Unit 2 Solution : Numericals Based on Raoult's Law

Q.1. Vapour Pressure of pure water is 40 mm Hg. On adding a nonvolatile solute, it reduces by 4 mm Hg. Find the molality of solution.

Sol^n- Given that,

Vapour Pressure of pure water (p^0_A) = 40 mm Hg

Vapour Pressure of solution (p_A) = (40 – 4) mm Hg = 36 mm Hg

Molality of solution, m = ?

From Raoult's law,

$$P_A = p^0_A X_A$$

$$\therefore \quad 36 = 40 \times X_A$$

$$\text{or} \quad X_A = \frac{36}{40} = 0.9$$

$$\therefore \quad X_B = (1 - X_A) = (1 - 0.9) = 0.1$$

Again since, molality,

$$m = \frac{X_B \times 1000}{X_A \times M_A} = \frac{0.1 \times 1000}{0.9 \times 18} = 6.17 \text{ m}$$

Q.2. The vapour pressure of water at 296 K is 19.8 mm Hg. 0.1 mole of glucose is dissolved in 178.2 g of water. Calculate the vapour pressure of resultant solution.

Sol^n- Given that,

Vapour Pressure of pure water (p^0_A) = 19.8 mm Hg

No. of moles of solute, (n_B) = 0.1 moles

Mass of solvent (water), (W_A) = 178.2 g

Vapour Pressure of solution, (p_A) = ?

From Raoult's law,

$$P_A = p^0_A X_A$$

$$= 19.8 \times \frac{n_A}{n_B + n_A}$$

Here, $n_A = \frac{178.2}{18}$

$= 9.9$ moles

$\therefore$ $P_A = 19.8 \times \frac{9.9}{0.1 + 9.9}$

$= 19.6$ mm Hg

Q.3. At a given temperature, vapour pressure of ethanol and methanol are 44.5 and 88.7 mm Hg respectively. An ideal solution is prepared by mixing 60 g of ethanol with 40 g of methanol at same temperature. Calculate the total vapour pressure of the solution and mole fraction of methanol in the vapour.

Sol^n- Given that,

Vapour pressure of ethanol (p^0_A) = 44.5 mm Hg
Vapour pressure of methanol (p^0_B) = 88.7 mm Hg
Mass of ethanol (W_A) = 60 g
Mass of methanol (W_B) = 40 g
Total vapour pressure of solution, (p_{Total}) = ?
Mole fraction of methanol in the vapour = ?

From Raoult's law, for an ideal solution,

$$P_{Total} = p^0_A X_A + p^0_B X_B$$

$$= 44.5 \times \frac{n_A}{n_B + n_A} + 88.7 \times \frac{n_B}{n_B + n_A}$$

Here, $n_A = \frac{60}{46}$

$= 1.304$ moles

And $n_B = \frac{40}{32}$

$= 1.25$ moles

$\therefore$ $P_{Total} = 44.5 \times \frac{1.304}{1.25 + 1.304} + 88.7 \times \frac{1.25}{1.25 + 1.304}$

$= (22.73 + 43.40)$ mm Hg

$= 66.13$ mm

$\because$ Mole fraction of a component in the vapour $= \frac{\text{Partial pressure of component}}{\text{Total vapour pressure}}$

∴ Mole fraction of a methanol in the vapour $= \dfrac{\text{Partial pressure of methanol}}{\text{Total vapour pressure}}$

$= \dfrac{43.40}{66.13}$

$= 0.6563$

Q.4. At a given temperature, vapour pressure of two liquids A and B are 120 and 180 mm Hg respectively. An ideal solution is prepared by mixing 2 moles of A and 3 moles of B. Calculate the vapour pressure of the solution at same temperature.

Sol^n- Given that,

Vapour pressure of liquid A (p^0_A) = 120 mm Hg

Vapour pressure of liquid B (p^0_B) = 180 mm Hg

No. of moles of A (n_A) = 2 moles

No. of moles of B (n_B) = 3 moles

Total vapour pressure of solution, (p_{Total}) = ?

From Raoult's law, for an ideal solution,

$$P_{Total} = p^0_A X_A + p^0_B X_B$$

$$= 120 \times \frac{n_A}{n_B + n_A} + 180 \times \frac{n_B}{n_B + n_A}$$

$$\therefore \quad P_{Total} = 120 \times \frac{2}{2+3} + 180 \times \frac{3}{2+3}$$

$$= (48 + 108) \text{ mm Hg}$$

$$= 156 \text{ mm Hg}$$

Q.5. At 20^0C temperature, vapour pressure of two liquids A and B are 22 and 75 mm Hg respectively. A solution is prepared by mixing equal moles of A and B. Assuming the solution to be ideal, calculate the vapour pressure of the solution at same temperature.

Sol^n- Given that,

Vapour pressure of liquid A (p^0_A) = 22 mm Hg

Vapour pressure of liquid B (p^0_B) = 75 mm Hg

No. of moles of A (n_A) = No. of moles of B (n_B)

Total vapour pressure of solution, (p_{Total}) = ?

Here since,

$$n_A = n_B$$

$\therefore \quad X_A = X_B$

$= \frac{1}{2}$

From Raoult's law, for an ideal solution,

$$P_{Total} = p^0_A X_A + p^0_B X_B$$

$$\therefore \quad P_{Total} = 22 \times \frac{1}{2} + 75 \times \frac{1}{2}$$

$$= (11 + 37.5) \text{ mm Hg}$$

$$= 48.5 \text{ mm Hg}$$

Q.6. 50 g of sucrose (molar mass = 342) is added to 500 g of water. If vapour pressure of pure water at 25^0C temperature is 23.8 mm Hg, find the lowering in vapour pressure of the solution.

Sol^n- Given that,

Vapour pressure of pure water (p^0_A) = 23.8 mm Hg

Mass of solute (sucrose), W_B = 50 g

Gram molecular mass of solute (sucrose), M_A = 342

Mass of solvent (water), W_A = 500 g

Lowering in vapour pressure, $(p^0_A - p_A)$ = ?

From Raoult's law about relative lowering in vapour pressure,

$$\frac{p0_A - p_A}{p0_A} = X_B$$

$$\therefore \quad \frac{p0_A - p_A}{p0_A} = \frac{n_B}{n_B + n_A}$$

$$\text{or} \quad \frac{p0_A - p_A}{p0_A} = \frac{W_B/M_B}{W_B/M_B + W_A/M_A}$$

$$\therefore \quad (p^0_A - p_A) = p^0_A \times \frac{W_B/M_B}{W_B/M_B + W_A/M_A}$$

$$= 23.8 \times \frac{\frac{50\text{ g}}{342\text{ g}}}{\frac{50\text{ g}}{342\text{ g}} + \frac{500\text{ g}}{18\text{ g}}}$$

$$= 23.8 \times \frac{0.146}{0.146 + 27.78}$$

$$= 0.124 \text{ mm Hg}$$

Q.7. 50 g of sucrose (molar mass = 342) is added to 500 g of water. If vapour pressure of pure water at 25^0C temperature is 23.8 mm Hg, find the relative lowering in vapour pressure of the solution.

Sol^n^- Given that,

Vapour pressure of pure water (p^0_A) = 23.8 mm Hg

Mass of solute (sucrose), W_B = 50 g

Gram molecular mass of solute (sucrose), M_A = 342

Mass of solvent (water), W_A = 500 g

Relative lowering in vapour pressure, $\frac{p0_A - p_A}{p0_A}$ = ?

From Raoult's law about relative lowering in vapour pressure,

$$\frac{p0_A - p_A}{p0_A} = X_B$$

$$\therefore \quad \frac{p0_A - p_A}{p0_A} = \frac{n_B}{n_B + n_A}$$

$$\text{or} \quad \frac{p0_A - p_A}{p0_A} = \frac{W_B/M_B}{W_B/M_B + W_A/M_A}$$

$$= \frac{\frac{50\ g}{342\ g}}{\frac{50\ g}{342\ g} + \frac{500\ g}{18\ g}}$$

$$= \frac{0.146}{0.146 + 27.78}$$

$$= 0.0052 \text{ mm Hg}$$

Q.8. The vapour pressure of 5 % aqueous solution of a non-volatile solute at 373 K temperature is 745 mm Hg. If vapour pressure of pure water at 373 K temperature is 760 mm Hg, find the molecular mass of the solute.

Sol^n^- Given that,

Vapour pressure of pure water at 373 K, p^0_A = 760 mm Hg

Vapour pressure of solution, at 373 K, p_A = 745 mm Hg

Mass of solute, W_B = 5 g

Mass of solvent (water), W_A = (100 – 5) g

= 95 g

Gram molecular mass of solute, M_B = ?

From Raoult's law about relative lowering in vapour pressure,

$$\frac{p0_A - p_A}{p0_A} = \frac{W_B \times M_A}{M_B \times W_A}$$

$$\therefore \quad M_B = \frac{p^0_A}{p^0_A - p_A} \times \frac{W_B \times M_A}{W_A}$$

$$= \frac{760}{760 - 745} \times \frac{5\ g \times 18}{95}$$

$$= 47.05$$

Q.9. **The vapour pressure of a solution containing 30 g of a non-volatile solute in 90 g of water at 298 K temperature is 21.85 mm Hg. When 18 g of water is added to this solution the vapour pressure of solution becomes 22.15 mm Hg. Find the molecular mass of the solute and the vapour pressure of water at 298 K temperature.**

Sol^n- Given that,

Vapour pressure of first solution at 298 K = 21.85 mm Hg

Vapour pressure of second solution at 298 K = 22.15 mm Hg

Mass of solute, W_B = 30 g

Mass of water in first solution = 90 g

Mass of water in second solution = (90 + 18) g

= 108 g

Molecular mass of solute, M_B = ?

Vapour pressure of pure water at 298 K, p^0_A = ?

From Raoult's law about relative lowering in vapour pressure,

$$\frac{p0_A - p_A}{p0_A} = \frac{W_B \times M_A}{M_B \times W_A}$$

Here, for first solution, $$\frac{p0_A - 21.85}{p0_A} = \frac{30 \times 18}{M_B \times 90} \quad \text{------- (1)}$$

For second solution, $$\frac{p0_A - 22.15}{p0_A} = \frac{30 \times 18}{M_B \times 108} \quad \text{------- (2)}$$

Dividing eq. (1) by eq. (2) we get,

$$\frac{p0_A - 21.85}{p0_A} \times \frac{p0_A}{p0_A - 22.15} = \frac{30 \times 18}{M_B \times 90} \times \frac{M_B \times 108}{30 \times 18}$$

or $$\frac{p0_A - 21.85}{p0_A - 22.15} = \frac{108}{90}$$

$\therefore \quad p^0_A = 23.65$ mm Hg

Putting this value of p^0_A in eq. (1) we get,

$$\frac{23.65 - 21.85}{23.65} = \frac{30 \times 18}{M_B \times 90}$$

$\therefore \quad M_B = 78.83$