

UNIT- 2: SOLUTIONS**LEVEL-1 QUESTIONS****2.1 What are solns?**

Homogeneous mixture containing two or more than two components.

2.2 What are binary solns?

Binary solution : Solutions containing only two components.

2.3. Define mole fraction

Ratio of number of moles of a component to the total number of moles of solutions.

2.4 Define molarity

Number of moles of solute dissolved in one litre of solution.

2.5 Define molality

Number of moles of the solute dissolved in 1 kg of the solvent.

2.6. State Henry's law

The partial pressure of the gas in vapour phase is directly proportional to the molefraction of the gas in the solution.

$$P = K_H \times$$

2.7. Mention one application of Henry's law

To increase the solubility of CO₂ in soft drinks , the bottle is sealed under high pressure.

2.8. State Raoult's Law

For a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction.

$$P_1 = p_1^0 \times x_1$$

2.9. What are Ideal solutions?

Solutions which obey Raoult's law . solute –solvent interaction is nearly equal to solute –solute or solvent – solvent interaction. $\Delta_{\text{mix}} H = 0$ and $\Delta_{\text{mix}} V = 0$

Eg: n- hexane and n-heptane

2.10. What are non-ideal solutions?

Solutions which do not obey Raoult's law . Inter molecular force of attraction between solute – solvent is Weaker or stronger than those between solute –solute or solvent – solvent interaction.

$$\Delta_{\text{mix}} H \neq 0 \quad \Delta_{\text{mix}} V \neq 0$$

Positive deviation: Solutions which do not obey Raoult's law. Inter molecular force of attraction between solute –solvent is Weaker than those between solute –solute or solvent – solvent interaction. Molecule find it easier to escape than in pure state. This will increase the vapour pressure and results positive deviation. $\Delta_{\text{mix}} H = + \text{ive}$ $\Delta_{\text{mix}} V = + \text{ive}$ eg. Mixture of ethanol and water.

Negative deviation: Solutions which do not obey Raoult's law. Inter molecular force of attraction between solute –solvent is stronger than those between solute –solute or solvent – solvent interaction due to the formation of H-bonding in between solute and solvent. This decreases escaping tendency of molecules and its decreases the vapour pressure and results negative deviation.

2.12. Define colligative property

Properties which depend on the number of solute particle irrespective of their nature relative to the total number of particle present in the solution.

2.13. Define Ebullioscopic constant

Elevation of boiling point of one molal solution.

2.14. Define Cryoscopic constant

Depression of freezing point of one molal solution.

2.15. Define Osmosis

Flow of solvent molecule through semi permeable membrane from pure solvent to the solution. This process of flow of the solvent is called osmosis.

2.16. Define Osmotic Pressure

Excess pressure that must be applied to a solution to prevent osmosis.

2.17. What is reverse osmosis

Pure solvent flows out of the solution through the semi permeable membrane when we apply pressure larger than the osmotic pressure. Application of reverse osmosis is desalination of seawater.

2.18. What are isotonic solution

Two solutions having same osmotic pressure at a given temperature.

2.19. Define van't Hoff factor

$i = \frac{\text{Normal molar mass}}{\text{abnormal molar mass}}$

$i = \frac{\text{observed colligative property}}{\text{calculated colligative property}}$

2.20. All formulas – Calculation of Molar mass using colligative property

$$\frac{p_A^0 - p}{p_A^0} \approx \frac{n_B}{n_A} = \frac{w_B / M_B}{w_A / M_A}$$

$$\pi V = \frac{w_2 RT}{M_2}$$

LEVEL-2 QUESTIONS.

- 2.1. Concentrated nitric acid used in the laboratory work is 68% nitric acid by mass in aqueous solution. What should be the molarity of such a sample of the acid if the density of solution is 1.504 g mL^{-1} ?**

Sol. Percentage mass (%) and molarity (M) of the solution are related as

$$\begin{aligned}\text{Molarity (M)} &= \frac{\% \text{ mass} \times \text{density} \times 10}{\text{Molar mass of solute (HNO}_3\text{)}} \\ &= \frac{68 \times 1.504 (\text{g mL}^{-1}) \times 10}{68 (\text{g mol}^{-1})} = 16.23 \text{ M}\end{aligned}$$

- 2.2. Calculate the percentage composition in terms of mass of a solution obtained by mixing 300 g of a 25% and 400 g of a 40% solution by mass.**

Sol. Mass of solute in 300 g of 25% solution = 75 g

Mass of solute in 400 g of 40% solution = 160 g

Total mass of solute = (75 + 160) g = 235 g

Total mass of solution = 700 g

$$\% \text{ of solute in final solution} = \frac{235 \times 100}{700} = 33.2\%$$

$$\% \text{ of water in final solution} = 100 - 33.5 = 66.5\%$$

- 2.3. An antifreeze solution is prepared from 222.6 g of ethylene glycol ($\text{C}_2\text{H}_6\text{O}_2$) and 200 g of water. Calculate the molality of the solution. If the density of the solution is 1.072 g mL^{-1} then what shall be the molarity of the solution ?**

Sol.
$$\text{Molality (m)} = \frac{W_B \times 10^3}{MM_B \times W_A} = \frac{222.6 \times 1000}{62 \times 260}$$

$$= 17.95 \text{ mol kg}^{-1}$$

$$\text{Total mass of solution} = 200 + 222.6 = 422.6 \text{ g}$$

$$\text{Vol. of solution} = \frac{\text{Mass}}{\text{Density}} = \frac{422.6 (\text{g})}{1.072 (\text{g mL}^{-1})} = 394.222$$

$$\begin{aligned}\text{Molarity (M)} &= \frac{W_B \times 10^3}{MM_B \times V_{(\text{mL})}} = \frac{222.6 (\text{g}) \times 10^3 (\text{mL})}{62 (\text{g mol}^{-1}) \times 394.22 (\text{mL})} \\ &= 9.107 \text{ mol L}^{-1}\end{aligned}$$

2.4. A sample of drinking water was found to be severely contaminated with chloroform, CHCl_3 , supposed to be carcinogen. The level of contamination was 15 ppm (by mass)

(i) Express this in percent by mass.

(ii) Determine the molality of chloroform in the water sample.

Sol. Mass of solution ($w_A + w_B$) = 10^6 g

Mass of solute (w_B) = 15 g

$$\% \text{ mass} = \frac{w_B \times 100}{w_A + w_B} = \frac{15 \times 100}{10^6} = 1.5 \times 10^{-3}\%$$

Mass of solvent (w_A) = $10^6 - 15 = 999985$ g

$$\begin{aligned} \text{Molality (m)} &= \frac{w_B \times 10^3}{MM_B \times w_A} = \frac{15(\text{g}) \times 10^3 (\text{g})}{119.5 (\text{g mol}^{-1}) \times 999985 \text{ g}} \\ &= 1.25 \times 10^{-4} \text{ m} \end{aligned}$$

2.5. What role does the molecular interaction play in solution of alcohol and water

The intermolecular forces both in alcohol and water are H-bonds. When alcohol (ROH) and water (H_2O) are mixed. They form solution because of formation of H-bonds between alcohol and H_2O molecules but these interactions are weaker and less extensive positive deviation from Raoult's law with both, ΔH_{mix} and $\Delta V_{\text{mix}} > 0$. The solution will have higher vapour pressure and lower boiling point than the individual components.

2.6. Why does gases nearly always tend to be less soluble in liquids as the temperature is raised?

Dissolution of gases is exothermic process. It is because of the fact that this process involves decrease of entropy ($\Delta S < 0$). Thus, increase of temperature tends to push the equilibrium, ($\text{Gas} + \text{Solvent} = \text{Solution}$; $\Delta H = -ve$) in the backward direction, thereby, suppressing the dissolution.

2.7. The partial pressure of ethane over a saturated solution containing 6.56×10^{-2} g of ethane is 1 bar. If the solution contains 5.00×10^{-2} g of ethane, then what shall be the partial pressure of the gas.

Sol. According to Henry's law, $m = K_H p$

$$K_H = \frac{m}{p} = \frac{6.56 \times 10^{-2} (\text{g})}{1(\text{bar})} = 6.56 \times 10^{-2} \text{ g bar}^{-1}$$

In the second case,

$$p \frac{m}{K_H} = \frac{5.00 \times 10^{-2}(\text{g})}{6.56 \times 10^{-2}(\text{g bar}^{-1})} = 76.21 \text{ bar}$$

2.8. An aqueous solution of 2 percent nonvolatile solute exerts a pressure of 1.004 bar at the boiling point of the solvent. What is the molecular mass of the solute?

Sol. The vapour pressure of pure water

$$(p_A^0) = 1 \text{ ATM} = 1.013 \text{ BAR}$$

Vapour pressure of solution (p) = 1.004 bar

$$w_B = 2 \text{ g} ; \quad w_A + w_B = 100 \text{ g} ; \quad w_A = 98 \text{ g}$$

$$\text{Now} \quad \frac{p_A^0 - p}{p_A^0} \approx \frac{n_B}{n_A} = \frac{w_B / M_B}{w_A / M_A}$$

$$\text{or} \quad M_B = \frac{w_B M_A}{w_A (\Delta p / p_A^0)} = \frac{2 \times 18 \times 1.013}{98 \times (1.013 - 1.004)}$$

$$= 41.35 \text{ g mol}^{-1}$$

2.9. The vapour pressure of water is 12.3 kPa at 300 K. Calculate the vapour pressure of 1 molal solution of a solute in it.

Sol. $p_{\text{H}_2\text{O}}^0 = 12.3 \text{ kPa}$

In 1 molal solution,

$$n_B = 1 ; \quad n_{\text{H}_2\text{O}} = \frac{1000}{18} = 55.5$$

$$\therefore x_{\text{H}_2\text{O}} = \frac{55.5}{55.5 + 1} = 0.982$$

$$p = 0.982 \times 12.3 = 12.08 \text{ kPa.}$$

2.10. Calculate the mass of a nonvolatile solute (molecular mass 40) which should be dissolved in 114 g octane to reduce its vapour pressure to 80%.

Sol. Vapour pressure of solution (p) = 80% of $p_A^0 = 0.8 p_A^0$

Let the mass of solute be w g

$$\therefore \text{Moles of solute} = \frac{w}{40}$$

$$\text{Mole of octane (no)} = \frac{114}{114} = 1 \text{ mol}$$

$$x_B = \frac{w/40}{(w/40)+1}$$

$$\text{Now, } \frac{\Delta p}{p^\circ} = x_B \quad \text{or} \quad \frac{p^\circ - 0.8p^\circ}{p^\circ} = \frac{w/40}{(w/40)+1}$$

$$\text{or} \quad w = \frac{0.2 \times 40}{0.8} = 10 \text{ g}$$

- 2.11. A 5% solution (by mass) of cane sugar in water has freezing point of 271 K. Calculate the freezing point a 5% glucose in water if freezing point of pure water is 273.15 K.

$$\text{Sol. Molality of sugar solution} = \frac{5 \text{ (g)} \times 1000 \text{ (g kg}^{-1}\text{)}}{342 \text{ (g mol}^{-1}\text{)} \times 100 \text{ (g)}} = 0.146 \text{ mol kg}^{-1}$$

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

$$\text{Now, } \Delta T_f = K_f \times m \quad \text{or} \quad K_f = \frac{\Delta T_f}{m} = \frac{2.15}{0.146} = 14.726$$

Molality of glucose solution

$$= \frac{5 \text{ (g)} \times 1000 \text{ (g kg}^{-1}\text{)}}{180 \text{ (g mol}^{-1}\text{)} \times 100 \text{ (g)}} = 0.278 \text{ mol kg}^{-1}$$

$$\Delta T_f = K_m = 14.726 \times 0.278 = 4.09^\circ$$

Freezing point of glucose solution

$$= 273.15 - 4.09 = 269.06 \text{ K}$$

- 2.12. At 300 K, 36 g of glucose present per litre in its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of solution is 1.52 bar at the same temperature. What would be its concentration?

$$\text{Sol. In 1}^{\text{st}} \text{ case } \pi_1 = CRT$$

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

$$\text{In 2}^{\text{nd}} \text{ case } 1.52 = C \times R \times 300 \quad \dots(ii)$$

Divided (ii) by (i)

$$\frac{1.52}{4.98} = \frac{C \times R \times 300 \times 180}{36 \times R \times 300}$$

$$\text{or} \quad C = 0.061 \text{ mol L}^{-1}.$$

2.13. Amongst the following compounds, identify which are insoluble, partially soluble and highly soluble in water:

(i) phenol

(ii) toluene

(iii) formic acid

(iv) ethylene glycol

(v) chloroform

(vi) pentanol.

Sol. Water is a polar substance and the intermolecular forces in water are H-bonds.

- (a) Toluene ($\text{C}_6\text{H}_5 - \text{CH}_3$) and chloroform (CHCl_3) are insoluble in water as they cannot form H-bonds with H_2O molecules
- (b) Phenol ($\text{C}_6\text{H}_5\text{OH}$) and pentanol ($\text{C}_5\text{H}_{11}\text{OH}$) are partially miscible with water because of very weak solute solvent interactions due to the significant non-polar part (aryl or alkyl) in their molecules.
- (c) Formic acid (CH_3COOH) and ethylene glycol ($\text{C}_2\text{H}_4(\text{OH})_2$) are highly soluble because of their strong tendency of forming H-bonds with water molecules.

2.14. Based on solute-solvent interactions arrange the following in order of increasing solubility in n-octane and explain: Cyclohexane, KCl, CH_3OH , CH_3CN .

n-octane is a non-polar substance. Following the principle of like dissolves like, the solubility increases as the polarity of the solute decreases. Thus, among the given substances the solubility in n-octane increases as $\text{KCl} < \text{CH}_3\text{OH} < \text{CH}_3\text{CN} < \text{Cyclohexane}$.

2.15. Calculate the percentage of aspirin ($\text{C}_9\text{H}_8\text{O}_4$) in acetonitrile (CH_3CN) when 6.5 g of $\text{C}_9\text{H}_8\text{O}_4$ is dissolved in 450 g of CH_3CN .

Sol.
$$\text{Mass \%} = \frac{W_B \times 100}{W_A + W_B} = \frac{6.5 \times 100}{6.5 + 450} = 1.424\%$$

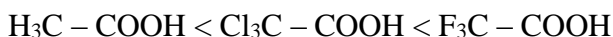
2.16. Calculate the amount of benzoic acid ($\text{C}_6\text{H}_5\text{COOH}$) required for preparing 250 mL of 0.15 M solution in methanol.

Sol.
$$M = \frac{W_B \times 1000}{(\text{MM})_B \times V} \quad \text{or} \quad W_B = \frac{M \times (\text{MM})_B \times V}{1000}$$

$$= 0.15 \text{ (mol L}^{-1}\text{)} \times 122 \text{ (g mol}^{-1}\text{)} \times 250 \times 10^{-3} \text{ (L)} = 4.575 \text{ g}$$

2.17. The depression in freezing point of water observed for the same amount of acetic acid, trichloroacetic acid and trifluoroacetic acid increases in the order given above. Explain briefly

Colligative property is directly proportional to the concentration of solute particles which further depends upon the degree of dissociation of electrolytes. Now, the strength of acid and its corresponding degree of ionization increases as



Consequently, the concentration of solute particles and thus, the value of ΔT_f increases in the same order.

2.18. Vapour pressure of water at 298 K is 17.535 mm Hg. Calculate vapour pressure of water at 293 K when 25 g of glucose is dissolved in 450 g of water.

Sol. $p_A^0 = 17.535$ mm Hg. Let vapour pressure of solution be p_s

$$\frac{p_A^0 - p_s}{p_A^0} = x_B \quad \text{or} \quad 1 - \frac{p_s}{p_A^0} = x_B \quad \text{or} \quad p_s = p_A^0 (1 - x_B)$$

$$\text{or} \quad p_s = p_A^0 \times x_A = 17.535 \times \frac{450/18}{25/180 + 450/18}$$

$$= 17.535 \times 0.9945 = 17.438 \text{ mm Hg}$$

$$\approx 17.44 \text{ mm Hg.}$$

2.19. Henry's law constant for the molarity of methane in benzene at 298 K is 4.27×10^5 mm Hg. Calculate the solubility of methane in benzene at 298 K under 760 mm Hg.

Sol. $K_H = 4.27 \times 10^5$ mm,

According to Henry's law, $p = K_H \cdot x_{CH_4}$

$$\text{Or} \quad x_{CH_4} = \frac{p}{K_H} = \frac{760 \text{ (mmHg)}}{4.27 \times 10^5 \text{ (mmHg)}} = 1.78 \times 10^{-3}$$

2.20. Determine the amount of $CaCl_2$ ($i = 2.47$) dissolved in 2.5 litre of water such that its osmotic pressure is 0.75 atm at 27°C .

$$\text{Sol.} \quad \pi = iCRT \quad \text{or} \quad \pi = \frac{i \times W_B \times R \times T}{(MM)_B \times V_{(L)}} \quad \text{or} \quad W_B = \frac{\pi \times (MM)_B \times V_{(L)}}{i \times R \times T}$$

$$= \frac{0.75 \text{ (atm)} \times 111 \text{ (g mol}^{-1}\text{)} \times 2.5 \text{ (L)}}{2.47 \times 0.0821 \text{ (L atm mol}^{-1}\text{ K}^{-1}\text{)} \times 300.15 \text{ (K)}}$$

$$= 3.40 \text{ g}$$

$$\text{or} \quad \frac{3.40 \text{ (g)}}{111 \text{ (g mol}^{-1}\text{)}} = 0.03 \text{ mol.}$$

LEVEL-3 QUESTIONS

2.1 Heptane and octane form ideal solution. At 373 K, the vapour pressure of the two liquid components are 105.2 kPa and 46.8 kPa, respectively. What will be the vapour pressure, in bar, of a mixture of 25.0 g of heptane and 35.0 g of octane?

$$\text{Sol.} \quad \text{Moles of heptane (n}_H\text{)} = \frac{25}{100} = 0.25$$

$$\text{Moles of octane (n}_O\text{)} = \frac{35}{114} = 0.307$$

$$x_H = \frac{0.25}{0.25 + 0.307} = \frac{0.25}{0.557} = 0.449 ; x_0 = 1 - 0.449 = 0.551$$

$$\text{Vapour pressure of heptane (p}_H\text{)} = 105.2 \times 0.449 = 47.2348 \text{ kPa} \approx 47.235 \text{ kPa}$$

$$\text{Vapour pressure of octane (p}_O\text{)} = 46.8 \times 0.551 = 25.787 \text{ kPa}$$

$$\text{Total vapour pressure } P_{\text{total}} = p_H + p_O = 47.235 + 25.787 = 73.022 \text{ kPa}$$

$$\text{Or } \frac{73.022 \times 10^3}{10^5} \text{ bar} = 0.7302 \text{ bar.}$$

2.2 2.2. A solution of glucose in water is labelled as 10 percent w/w. What would be the molality and mole fraction of each component in the solution? If the density of the solution is 1.2 g mL^{-1} , then what shall be the molarity of the solution?

$$\begin{aligned} \text{Sol. Molarity (M)} &= \frac{\% \times d \times 10}{\text{Molar mass (glucose)}} \\ &= \frac{10 \times 1.2 (\text{g mol}^{-1}) \times 10}{180 (\text{g mol}^{-1})} = 0.67 \text{ M} \end{aligned}$$

Consider 100 g of solution.

$$\text{Mass of glucose} = 10 \text{ g; mole of glucose (n}_B\text{)} = 10/180$$

$$\text{Mass of water} = 90 \text{ g; mol of water (n}_A\text{)} = \frac{90}{18} = 5 \text{ mol}$$

$$\text{Molality (m) of solution} = \frac{10/180}{90 \times 10^{-3}} = 0.617 \text{ M}$$

Mole fraction of glucose

$$(x_B) = \frac{10/180}{5 + 10/180} = \frac{0.055}{5.05} = 0.01$$

$$\text{Mole fraction of water (x}_A\text{)} = 1 - 0.01 = 0.99$$

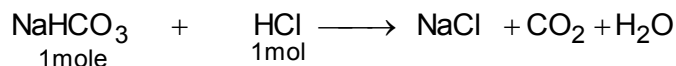
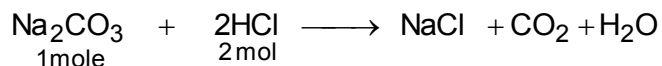
2.3 How many mL of a 0.1 M HCl are required to react completely with 1 g mixture of Na_2CO_3 and NaHCO_3 containing equimolar amounts of two?

Sol. Let Na_2CO_3 be x g

$$\therefore \text{Mol of } \text{Na}_2\text{CO}_3 \text{ (n}_1\text{)} = \frac{x}{106} \text{ mol}$$

$$\text{NaHCO}_3 = (1 - x) \text{ g}$$

$$\therefore \text{Mol of } \text{NaHCO}_3 \text{ (n}_2\text{)} = \frac{(1 - x)}{84} \text{ mol}$$



$$\text{HCl required for } \frac{x}{106} \text{ mol of Na}_2\text{CO}_3 = \frac{2x}{106} \text{ mol}$$

$$\text{HCl required for } \frac{(1-x)}{84} \text{ mol of NaHCO}_3 = \frac{(1-x)}{84} \text{ mol}$$

Since given mixture contains equimolar amount

$$\therefore \frac{x}{106} = \frac{(1-x)}{84} \quad \text{or} \quad x = 0.56$$

$$\begin{aligned} \text{Total HCl required} &= \left[\frac{2x}{106} + \frac{1-x}{84} \right] = \frac{2 \times 0.56}{106} + \frac{1-0.56}{84} \\ &= 0.01578 \text{ mol} \end{aligned}$$

If V is the volume of HCl required, then

$$V_{(L)} \times 0.1 = 0.01578$$

$$\text{or} \quad V_L = 0.1578 \text{ L} \quad \text{or} \quad 157.8 \text{ mL}$$

2.4 Heptane and octane form ideal solution. At 373 K, the vapour pressure of the two liquid components are 105.2 kPa and 46.8 kPa, respectively. What will be the vapour pressure, in bar, of a mixture of 25.0 g of heptane and 35.0 g of octane?

Sol. Moles of heptane (n_H) = $\frac{25}{100} = 0.25$

$$\text{Moles of octane } (n_O) = \frac{35}{114} = 0.307$$

$$x_H = \frac{0.25}{0.25 + 0.307} = \frac{0.25}{0.557} = 0.449 ; x_O = 1 - 0.449 = 0.551$$

$$\text{Vapour pressure of heptane } (p_H) = 105.2 \times 0.449 = 47.2348 \text{ kPa} \approx 47.235 \text{ kPa}$$

$$\text{Vapour pressure of octane } (p_O) = 46.8 \times 0.551 = 25.787 \text{ kPa}$$

$$\begin{aligned} \text{Total vapour pressure } P_{\text{total}} &= p_H + p_O \\ &= 47.235 + 25.787 = 73.022 \text{ kPa} \end{aligned}$$

$$\text{Or} \quad \frac{73.022 \times 10^3}{10^5} \text{ bar} = 0.7302 \text{ bar.}$$

2.5 A solution containing 30 g of a nonvolatile solute exactly in 90 g water has a vapour pressure of 2.8 kPa at 298 K. Further 18 g of water is then added to solution, the new vapour pressure becomes 2.9 kPa at 298 K. Calculate,

- (i) Molecular mass of the solute
(ii) Vapour pressure of water at 298 K.

Sol. Moles of solute (n_B) = $\frac{30}{M}$; Moles of H_2O (n_{H_2O}) = $\frac{90}{18} = 5$

$$x_{H_2O} = \frac{5}{5 + 30/M} = \frac{5M}{30 + 5M} = \frac{M}{6 + M}$$

$$P_{sol} = p^\circ \times \frac{M}{6 + M} \text{ or } \frac{M + p^\circ}{6 + M} = 2.8 \quad \dots(i)$$

After adding 18 g (= 1 mol) of water to solution

$$x'_{H_2O} = \frac{6}{6 + 30/M} = \frac{M}{5 + M}$$

Now, $p'_{sol} = p^\circ \times \frac{M}{5 + M} \text{ or } \frac{M + p^\circ}{5 + M} = 2.9 \quad \dots(ii)$

Now, divide (i) by (ii), $\frac{5 + M}{6 + M} = \frac{2.8}{2.9}$

or $M = 23 \text{ g mol}^{-1}$

Substitute the value of M in (ii),

$$p^\circ = \frac{2.9 \times (5 + M)}{M} = \frac{2.9 \times 28}{23} = 3.53 \text{ kPa.}$$

2.6 Two elements A and B, form compounds having molecular formula AB_2 and AB_4 . When dissolved in 20 g of C_6H_6 , 1 g of AB_2 lowers the freezing point by 2.3 K, whereas 1.0 g of AB_4 lowers it by 1.3 K. The molal depression constant for benzenes is $5.1 \text{ K kg mol}^{-1}$. Calculate atomic mass of A and B.

Sol. We know, $M_B = \frac{1000 \times K_f \times w_B}{w_A \times \Delta T_f}$

$$\therefore M_{AB_2} = \frac{1000 \times 5.1 \times 1}{20 \times 2.3} = 110.87 \text{ g mol}^{-1}$$

$$M_{AB_4} = \frac{1000 \times 5.1 \times 1}{20 \times 1.3} = 196.15 \text{ g mol}^{-1}$$

If a and b are respectively atomic masses of A and B then,

$$M_{AB_2} = a + 2b \quad \text{or} \quad a + 2b = 110.87$$

$$M_{AB_4} = a + 4b \quad \text{or} \quad a + 4b = 196.15$$

Solving the simultaneous equations we have

$$a = 25.58 \text{ u}; \quad b = 42.64 \text{ u.}$$

2.7 If density of some lake water is 1.25 g mL^{-1} and it contains 92.0 g of Na^+ ions per kg of water. Calculate the molality and molarity of Na^+ ions in lake.

Sol. $\text{Molality} = \frac{\text{Mol. of Na}^+ \text{ ions}}{\text{Mass of water (kg)}}$

$$= \frac{92(\text{g}) / 23(\text{g mol}^{-1})}{1(\text{kg})} = 4 \text{ m}$$

$\text{Molarity} = \frac{\text{Mol. of Na}^+ \text{ ions}}{\text{Vol. of water (L)}}$

$$= \frac{92(\text{g}) / 23(\text{g mol}^{-1})}{1000(\text{g}) / 1.25 \times 10^3(\text{g L}^{-1})}$$

$$= \frac{92(\text{g}) \times 1.25 \times 10^3(\text{g L}^{-1})}{23(\text{g mol}^{-1}) \times 1000(\text{g})} = 5\text{M}$$

2.8 If solubility product of CuS is 6×10^{-16} , Calculate the maximum molarity of CuS in aqueous solution.

Sol. $K_{sp} = [\text{Cu}^{2+}] [\text{S}^{2-}] = 6 \times 10^{-6}$

Maximum molarity of CuS = Solubility of CuS

If $S \text{ mol L}^{-1}$ is solubility of CuS

$$S^2 = 6 \times 10^{-18} \quad \text{or} \quad S = (6 \times 10^{-18})^{1/2}$$

$$S = 2.45 \times 10^{-9} \text{ M.}$$

2.9 Nalorphene ($\text{C}_{19}\text{H}_{21}\text{NO}_3$), similar to morphine, is used to combat withdrawal symptoms in narcotic users. Dose of nalorphene generally given is 1.5 mg . Calculate the mass of $1.5 \times 10^{-3} \text{ m}$ aqueous solution required for the above dose.

Sol. $m = \frac{W_B \times 1000}{(\text{MM})_B \times W_A} \quad \text{or} \quad W_A = \frac{W_B \times 1000}{(\text{MM})_B \times m}$

$$= \frac{1.5 \times 10^{-3}(\text{g}) \times 1000}{311(\text{g mol}^{-1}) \times 1.5 \times 10^{-3}} = 3.215 \text{ g}$$

Mass of solution

$$= (W_A + W_B) = 3.215 \text{ (g)} + 1.5 \times 10^{-3} \text{ (g)}$$

$$= 3.217 \text{ g}$$

2.10 Calculate the depression in the freezing point of water when 10.0 g of $\text{CH}_3\text{CH}_2\text{CH}(\text{Cl})\text{COOH}$ is added to 250 g of water. $K_a = 1.4 \times 10^{-5}$ K_f for water = $1.86 \text{ K kg mol}^{-1}$. The density of the solution is 0.904 g mL^{-1} .

Sol. Calculation of molarity of the solution

$$\text{Mass of solution} = 250 + 10 = 260 \text{ g}$$

$$\text{Volume of the solution} = \text{Mass/density} = \frac{260 \text{ (g)}}{0.904 \text{ (g mL}^{-1})} = 287.6 \text{ mL}$$

$$\text{Molarity} = \frac{W_B \times 1000}{(\text{MM})_B \times V} = \frac{10 \times 1000}{122.5 \times 287.6}$$

$$= 0.284 \text{ mol L}^{-1}$$

Calculation of Vant Hoff's factor (i)

Let degree of dissociation of acid be α

$$\alpha = \sqrt{K_a/c} = \sqrt{\frac{1.4 \times 10^{-5}}{0.284}} = 0.07$$

$$\alpha = \frac{i-1}{m-1} = \frac{i-1}{2-1} \quad \text{or} \quad i = 1 + \alpha = 1 + 0.07$$

or $i = 1.07$

Calculation of ΔT_f

$$\Delta T_f = i \times K_f \times m = \frac{1.07 \times 1.86 \times 10 \times 1000}{122.5 \times 250} = 0.649 \approx 0.65^\circ$$

2.11 19.5 g of CH_2FCOOH is dissolved in 500 g of water. The depression in the freezing point observed is 1.0°C . Calculate the van't Hoff factor and dissociation constant of the acid. K_f for $\text{H}_2\text{O} = 1.86 \text{ K kg mol}^{-1}$ and density of solution is 1.124 g mL^{-1} .

Sol. Mass of solution = $500 + 19.5 = 519.5 \text{ g}$

$$\text{Volume of solution} = \frac{519.5 \text{ (g)}}{1.124 \text{ (g mL}^{-1})} = 462.18 \text{ mL}$$

$$\text{Molarity of solution} = \frac{19.5 \times 1000}{78 \times 462.18} = 0.541 \text{ mol L}^{-1}$$

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

$$\text{or } i = \frac{1 \times 78 \times 500}{1.86 \times 19.5 \times 1000} = 1.0753$$

$$\alpha_{\text{diss.}} = \frac{i-1}{m-1} = \frac{1.0753-1}{2-1} = 0.0753$$

$$\begin{aligned} \text{Also } \alpha_{\text{diss.}} &= \sqrt{K_a / c} & \text{or } K_a &= \alpha_{\text{diss.}}^2 \times c \\ &= (0.0753)^2 \times 0.541 = 3.07 \times 10^{-3} \end{aligned}$$

2.12 100 g of liquid A (molar mass 140 g mol⁻¹) was dissolved in 1000 g of liquid B (molar mass 180 g mol⁻¹). The vapour pressure of pure liquid B was found to be 500 torr. Calculate the vapour pressure of pure liquid A and its vapour pressure in the solution if the total vapour pressure of the solution is 475 torr.

Sol. Let vapour pressure of pure A be p_A^0

$$p_B^0 = 500 \text{ torr}; \quad n_A = \frac{100}{140} = 0.714; \quad n_B = \frac{1000}{180} =$$

5.55

$$x_A = \frac{0.714}{5.55 + 0.714} = 0.114$$

$$x_B = 1 - 0.114 = 0.886$$

$$p_{\text{total}} = p_A^0 x_A + p_B^0 x_B$$

$$\text{or } 475(\text{torr}) = p_A^0 \times 0.114 + 500 \times 0.886$$

$$\text{or } p_A^0 = 280.70 \text{ torr.}$$

$$P_A = 280.70 \times 0.114 = 32 \text{ torr.}$$

2.13 Benzene and naphthalene (C₁₀H₈) form ideal solution over entire range of composition. The vapour pressure of pure benzene and naphthalene at 300 K are 50.71 mm Hg and 32.06 mm Hg respectively. Calculate mol fraction of benzene in vapour phase if 80 g of benzene is mixed with 100 g of naphthalene

Sol. if y_b is the mol fraction of benzene in vapour form

$$y_b = \frac{\text{partial pressure of benzene}}{\text{total vapour pressure}}$$

$$= \frac{p_b}{p_n + p_b} = \frac{x_b p_b^0}{x_n p_n^0 + x_b p_b^0}$$

$$n_b = \frac{80}{78} = 1.025; \quad n_n = \frac{100}{128} = 0.781$$

$$x_b = \frac{1.025}{1.025 + 0.781} = 0.567; \quad x_n = 1 - 0.567 = 0.433$$

$$y_b = \frac{0.567 \times 50.71}{0.567 \times 50.71 + 0.433 \times 32.06}$$

$$= \frac{28.75}{28.75 + 13.88} = \frac{28.75}{42.63} = 0.6744$$

$$y_n = 1 - y_b = 1 - 0.6744 = 0.325.$$

2.14 The air is a mixture of a number of gases. The major components are oxygen and nitrogen with approximate proportion of 20% is to 79% by volume at 298 K. The water is in equilibrium with air at a pressure of 10 atm. At 298 K, if the Henry's law constant for oxygen and nitrogen are 3.30×10^7 mm and 6.51×10^7 mm respectively, calculate the composition of these gases in water.

Sol. Consider 1 mol of air and its volume at 10 atm be V

$$\text{Volume of O}_2 = \frac{V \times 20}{100} = 0.2 V; \quad \text{Volume of N}_2 = \frac{V \times 79}{100} = 0.79 V$$

$$\text{Partial pressure of O}_2 (p_{\text{O}_2}) = \frac{10 \times 0.2V}{V} = 2 \text{ atm.}$$

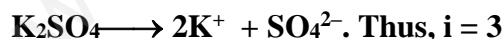
$$\text{Partial pressure of N}_2 (p_{\text{N}_2}) = \frac{10 \times 0.79 V}{V} = 7.9 \text{ atm.}$$

$$\text{Solubility of O}_2 (x_{\text{O}_2}) = p_{\text{O}_2} / K_H = \frac{2 \times 760 \text{ (mm)}}{3.30 \times 10^7 \text{ (mm)}} = 4.606 \times 10^{-6}.$$

$$\text{Solubility of N}_2 (x_{\text{N}_2}) = p_{\text{N}_2} / K_H = \frac{2 \times 760 \text{ (mm)}}{6.51 \times 10^7 \text{ (mm)}} = 9.22 \times 10^{-5}$$

2.15 Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 litre of water at 25°C , assuming that it is completely dissociated.

Sol. Since K_2SO_4 is completely dissociated as



$$\text{Now, } \pi = i CRT = 3 \times 25 \times 10^{-3} \text{ (g)} \times 0.0821$$

$$= \frac{(L - \text{atm K}^{-1} \text{ mol}^{-1}) \times 298.15 \text{ (K)}}{174 \text{ (g mol}^{-1}) \times 2(L)}$$

$$= 5.27 \times 10^{-3} \text{ atm.}$$