

SOLUTION

Solution : Homogeneous mixture of two or more substances.

Concentration of solution:

Let solute = A, solvent = B

Mass percentage (w/w): of A = $\frac{W_A}{W_A + W_R} \times 100$

Volume percentage (V/V) : of A = $\frac{V_A}{V_A + V_B} \times 100$

Molarity (M): No of moles of solute per litre of solution

$$M = \frac{\eta_A}{V_s} = \frac{W_A \times 1000}{M_A \times Vs_{(ml)}}$$

Molality(m) : No. of moles of solute present in 1 kg of solution.

$$m = \frac{\eta_A}{W_{B(kg)}} = \frac{W_A \times 1000}{M_A \times W_{B(g)}}$$

Mole fraction: The ratio of moles of solute or solvent to the total no of moles of the solution .

$$X_{A} = \frac{\eta_{A}}{\eta_{A} + \eta_{B}} \qquad , \qquad X_{B} = \frac{\eta_{B}}{\eta_{A} + \eta_{B}} \qquad X_{A} + X_{B} = 1$$

Parts per million (ppm): The number of parts by weight of solute in 1 million parts by weight of the solution.

$$ppm_{A} = \frac{W_{A}}{W_{S}} \times 10^{6}$$
Solubility of gases in liquids -depends on
(a) Nature of gas
(b) Nature of liquid
(c) Temperature of solution \rightarrow solubility \propto

ublity Temperature

(d) Pressure \rightarrow solubility \propto Pressure Henry's law - The solubility of a gas in a liquid at a given temperature is directly proportional to the partial pressure of the gas over the solution.

$$m \propto p \Rightarrow m = K_{\mu}P$$

...

According to Dalton - Expressing solubility in terms of mole fraction.

for gas A $P_A \propto X_A \implies P_A = K_H X_A$ $(P_{A} = partial Pressure)$ Solubility of solids in liquids - depends on . (a) Nature of solute and solvent (b) temperature - Solubility \propto temperature (For endothermic) Solubility $\propto \frac{1}{\text{Temperature}}$ (For exothermic)

Vapour pressure - The pressure exerted by the vapours of a liquid in equilibrium with the liquid at a particular temperature.

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Vapour pressure $\,^{\infty}\,$ Temperature $\,^{\infty}\,$ Inter molecular forces amongliquid moleculers

But if we add non volatile solute in the solution, the vapour pressure decreases.

Raoult law : The vapour pressure of a solution containing a volatile solute is directly proportional to mole fraction of the solvent. $P_A \propto x_A$.

OR

"The relative lowering of vapour pressure of solution having non volatile solute is equal to the mole fraction of solute"

$$\frac{\mathsf{P}^{\mathsf{o}}_{\mathsf{A}} - \mathsf{P}_{\mathsf{A}}}{\mathsf{P}^{\mathsf{o}}_{\mathsf{A}}} = \mathsf{X}_{\mathsf{B}}$$

Ideal solution: Those solutions which obey Raults low over entire range of concentration. In ideal solution intermolecular interaction between the two component (A $\leftarrow \rightarrow$ B) are of same magnitude as the intermolecular interaction between pure components $A \leftarrow A$ and $B \leftarrow B$. Charsctersties of ideal solutions (1) obey Raoult law

(2)
$$A = 0$$
 (2) $AV = 0$

(2) $\Delta_{\text{mix}} H = 0$ $(3) \Delta V_{mix} = 0$ Non ideal solution: The solution which do not obey Raoults low over entire range of concentrations are called non ideal solution. In these solutions intermolecular interaction between the 2 components (A $\leftarrow \rightarrow$ B) are of different magnitude as the intermolecular interactions between pure components A $\leftarrow \rightarrow$ A and $B \longleftrightarrow B$.

Characterstics of non ideal solution:

- Does not obey Raoults law 1.
- 2. $\Delta H_{mix} \neq 0$
- 3.



Colligative properties

Those properties of a solution which depend on the number of solute particles only but not on the nature of the solute are called colligative properties. These are

(a) **Relative lowering of vapour pressure** of a solution is equal to the mole fraction of the solute .

$$\frac{P_A^o - P_A}{P_A^o} = X_{_B} = \frac{W_A / M_A}{W_B / M_B}$$



(b) Elevation in boiling point $\Delta T_b \propto m \rightarrow \Delta T_b \propto K_b m$

(c) Depression in feezing point
$$\Delta T_f \propto m \rightarrow \Delta T_b \propto K_f m$$

(d) **Osmotic pressure:** The pressure which must be applied to the solution side to just prevent the passage of pure solvent into it through a semipermeable membrane π = CRT.

$$\pi = \frac{\eta_A}{V}RT = \frac{W_ART}{M_AV}$$

Azeotropes:-

Those solutions which have same composition in liquid and vapour phase

Two, Types

Minimum boiling Azeotropes :

Non -ideal solution showing laye positive deviation from Raoults law form min boiling azeotropes which boil at temperature lower than boiling point of its components eg. water and benzene, chloroform and methanol.

Maximum boiling Azeotropes :

Non -ideal solutions showing negative deviation from Raoults law They boil at temperature higher than the boiling point of its components eq. mixture of HCl and H_2O containing 20.2% of HCl by weight boils a t

108.5°C higher than either pure HCl (85°C) or water (100°C). eq. 68% HNO₃ and 32% water by mass (b.p. 393.5 k)

Reverse Osmoses : If a pressure more than osmotic pressure is applied on the solution side, the solvent will flow from the solution side to solvent side a through semipermeable membranes. This phenomenon is called Reverse osmosis

Example - Disalination of sea water.

Abnormal molecular mass: Sometimes the observed molecular mass of a substance determined with the help of colligative properties is quite different as compared to the normal molecular mass. This is called abnormal molecular mass.

It is mainly due to the dissociation or association of the solute in the solution.

Van't Hoff factor(i) : It is the ratio of normal molecular mass to the abnormal molecular mass.

Or

The ratio of observed colligative property to the normal or calculated colligative property

- $i = \frac{\text{Normal molecular mass}}{\text{Abnormal molecular mass}}, \qquad i = \frac{\text{Observed colligative property}}{\text{Normal Coligative property}}$
- i = 1 (neither association or dissociation)
- i > (for dissociation)
- i < (for association)

Degree of Association
$$\alpha = \frac{m(i-1)}{1-m}$$
 [m = no. of moles associated]

Degree of Dissociation $\alpha = \frac{(i-1)}{m-1}$ [m = no. of moles dissociated]

Modified Colligative properties: The inclusion of van't Hoff factor modifies the equation for the coagulative properties as follows :

$$\frac{\mathsf{P}^{o}_{\mathsf{A}}-\mathsf{P}_{\mathsf{A}}}{\mathsf{P}^{o}_{\mathsf{A}}} = \mathsf{i}. \ X_{_{\mathsf{B}}}. \qquad \Delta \mathsf{T}_{_{\mathsf{f}}}=\mathsf{i}\mathsf{K}_{_{\mathsf{f}}}\mathsf{m} \qquad \Delta \mathsf{T}_{_{\mathsf{b}}}=\mathsf{i}\mathsf{K}_{_{\mathsf{b}}}\mathsf{m} \qquad \pi=\mathsf{i}\mathsf{C}\mathsf{R}\mathsf{T}.$$



SOLVED PROBLEMS

- Q.1 Calculate the mole fraction of benzene in solution containing 30% by mass in carbon tetrachloride.
- **Sol.** 30% by mass of benzene in CCl_4 means 30 g benzene dissolved in 70 g of CCl_4 Molecular mass of $C_6H_6 = 78$ Molecular mass of $CCl_4 = 154$

Number of moles of benzene = $\frac{30}{78}$ = 0.38 mol

Number of moles of $CCl_4 = \frac{70}{154} = 0.45$ mol

 $x_{\text{Benzene}} = \frac{0.38}{0.38 + 0.45} = \frac{0.38}{0.83} = 0.485$

- Q.2 Calculate the molarity of each of the following solutions: (a) 30 g of $Co(NO_3)_2$. $6H_2O$ in 4.3 L of solution . (b) 30 mL of 0.5 M H_2SO_4 diluted to 500 mL
- **Sol.** (a) Molarity of $Co(NO_3)_2.6H_2O$
 - $M = \frac{\text{Mass of Co}(\text{NO}_3)_2.6\text{H}_2\text{O} \times 1000}{\text{Molecular mass} \times \text{Volume in mL}}$

$$M = \frac{30}{310.7} \times \frac{1000}{4300} = 0.023 N$$

(b) We know that $M_1V_1 = M_2V_2$ $30 \times 0.5 = M_2 \times 500$

 $M_2 = \frac{30 \times 0.5}{500} = 0.03 \text{ M}$

- Q.3 Calculate the mass of urea (NH_2CONH_2) required in making 2.5 kg of 0.25 molal aqueous solution.
- **Sol.** Urea has molar mass = 60 g mol^{-1}
 - $w_2 = Mas sof solute$
 - $w_1 = Mass of the solvent$
 - $M_2 = Molecular$ mass of solute

$$m = \frac{w_2}{M_2} \times \frac{1000}{w_1}$$

$$0.25 = \frac{w_2}{60} \times \frac{1000}{2500}$$

$$w_2 = \frac{0.25 \times 60 \times 2500}{1000} = 37.50 \text{ g}$$

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Q.4 Calculate (a) molality (b) molarity and (c) mole fraction of KI if the density of 20% $\left\lfloor \frac{Mass}{Mass} \right\rfloor$ aqueous solution KI is 1.202 gL⁻¹.

Sol. $20\% \left[\frac{\text{Mass}}{\text{Mass}}\right]$ KI means 20 g of KI is dissolved in 80 g of water. Molar mass of KI = 166 g

(a) Molality of KI = $\frac{w_2}{M_2} \times \frac{1000}{w_1} = \frac{20}{166} \times \frac{1000}{80} = 1.5 \text{ m}$ (b) Molarity of KI = $\frac{w_2}{M_1} \times \frac{1000 \times \text{Density}}{\text{Solution in gram}} = \frac{20}{166} \times \frac{1000 \times 1.202}{100} = 1.448 \text{ m}$ (c) No. of moles of KI = $\frac{80}{18} = 04.4 \text{ mol}$ $x_{\text{KI}} = \frac{n_{\text{KI}}}{n_{\text{KI}} + n_{\text{H}_2\text{O}}} = \frac{0.12}{4.4 + 0.12}$ $x_{\text{KI}} = \frac{0.12}{4.52} = 0.0265$

Q.5 H₂S, a toxic gas with rotten egg like smell, is used for the qualitative analysis. If the solubility of H₂S in water at STP is 0.195 m, calculate Henry's law constant.

0.195 mole of H₂S dissolved in 1000 g of solvent water.

$$x_{H_2S} = \frac{0.195}{55.55 + 0.195} = \frac{0.195}{55.745}$$

 $p = K_H x$

Pressure at STP = 0.987 bar

∴ 0.987 =
$$K_{\rm H} \times \frac{0.195}{55.745} = K_{\rm H} \times 0.0035$$

 $K_{\rm H} = 282 \text{ bar}$

Q.6 Henry's law constant for CO_2 in water is 1.67×10^8 Pa at 298 K. Calculate the quantity of CO_2 in 500 mL of soda water when packed under 2.5 atm CO_2 pressure at 298 K.

$$K_{\rm H} = 1.67 \times 10^{\circ} \, \rm Pa$$

$$_{CO_2} = 2.5 \text{ atm} = 2.5 \times 101325 \text{ Pa}$$

Applying Henry's law, $P_{CO_2} = 'K_H \times x_{CO_2}$

$$\therefore \quad x_{CO_2} = \frac{P_{CO_2}}{K_H} = \frac{2.5 \times 101325 \text{Pa}}{1.67 \times 10^8 \text{ Pa}} = 1.517 \times 10^{-3} \qquad \text{i.e.,} \quad \frac{n_{CO_2}}{n_{H_2O} + n_{CO_2}} \approx \frac{n_{CO_2}}{n_{H_2O}} = 1.517 \times 10^{-3}$$

For 500 mL of soda water, water present

500 mL = 500 g =
$$\frac{500}{18}$$
 = 2778 moles i.e., nH₂O = 27.78 moles

$$\therefore \quad \frac{n_{CO_2}}{27.78} = 1.517 \times 10^{-3} \qquad n_{CO_2} = 42.14 \times 10^{-3} \text{ mole}$$

= 42.14 m mol = 42.14 × 10⁻³ × 44 g = 1.854 g



- Q.7 The vapour pressure of pure liquid A and B are 450 and 700 mm Hg at 350 K respectively. Find out the composition of the liquid mixture if total vapour pressure is 600 mm Hg. Also find the composition of vapour phase.
- **Sol.** For A and B liquids

$$P = p^{0}{}_{A}x_{A} \times p^{0}{}_{B}x_{B}$$

So, 600 = 450 (x_A) + 700 (1 - x_A)
($\therefore x_{A} + x_{B} = 1$) 250 x_a = 100

$$x_A = \frac{2}{5}$$
 \therefore $x_B = \frac{3}{5}$

- $P_{A} = p_{A}^{o} x_{A} = 450 \times \frac{2}{5} = 180 \text{ mm Hg}$
- $P_{_{B}} = p_{_{B}}^{0} x_{_{B}} = 700 \times \frac{3}{5} = 420 \text{ mm Hg}$
- \therefore Mole fraction of A component in the vapour phase = $\frac{180}{600}$ = 0.3
- \therefore Mole fraction of B component in the vapour phase = $\frac{420}{600}$ = 0.7
- Q.8 Boiling point of water at 750 mm Hg is 99.63° C. How much sucrose is to be added to 500 g of water such that it boils 100° C?

Sol.
$$T_b^o = 99.63^{\circ}C$$
, $T_b = 100^{\circ}C$, $M_2 = 342 \text{ g mol}^{-1}$, $K_b = 0.52 \text{ K kg mol}^{-1}$
 $\Delta T_b = T_b - T_b^o = 100 - 99.63 = 0.37^{\circ}C$

$$M_{2} = \frac{K_{b} \times 1000 \times W_{2}}{\Delta T_{b} \times W_{1}}$$

$$342 = \frac{0.52 \times 1000 \times W_{2}}{0.37 \times 500}$$

$$W_{2} = \frac{342 \times 0.37 \times 500}{0.52 \times 1000}$$

$$W_{2} = 121.7 \text{ g}$$

Q.9 A solution is obtained by mixing 300 g of a 25 % and 400 g of a 40% solution by mass. Calculate the mass percentage of the resulting solution.

Sol. 25% solution means 25 g solute in 100 g solution. 40% solution means 40 g solute in 100 g solution

$$\therefore \text{ Mass of solute in 300 g solution} = \frac{25 \times 300}{100} = 75 \text{ g}$$

 $\therefore \text{ Mass of solute in 400 g solution} = \frac{40 \times 400}{100} = 160 \text{ g}$

Total mass of solute = 75 + 160 = 235 g Total mass of the solution = 300 g + 400 g = 700 g

So, mass percentage of solute in mixture = $\frac{235}{700} \times 100 = 33.57\%$ mass percentage of solvent in mixture = 100 - 33.57 = 66.43%



- Q.10 An antifreeze solution is prepared from 222.6 g of ethylene glycol (C₂H₆O₂) 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.** Molecular mass of $C_2H_6O_2 = 2 \times 12 + 6 \times 1 + 2 \times 16 = 62$ According to question, $W_B = 222.6$ g, $M_B = 62$, $W_A = 200$ g

Molality (m) =
$$\frac{W_B \times 1000}{M_B \times W_A}$$

Molality of ethylene glycol = $\frac{222.6 \times 1000}{62 \times 200}$ = 17.95 m

Mass of solution = Mass of glycol + Mass of water 222.6 + 200 = 422.6 g

Volume of solution (V) = $\frac{\text{Massof solution}}{\text{Density}} = \frac{422.6}{1.072}$ mL = 394.2 mL

 $Molarity (M) = \frac{W_B \times 1000}{M_B \times V(mL)}$

Molarity of ethylene glycol = $\frac{222.6 \times 1000}{62 \times 394.21} = 9.11 \text{ M}$

- Q.11 the partial pressure of ethane over a solution 6.56 × 10⁻³ 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

 $\begin{array}{ccc} m \propto P, & m = K_{H}P \\ \text{thus,} & 6.56 \times 10^{-3} = K_{H} \times 1 \ (P = 1 \ \text{bar}) & \dots \dots \dots (i) \\ \text{and} & 5.00 \times 10^{-2} = K_{H} \times 1 \\ \text{Compare equation (i) and (ii), we have} \end{array}$

$$\frac{6.56 \times 10^{-3}}{5.0 \times 10^{-2}} = \frac{K_H \times 1}{K_H P} \Rightarrow P = \frac{1 \times 5.0 \times 10^{-2}}{6.56 \times 10^{-3}} = 7.62 \text{ bar}$$

- Q.12 An aqueous solution of a 2 percent non-volatile solution exerts a pressure of 1.004 bar at the normal boiling point of the solvent. What is the molar mass of the solute?
- **Sol.** Given $p_s = 1.004$ bar, $p^0 = 1.013$ bar 9at boiling point p = 1.013 bar)

 $W_B = 2g$, $W_A = 100 - 2 = 98 g$, $M_A = 18 (H_2O)$ According to Raoult's law :

$$\frac{p_A^0 - p}{p_A^0} = \frac{W_B \times W_A}{M_B \times W_A} \qquad M_B = \frac{W_B \times W_A}{W_A} \times \frac{p_A^0}{p_A^0 - p}$$
$$M_B = \frac{2 \times 18 \times 1.013}{98(1.013 - 1.004)} \qquad M_B = \frac{2 \times 18 \times 1.013}{98 \times 0.009}$$
$$= 41.35 \text{ g mol}^{-1}$$

Q.13 A 55 solution (by mass) of cane sugar in water has freezing point of 271 K. Calculate the freezing point of a 5% glucose in water if freezing point of pure water is 273.15 K.



Sol. 5% glucose 5 g glucose in 100 g of solution $W_B = 5 \text{ g}, W_A = 100 - 5 = 95 \text{ g}, \Delta T_f = 273.15 - 271 = 2.15 \text{ K}, M_B = 342 \text{ (for sugar)}$ $\Delta T_{f} = \frac{1000 \times K_{f} \times W_{B}}{M_{R} \times W_{A}}$ For sugar, 2.15 = $\frac{1000 \times K_f \times W_B}{342 \times 95}$ $\Rightarrow 2.15 = K_f \times 0.154$ (i) For Glucose , $\Delta T_f = \frac{1000 \times K_f \times 5}{180 \times 95} \Rightarrow \Delta T_f = K_f \times 0.292$ (ii) Compare the equation (i) and (ii), we have $\frac{2.15}{\Delta T_{f}} = \frac{K_{f} \times 0.154}{K_{f} \times 0.292}$ $\Delta T_{f} = \frac{2.15 \times 0.292}{0.154} = 4.08 \text{ K}$ Q.14 At 300 K, 36 g of glucose present in a litre of 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? W = 36 g, V = 1 litre Osmotic pressure = 4.98 bar, (Case I) Sol. given, (Case II) Osmotic pressure = 1.52 bar, $\pi B = \frac{W_B}{W_B} RT$ For case I : $4.98 \times 1 = \frac{36}{180} \times R \times T$ or 4.98 = 0.2 RT(i)(ii) [C = $\frac{W_B}{M_B \times V}$] For case II : $1.52 = C \times R \times T \Rightarrow 1.52 = CRT$ Comparing the equations (i) and (ii), we have $C = \frac{0.2 \times 1.52}{4.98} = 0.061 \text{ M}$ $\frac{4.98}{0.2 \text{ RT}}$ 1.52 ĊRT Q.15 Calculate the mass percentage of aspirin $(C_9H_8O_4)$ is acetonitrile (CH_3CN) when 6.5 g of $C_9H_8O_4$ is dissolved in 450 g of CH_3CN . Mass % of solute = $\frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$ \therefore Mass % of solute aspirin = $\frac{6.5}{450 + 6.5} \times 100 = 1.424$ % Sol. Q.16 Nalorphene (C₁₉H₂₁NO₃) 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 1.5×10^{-3} m aqueous solution required for the above dose.



Sol. As we know $m = \frac{W_B}{M_B} \times \frac{1000}{W_A}$

For nalorphene $M_B = 311 \text{ g mol}^{-1}$, $m = 1.5 \times 10^{-3} \text{ m}$, $W_B = 1.5 \text{ mg} = 1.5 \times 10^{-3} \text{ g}$

$$1.5 \times 10^{-3} = \frac{1.5 \times 10^{-3}}{311} \times \frac{1000}{W_A}$$
 $W_A = 3.215 \text{ g}$

Mass of solution = $3.215 \text{ g} + 1.5 \times 10^{-3} \text{ g} = 3.2165 \text{ g}$

Q.17 Calculate the amount of benzoic acid (C₆H₅COOH) required for preparing 250 mL of 0.15 M solution in methanol.

Sol. Molarity (M) = $\frac{W_B}{M_B} \cdot \frac{1000}{V(\text{in mL})} = 0.15 \text{ M} = \frac{W_B}{122} \cdot \frac{1000}{250} = 4.575 \text{ g}$

Q.18 Calcualte the depression in the freezing point of water when 10 g of CH₃CH₂CHClCOOH is added to 250 g of water.

- $\Delta T_{f} = i, K_{f} m = (1.065) \times (1.86) \times 0.33 = 0.65^{\circ}$
- Q.19 19.5 g CH₂FCOOH is dissolved in 500 g of water. The depression in the freezing point of water observed is 1.0°C. Calculate the van't Hoff factor and dissociation constant of fluoroacetic acid.

Sol. Molality =
$$\frac{W_2}{M_2} \times \frac{1000}{W_1} = \frac{19.5}{78} \times \frac{1000}{500} = \frac{1}{2}$$

 $\Delta T_f = K_f \times m$
 $\Delta T_f = 1.86 \times \frac{1}{2} = 0.93$ $i = \frac{(\Delta T)obs}{(\Delta T)exp} = \frac{1}{0.93} = 1.0753$
 $\alpha = \frac{i-1}{m-1} = \frac{1.0753-1}{2-1}$ $\alpha = 0.0753$
 $K_a = \frac{C\alpha^2}{1-\alpha} = \frac{(0.5)^2 \times (0.075)^2}{(1-0.075)} = 3.04 \times 10^{-3}$



Q.20 Vapour pressure of water at 293 K is 17.535 mm Hg. Calculate the vapour pressure of water at 298 K when 25 of glucose is dissolved in 450 g of water.

Sol. As we know for dilute solution

 $\frac{p_1^0 - p_A}{p_1^0} = x_2 = \frac{n_2}{n_1} = \frac{W_B}{M_B} \times \frac{M_A}{W_A} \qquad \frac{17.535 - p_A}{17.535} = \frac{25 \times 18}{180 \times 450}$ $\frac{17.535 - p_A}{17.535} = \frac{1}{180} \qquad 17.535 \times 180 - 180 \ p_A = 17.535$ $p_A = 17.44 \ \text{mm of Hg.}$

- Q.21 Henry's law constant for the molarity of methane in benzene at 298 K is 4.27 × 10⁵ mm Hg. Calculate the solubility of methane in benzene at 298 K under 760 mm Hg.
- **Sol.** According to Henry's law

$$p = K_H \times x$$

$$x = \frac{760 \text{ mm of Hg}}{4.27 \times 10^5 \text{ mm of Hg}} \qquad x = \frac{760 \times 10^{-5}}{4.27} = 178 \times 10^{-5}$$

Q.22 100 g of liquid A (molar mas s140 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.
$$n_A = \frac{100}{140} = 0.714$$
 $n_B = \frac{1000}{180} = 5.55$

$$x_{A} = \frac{0.714}{5.555 + 0.714} = \frac{0.714}{6.269} = 0.114$$
 $x_{B} = 1 - 0.114 = 0.886$

$$p_{\text{total}} = p^{0}{}_{A}x_{A} + p^{0}{}_{B}x_{B}$$

475 = $p_{A}^{o} \times 0.114 + 0.886 \times 500$ $p_{A}^{o} = \frac{475 - 0.886 \times 500}{0.114} = 280.7$ torr

We also know that

 $p_A = p_A^o x_A = 280.7 \times 0.114 = 32$ torr.

Q.23 Benzene and toluene form ideal solution over the 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 the mole fraction of benzene in vapour phase of 80 g benzene is mixed with 100 g of naphthalene.

Sol. No. of moles of benzene =
$$\frac{80}{78}$$
 = 1.026 mol

No. of moles of toluene =
$$\frac{100}{92}$$
 = 1.087 mol



$$x_{\rm B} = \frac{1.026}{1.026 + 1.087} = 0.486$$

 $\begin{array}{ll} x_B + x_T = 1 & \Rightarrow x_T = 1 - 0.486 = 0.514 \\ \mbox{Total pressure P} = \ p^o{}_B \times x_B + p^o{}_T \times x_T = 50.71 \times 0.486 + 32.06 \times 0.514 = 41.13 \end{array}$

Mole fraction benzene in vapour phase = $\frac{50.71 \times 0.486}{41.13}$ = 0.60 mol

- Q.24 The air is a mixture of no. 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 3.3 $\times 10^7$ mm and 6.51 $\times 10^7$ mm respectively then calculate the composition of these gases in water.
- **Sol.** Consider 1 mole of air and let its volume at 100 atm be V

Volume
$$O_2 = \frac{V \times 20}{100} = 0.2 V$$
; Volume of $N_2 \frac{V \times 79}{100} = 0.79 V$

Partial pressure of $O_2(Po_2) = \frac{10 \times 0.2V}{V} = 2$ atm

Partial pressure of N(p_{N_2}) = $\frac{10 \times 0.79V}{V}$ = 7.9 atm

Solutility of
$$O_2(x_{O_2}) = \frac{p_{O_2}}{k_H} = \frac{2 \times 750(\text{mm})}{3.30 \times 10^7(\text{mm})} = 4.606 \times 10^{-5}$$

Solutbility of N₂(x_{N₂}) = $\frac{P_{N_2}}{K_H} = \frac{7.9 \times 750(mm)}{6.51 \times 10^7(mm)} = 9.22 \times 10^{-5}$

- Q.25 Determine the amount of CaCl₂(i = 2.47) dissolved in 2.5 litre of water such that its osmotic pressure is 0.75 atm at 27°C.
- **Sol.** We know that $\pi = iCRT = i \frac{W_B}{M_B} \times \frac{RT}{V}$

$$W_{B} = \frac{\pi \times V \times M_{B}}{i \times RT}$$

Put the values according to question,

$$W_{B} = \frac{0.75 \times 2.5 \times 111}{2.47 \times 0.0821 \times 300} = 3.42 \text{ g}$$

 \therefore No. of moles of CaCl₂ = $\frac{3.42}{111}$ = 0.03 mol



EXERCISE – I

UNSOLVED PROBLEMS

- Q.1 Suppose a solid solution is formed between two substances, one whose particles are very large and the other whose particles are very small. What kind of solid solution is this likely to be?
- Q.2 Define the following terms: (i) Mole fraction (ii) Molarlity

(iii) Molarity

(iv) Mass percentage.

- Concentrated nitric acid used in laboratory work is 68% nitric acid by mass in aqueous solution. What Q.3 should be the molarity of such a sample of the acid if the density of the solution is $1.504 \text{ mL}^{-1?}$
- A solution of glucose in water is labelled as 10% w/w, what would be the molality and mole fraction of Q.4 each component in the solution? If the density of solution is 1.2 g mL^{-1} , then what shall be the molarity of the solution?
- How many mL of 0.1 M HCl are required to react completely with 1 g mixture of Na₂CO₃ and NaHCO₃ Q.5 containing equimolar amounts of both?
- Q.6 An antifreeze solution is prepared from 222.6 g of ethylene glycol $(C_2H_6O_2)$ 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?
- Q.7 What role does the molecular interaction play in a solution of alcohol and water?
- Why do gases always tend to be less soluble in liquids as the temperature is raised? Q.8
- Q.9 State Henry's law and mention some important applications?
- **Q.10** What is meant by positive and negative deviations from Raoult's law and how is the sign of Δ_{miv} H related to positive and negative deviations from Raoult's law?
- Q.11 The vapour pressure of water is 12.3 kPa at 300 K. Calculate vapour pressure of 1 molal solution of a non-volatile solute in it.
- **0.12** Based on solute-solvent interactions, arrange the following in order of ncreasing solubility in n-octane and explain. Cyclohexane. KCl, CH₂OH, CH₂CN.
- Q.13 If the density of some lake water is 1.25 g mL⁻¹ and contains 92 g of Na⁺ ions per kg of water, calculate the molality of Na⁺ ions in the lake.
- Q.14 Calculate the amount of benzoic acid (C_kH_cCOOH) required for preparing 250 mL of 0.15 M solution in methanol.
- Q.15 Calculate the depression in the freezing point of water when 10 g of CH₂CH₂CHClCOOH is added to 250 g of water. $K_a = 1.4 \times 10^{-3}$, $K_f = 1.86$ K kg mol⁻¹.
- Q.16 19.5 g of CH₂FCOOH is dissolved in 500 g of water. The depression in the freezing point of water observed is 1.0°C. Calculate the van't Hoff factor and dissociation constant of fluoroacetic acid.
- **Q.17** Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K₂SO₄ in 2 litre of water at 25°C. Assuming that it is completely dissociated.



EXERCISE – II BOARD PROBLEMS

- **Q.1** Mention a large scale use of the phenomenon called reverse osmosis.
- **Q.2** Two elements A and B form compounds having molecular formula AB₂ and AB₄. When dissolved in 20 g of benzene, 1 g of AB₂ lowers the freezing point by 2.3 K, whereas 1 g of AB₄ lowers it by 1.3 K. The molar depression constant for benzene is 5.1 K kg/mol. Calculate the atomic masses of A and B.
- **Q.3** State Henry's law about the solubility of a gas in a liquid.
- **Q.4** What is the sum of the mole fractions of all the components in a three component system?
- **Q.5** Define mole fraction of a component in a solution.
- **Q.6** State the formula relating pressure of a gas with its mole fraction in a liquid solution in contact with it.
- Q.7 A solution is made by dissolving 30 g of non-volatile solute in 90 g of water. It has a vapour pressure of 2.8 KPa at 298 K. At 298 K, vapour pressure of pure water is 3.64 K Pa. Calculate the molar mass of the solute.
- **Q.8** What would be the value of van't Hoff factor for a dilute solution of K_2SO_4 in water?
- **Q.9** State Henry's law for solubility of a gas in a liquid. Explain the significance of Henry's law constant. At the same temperature, hydrogen is more soluble in water than helium. Which of them will have a higher value of K_{μ} and why?
- **Q.10** Two liquids A and B boil at 145° C and 190°C respectively. Which of them has a higher vapour pressure at 80°C?
- Q.11 (a) Why is the vapour pressure of a soltuion of glucose in water lower than that of water?
 (b) A 6-90 M solution of KOH in water contains 30% by mass of kOH. Calculate the density of the KOH solutin. [Molar mass of KOH = 56 mol⁻¹]
- Q.12 (a) Urea forms an ideal solution in water. Determine the vapour pressure of an aqueous solution containing 10% by mass of urea at 40°C, (P°_s = 55.3 mm of Hg)
 (b) Why is freezing point depression of 0.1 M sodium chloride solution nearly twice that of 0.1 M glucose solution?
- **Q.13** Define osmosis.
- **Q.14** An antifreeze solution is prepared from 222.6 g of ethylene glycol and 200 g of water. calculate the molality of the solution, if the density of this solution be 1.072 g mol⁻¹. What will be the molarity of the solution?
- **Q.15**. A 0.1539 molal aqueous solution of cane sugar (342) has a freezing point 271 K while the freezing point of pure water is 273.15 K. What will be the freezing point of an aqueous solution containing 5g of glucose (180) per 100 g of solution ?
- **Q.16** State Henry's Law correlating the pressure of a gas and its solubility in a solvent and mention two applications for the law.
- **Q.17** Calculate the temperature at which a solution containing 54 g of glucose $(C_6H_{12}O_6)$ in 250 g of water will freeze. $(K_f \text{ for water } = 1.86 \text{ k mol}^{-1} \text{ kg})$

- **Q.18** State Raoult's law for solutions of volatile liquids. Taking suitable examples explain teh meaning of positive and negative deviations from Raoult's law.
- **Q.19** Define the term osmotic pressure. Describe how the molecular mass of a substance can be determined by method based on the measurement of osmotic pressure.
- **Q.20** What mass of NaCl (molar mass = 58.5 g mol^{-1}) must be dissolved in 65 g of water to lower the freezing point by 7.5"C? The freezing point depression constant, K_f for water is 1.86 K kg mol⁻¹. Assume van't Hoff factor for NaCl is 1.87.
- **Q.21** define the terms, 'osmosis' and 'osmotic pressure'. What is the advantage of using osmotic pressure as compared to other colligative properties for the determination of molar masses of solutes in solution?
- **Q.22 (a)** Define the following terms:
 - (i) Mole fraction
 - (ii) Van't Hoff factor
 - (b) 100 mg of a protein is dissolved in enough water to amke 10.0 mL of a solution. If this solution
 - has an osmotic pressure of 13.3 mm Hg at 25°C, what is the molar mass of protein? (R = 0.0821 L atm mol⁻¹ K⁻¹ and 760 mm Hg = 1 atm.)
- **Q.23 (a)** What is meant by :
 - (i) Colligative propertion
 - (ii) Molality of a solution

(b) What concentration of nitrogen should be present in a glass of water at room temperature? Assume a temperature of 25° C, a total pressure of 1 atmosphere and mole fraction of nitrogen in air of 0.78 [K_H for nitrogen = 8.42×10^{-7} M/mm Hg]

- Q.24 What is meant by 'reverse osmosis'?
- **Q.25** Differentiate between molarity and molality values for a solution. What is the effect of change in temperature on molarity and molality values?
- **Q.26** A solution prepared by dissolving 8.95 mg of a gene fragement in 35.0 mL of water has an osmotic pressure of 0.335 torr at 25°C. Assuming that the gene fragment is a non-electrolyte, calculate its molar mass.
- **Q.27** What mass of NaCl (molar mass = 58.5 g mol⁻¹) must be dissolved in 65 g of water to lower the freezing point by 7.5° C? The freezing point depression constant, K_f, for water is 1.86 K kg mol⁻¹. Assume van't Hoff factor for NaCl is 1.87.
- **Q.28** (a) State Rault's law for a solution containing volatile components.
 - How does Rault's law become a special case of Henry's law ?

(b) 1.00 g of a non-electrolyte solute dissolved in 50 g of benzene lowered the freezing point of benzene by 0.40 K. Find the molar mass of the solute. (K_r for benzene = 5.12 K kg mol⁻¹)

OR

- (a) Define the following terms :
- (i) Ideal solution
- (ii) Azeotrope
- (iii) Osmotic pressure

(b) A solution of glucose $(C_6H_{12}O_6)$ in water is labelled as 10% by weight. What would be the molality of the solution ?

(Molar mass of glucose = 180 g mol⁻¹)