1.2$ g

$M_A = 78$ g mol^{-1}

$M_B = ?$

We know,

$$M_B = \frac{P^\circ_A \times W_B \times M_A}{(P^\circ_A - P_S) \times W_A}$$

$$= \frac{1.25 \times 1.2 \times 78}{(1.25 - 1.237) \times 60}$$

$$= \frac{117}{0.78}$$

$$= 150 \text{ g mol}^{-1}$$

OR

(b) $T^\circ_b = 353.23$ K

$T_b = 354.11$K

$\Delta T_b = T_b - T^\circ_b$

$= 354.11 - 353.23$

$= 0.88$ K

$w = 1.80$ g

$W = 90$ g

$K_b = 2.53$ K kg mol^{-1}

$$M_B = \frac{K_b \times 1000 \times w}{\Delta T_b \times W}$$

$$= \frac{2.53 \times 1000 \times 1.80}{0.88 \times 90}$$

$$= 57.5 \approx 58 \text{ g mol}^{-1}$$

2. (i) The solution formed after mixing liquid A and liquid B is a non-ideal solution that show negative deviation from Raoult's law.

(ii) Carbon disulphide and acetone – Positive deviation

Phenol and aniline - Negative deviation

Ethanol and acetone - Positive deviation

(iii) (a) $P^\circ_A = 760$ mm of Hg

$P_S = 750$ mm of Hg

$$\frac{P^\circ_A - P_S}{P^\circ_A} = x_B$$

$$\frac{760 - 750}{760} = x_B$$

$$= \frac{10}{760} = \frac{1}{76}$$

$$= 0.013$$

OR

(b) NaCl is a non-volatile solute. On adding NaCl to water, varpour pressure is lowered and hence boiling point of water increases. Methyl alcohol is more volatile than water. On adding methyl alchol into water, vapour pressure of solution is greater than than of water. Hence, boiling point decreases.

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. (i) Saline is a homogeneous solution — a true solution of sodium chloride (NaCl) in water.

Solute: Sodium chloride (NaCl)

Solvent: Water (H_2O)

It is a solid-in-liquid solution and is electrolytic in nature.

(ii) Isotonic solutions have the same osmotic pressure as blood plasma. This ensures no net movement of water into or out of blood cells, maintaining their normal shape and function. It prevents cell shrinkage (in hypertonic solutions) or cell swelling and bursting (in hypotonic solutions).

(iii) Hypertonic solution: Has higher solute concentration than blood; as a result solvent water leaves cells, causing cell shrinkage (crenation).

Hypotonic solution: Has lower solute concentration; as a result water enters cells, possibly causing cell swelling and lysis (bursting).

Both can lead to severe medical complications like dehydration or hemolysis.

(iv) Osmotic pressure is the minimum pressure required to stop the flow of solvent molecules through a semi-permeable membrane from dilute to concentrated solution. It depends on the solute particle concentration, a colligative property.

In IV therapy, osmotic pressure of the fluid must match that of blood plasma to avoid disturbing the fluid balance across cell membranes. It ensures safe and effective rehydration without harming cells.

2. (i) When salt (like NaCl or $CaCl_2$) is sprinkled on ice, it dissolves in the thin layer of water on the ice surface and forms a solution. According to colligative properties, the freezing point of a solution is lower than that of pure water. So, the solution's freezing point becomes lower than 0°C, and the ice melts even though the temperature is below 0°C. This phenomenon is called freezing point depression, a type of colligative property that depends on the number of solute particles.

(ii) $\Delta T_f = i.K_f.m$

Where: ΔT_f = Depression in freezing point (how much lower the freezing point is)

i = van't Hoff factor (number of particles the solute dissociates into)

K_f = Cryoscopic constant or freezing point depression constant of the solvent (for water, ~ 1.86 *K.kg/*mol)

m = Molality of the solution (mol of solute per kg of solvent)

The greater the value of ΔT_f, the more the ice melts at sub-zero temperatures.

(iii) Higher van't Hoff factor i means more dissociated particles, resulting in a greater depression in freezing point.

For example:

$NaCl \rightarrow Na^+ + Cl^- \Rightarrow i = 2$

$CaCl_2 \rightarrow Ca^{2+} + 2Cl^- \Rightarrow i = 3$

So, $CaCl_2$ is more effective than NaCl in lowering the freezing point because it produces more particles in solution.

(iv) (1) $CaCl_2$ has a higher van't Hoff factor (i = 3) than NaCl (i = 2), so it causes greater freezing point depression.

(2) It is more hygroscopic — attracts water, helping dissolve more ice quickly.

(3) It is effective at lower temperatures than NaCl.

(4) Requires less quantity to achieve the same effect, making it cost-efficient and faster acting.

Hence, $CaCl_2$ is more efficient in de-icing icy roads, especially in very cold regions.

3. (i) The solution formed is a gas–liquid solution, where solute is Carbon dioxide (CO_2, a gas) and solvent is Water (a liquid). This is an example of a homogeneous solution, where CO_2 is dissolved uniformly in water under pressure.

(ii) Henry's Law states $C = k_H.P$

Where: C = concentration (solubility) of the gas in the liquid

k_H = Henry's law constant (specific to the gas-liquid pair)

P = partial pressure of the gas above the solution

According to this law, the solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid.

Thus, at higher pressure more gas dissolves in the liquid.

(iii) When the bottle is sealed, CO_2 is dissolved under high pressure. Upon opening the bottle, the pressure above the liquid decreases suddenly.

According to Henry's law, lower pressure $\Rightarrow$ lower solubility of CO_2. As a result, CO_2 escapes as bubbles, leading to fizzing. Hence, the sudden drop in pressure leads to release of dissolved CO_2 gas.

(iv) Carbonated drinks are bottled under high pressure to increase the solubility of CO_2 in water using Henry's law. High pressure ensures:

(1) A larger amount of CO_2 remains dissolved.

(2) Fizziness is maintained until the bottle is opened.

(3) The beverage has a refreshing taste and longer shelf life.

So, soft drinks are bottled under high pressure to dissolve sufficient CO_2 and retain carbonation until consumption.

4. (i) The solubility of gases in liquids decreases with an increase in temperature. As temperature rises the kinetic energy of gas molecules increases and gas molecules escape more easily from the liquid into the atmosphere. Hence, less oxygen remains dissolved in water at higher temperatures. Warmer water holds less oxygen, making it harder for aquatic organisms to breathe.

(ii) The relationship between gas solubility and pressure is governed by Henry's Law:

$$C = k_H.P$$

While Henry's Law relates pressure to solubility, temperature affects the Henry's constant k_H. As temperature increases, k_H increases (for most gases), meaning lower solubility. So, temperature indirectly affects gas solubility via changes in Henry's constant.

(iii) During warmer seasons or climate change dissolved oxygen levels drop. Aquatic animals (like fish and amphibians) face oxygen stress.

This can lead to:

(1) Reduced growth or reproduction

(2) Migration of species

(3) Fish kills (mass deaths due to hypoxia)

Warmer temperatures may also increase the metabolism of aquatic organisms, increasing oxygen demand just when supply is low.

(iv) The two real-life measures to reduce thermal pollution in water bodies are:

(1) **Use of cooling towers or ponds in power plants and industries:** These reduce the temperature of wastewater before releasing it into water bodies.

(2) **Reforestation and riparian vegetation:** Planting trees along riverbanks helps provide shade, which lowers water temperature and reduces sunlight-driven warming.