

Short Answer Questions-II

Short Answer Questions-II (PYQ)

Q.1. 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?

[CBSE (AI) 2014] [HOTS]

(Density of solution = 1.2 g mL^{-1})

Ans.

Let the mass of solution = 100 g

\therefore Mass of glucose = 10 g

Number of moles of glucose = $\frac{\text{Mass of glucose}}{\text{Molar mass}}$

$$= \frac{10 \text{ g}}{180 \text{ g mol}^{-1}} = 0.056 \text{ mol}$$

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

$$= \frac{100 \text{ g}}{1.2 \text{ g mL}^{-1}} = 83.3 \text{ mL}$$

$$= \frac{83.3}{1000} \text{ L} = 0.083 \text{ L}$$

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

$$= \frac{0.056 \text{ mol}}{0.083 \text{ L}} = 0.67 \text{ mol L}^{-1}$$

Mass of solvent, water = 100 g – 10 g = 90 g

$$= \frac{90 \text{ g}}{1000 \text{ g kg}^{-1}} = 0.09 \text{ kg}$$

$$\text{Molality} = \frac{\text{Moles of glucose}}{\text{Mass of water in kg}}$$

$$= \frac{0.056 \text{ mol}}{0.09 \text{ kg}}$$

$$= 0.62 \text{ mol kg}^{-1}$$

Q.2. At 25°C the saturated vapour pressure of water is 3.165 kPa (23.75 mm Hg). Find the saturated vapour pressure of a 5% aqueous solution of urea (carbamide) at the same temperature. (Molar mass of urea = 60.05 g mol⁻¹)

[CBSE (F) 2012]

Ans.

$$W_B = 5 \text{ g}, W_A = 95 \text{ g}, M_B = 60.05 \text{ g mol}^{-1}, M_A = 18 \text{ g mol}^{-1}, P_A^0 = 3.165 \text{ kPa}$$

Substituting the values in the expression

$$\frac{P_A^0 - p}{P_A^0} = \frac{W_B \times M_A}{M_B \times W_A}, \text{ we get}$$

$$\frac{3.165 \text{ kPa} - p}{3.165 \text{ kPa}} = \frac{5 \text{ g} \times 18 \text{ g mol}^{-1}}{60.05 \text{ g mol}^{-1} \times 95 \text{ g}} = 0.015$$

$$p = 3.165 \text{ kPa} - 0.015 \times 3.165 \text{ kPa}$$

$$p = 3.118 \text{ kPa}$$

Q.3. Calculate the freezing point of a solution when 3 g of CaCl₂ (M = 111 g mol⁻¹) was dissolved in 100 g of water, assuming CaCl₂ undergoes complete ionisation. (K_f for water = 1.86 K kg mol⁻¹)

[CBSE East 2016]

Ans.

$$\text{Here, } W_B = 3 \text{ g}, i = \frac{3}{1} = 3 (\text{CaCl}_2 \rightarrow \text{Ca}^{2+} + 2 \text{Cl}^-), W_A = 100 \text{ g}, K_f = 1.86 \text{ K kg mol}^{-1}, M_B = 111 \text{ g mol}^{-1}$$

Substituting these values in the expression,

$$\Delta T_f = \frac{i \times K_f \times W_B \times 1000}{M_B \times W_A}, \text{ we get}$$

$$\Delta T_f = \frac{3 \times 1.86 \text{ K kg mol}^{-1} \times 3 \text{ g} \times 1000 \text{ g kg}^{-1}}{111 \text{ g mol}^{-1} \times 100 \text{ g}} = 1.508 \text{ K}$$

Freezing point of solution,

$$\begin{aligned} T_f &= T_f^0 - \Delta T_f \\ &= 273.15 \text{ K} - 1.508 \text{ K} = 271.642 \text{ K} \end{aligned}$$

Q.4. 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)

[CBSE Delhi 2015]

Ans.

The given quantities are

$$W_B = 3.9 \text{ g}, W_A = 49 \text{ g}, \Delta T_f = 1.62 \text{ K}, M_B = 122 \text{ g mol}^{-1} \text{ and } K_f = 4.9 \text{ K kg mol}^{-1}$$

Substituting these values in the equation, $M_B = \frac{K_f \times W_B \times 1000}{\Delta T_f \times W_A}$, we get

$$M_B = \frac{4.9 \text{ K kg mol}^{-1} \times 3.9 \text{ g} \times 1000 \text{ g kg}^{-1}}{1.62 \text{ K} \times 49 \text{ g}}$$

$$M_B = 240.74 \text{ g mol}^{-1}$$

Thus, observed molecular mass of benzoic acid in benzene = 240.74 g mol⁻¹

Normal molecular mass of benzoic acid = 122 g mol⁻¹

$$i = \frac{\text{Normal molecular mass}}{\text{Observed molecular mass}}$$

$$i = \frac{122 \text{ g mol}^{-1}}{240.74 \text{ g mol}^{-1}} = 0.506$$

As $i < 1$, therefore, benzoic acid will undergo association in benzene.

Q.5. 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 $1.86 \text{ K kg mol}^{-1}$ and $0.512 \text{ K kg mol}^{-1}$ respectively.

[CBSE (F) 2017]

Ans.

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

$$\Delta T_b = K_b \cdot m \quad \Rightarrow m = \Delta T_b / K_b$$

$$\Delta T_f = K_f m, \quad \Delta T_f = 1.86 \text{ K kg mol}^{-1} \times 0.39 \text{ mol kg}^{-1} = 0.725 \text{ K}$$

$$T_f = T_f^0 - \Delta T_f = 273.15 \text{ K} - 0.725 \text{ K} = 272.425 \text{ K}$$

Q.6. Calculate the boiling point of solution when 2 g of Na_2SO_4 ($M = 142 \text{ g mol}^{-1}$) was dissolved in 50 g of water, assuming Na_2SO_4 undergoes complete ionisation.

(K_b for water = $0.52 \text{ K kg mol}^{-1}$)

[CBSE North 2016]

Ans.

$$i = \frac{3}{1} = 3 \quad (\text{Na}_2\text{SO}_4 \rightarrow 2\text{Na}^+ + \text{SO}_4^{2-})$$

$$\text{Given, } W_B = 2 \text{ g, } W_A = 50 \text{ g, } M_B = 142 \text{ g mol}^{-1}, K_b = 0.52 \text{ K kg mol}^{-1}$$

$$\text{Substituting the values in the expression, } \Delta T_b = \frac{i \times K_b \times W_B \times 1000}{M_B \times W_A}$$

$$\Delta T_b = \frac{3 \times 0.52 \text{ K kg mol}^{-1} \times 2 \text{ g} \times 1000 \text{ g kg}^{-1}}{142 \text{ g mol}^{-1} \times 50 \text{ g}} = 0.439 \text{ K}$$

$$\text{So, boiling point of solution, } T_b = T_b^0 + \Delta T_b$$

$$= 373.15 \text{ K} + 0.439 \text{ K} = 373.589 \text{ K}$$

Q.7. 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 = $1.86 \text{ K kg mol}^{-1}$)

[CBSE (F) 2015]

Ans.



Substituting $K_f = 1.86 \text{ K kg mol}^{-1}$, $W_A = 37.2 \text{ g}$, $M_B = 58.5 \text{ g mol}^{-1}$, $i = 2$, $\Delta T_f = 2^\circ\text{C}$ or 2 K in the equation,

$$W_B = \frac{\Delta T_f \times M_B \times W_A}{i \times K_f \times 1000} , \text{ we get}$$

$$W_B = \frac{2\text{K} \times 58.5 \text{ g mol}^{-1} \times 37.2 \text{ g}}{2 \times 1.86 \text{ K kg mol}^{-1} \times 1000 \text{ g kg}^{-1}} = 1.17 \text{ g}$$

Short Answer Questions-II (OIQ)

Q.1 Which aqueous solution has higher concentration—1 molar or 1 molal solution of the same solute? Give reason.

[HOTS]

Ans. Here density determines the relative concentrations of the solutions.

Case (i): When density of solvent is 1 g/mL : In aqueous solution, density of water is normally taken as 1. This means that 1 m solution has 1 mole of the solute dissolved in 1000 g or 1000 mL of the solvent. At the same time 1 M solution contains 1 mole of the solute in 1000 mL solution, which is the volume of both the solute and solvent present in the solution. This clearly shows that the solvent present in 1 M solution is less as compared to 1 m solution. Therefore, 1 M solution is more concentrated than 1 m solution.

Case (ii): When density of the solvent is less than 1 g/mL : This means that the volume of solvent (mass/density) will be more as compared to its mass. Thus, 1 M solution will be less concentrated than 1 m solution.

Case (iii): When density of the solvent is more than 1 g/mL: This means that the volume of solvent will be less than its mass. Under these circumstances, 1 M solution will be more concentrated than 1 m solution.

Q.2. Calculate the boiling point of a 1 M aqueous solution (density 1.04 g mL⁻¹) of potassium chloride

(K_b for water = 0.52 K kg mol⁻¹, Atomic masses: K = 39 u, Cl = 35.5 u)

Assume, potassium chloride is completely dissociated in solution.

[CBSE Sample Paper 2016]

Ans. Mass of solution = Density of solution \times Volume of solution

$$= 1.04 \text{ g mL}^{-1} \times 1000 \text{ mL} = 1040 \text{ g}$$

Molar mass of solute KCl, $M_B = 39 + 35.5 = 74.5 \text{ g mol}^{-1}$

\therefore Mass of solvent water, $W_A = 1040 \text{ g} - 74.5 \text{ g} = 965.5 \text{ g}$

As KCl dissociates ($\text{KCl} \rightarrow \text{K}^+ + \text{Cl}^-$) completely, $i = \frac{2}{1} = 2$

For water, $K_b = 0.52 \text{ K kg mol}^{-1}$, $W_B = 74.5 \text{ g}$

Substituting these values in the expression $\Delta T_b = \frac{i \times K_b \times W_B \times 1000}{M_B \times W_A}$, we get

$$\Delta T_b = \frac{2 \times 0.52 \text{ K kg mol}^{-1} \times 74.5 \text{ g} \times 1000 \text{ g kg}^{-1}}{74.5 \text{ g mol}^{-1} \times 965.5 \text{ g}}$$

$$= 1.077 \text{ K}$$

Boiling point of solution, $T_b = T_b^0 + \Delta T_b$

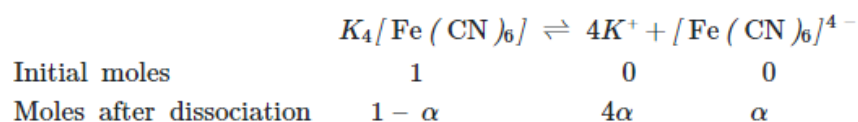
$$= 373.15 \text{ K} + 1.077 \text{ K}$$

$$= 374.227 \text{ K}$$

Q.3. A decimolar solution of potassium ferrocyanide is 50% dissociated at 300 K. Calculate the osmotic pressure of the solution. ($R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$).

Ans.

Here, $\alpha = 0.5$



Total moles of particles = $1 - \alpha + 4\alpha + \alpha = 1 + 4\alpha$

\therefore van't Hoff factor, $i = \frac{1 + 4\alpha}{1}$

$$= 1 + 4 \times 0.5 = 3$$

Osmotic pressure, $\pi = iCRT$

$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$, i.e., it is in SI units.

$$C = 0.1 \text{ M} = \frac{0.1}{10^{-3}} \text{ mol m}^{-3} = 10^2 \text{ mol m}^{-3}$$

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

n = number of particles after dissociation

$$\frac{50}{100} = \frac{i-1}{5-1}$$

$$i = 3$$

Hence, $\pi = 3 \times 10^2 \times 8.314 \times 300$

$$= 7.483 \times 10^5 \text{ Nm}^{-2}$$

$$= 7.483 \text{ atm}$$

Q.4. At 300 K, 36 g of glucose, $C_6H_{12}O_6$ present per litre in its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of another glucose solution is 1.52 bar at the same temperature, calculate the concentration of the other solution.

[CBSE Sample Paper 2017]

Ans.

$$\pi = \frac{W_B \times R \times T}{M_B \times V} = CRT$$

$$4.98 = \frac{36 \times R \times 300}{180 \times 1} = 60 R \quad \dots (i)$$

$$1.52 = C \times R \times 300 = 300 CR \quad \dots (ii)$$

Dividing equation (ii) by (i), we get

$$\frac{300\text{ CR}}{60R} = \frac{1.52}{4.98}$$

$$\mathbf{C = 0.061\text{ M}}$$