

## Chapter - 2 Solutions

Solution:- Solutions are homogeneous mixtures of two or more than two components.

Homogeneous:- Homo - means same - , composition is uniform.

Solvent:- Component that is present in the largest quantity. decide physical state.

Solute:- less that is present in the smaller quantity.

Binary Solutions:- Binary means two, if two components present in a solution called Binary Solution.

Types of Solutions:-

- (i) Solid Solutions
- (ii) liquid "
- (iii) Gaseous "

Gaseous solutions:- gaseous component:-

- (i) Solid in Gas:- Camphor in nitrogen gas
- (ii) Liquid " " :- chloroform mixed with nitrogen gas
- (iii) Gas " " :- ~~air~~ ex - air

Liquid Solutions:- liquid components.

- (i) Solid in liquid:- Sugar dissolve in water.
- (ii) liquid " " :- ethanol " " " "
- (iii) Gas " " :- oxygen " " " "



Solid Solution :- Solid solvent or components.

(i) Solid in Solid :- Copper dissolved in gold (ornamental gold)

(ii) Liquid " " :- Amalgam of mercury with sodium.

(iii) Gas " " :- Solution of hydrogen in palladium.

Concentration of a solution :- Composition of a solution can be described by expressing its concentration.

Types of Concentration :-

(i) Qualitatively :- (ii) Quantitatively

Solution : Quantitative concentration :-

(i) Mass percentage (w/w) :-  
mass % of a component (Solute/Solvent) =

$$\Rightarrow \frac{\text{mass of the component in the solution}}{\text{Total mass of the solution}} \times 100$$

$$\text{Solvent mass \%} = \frac{\text{mass of the solvent}}{\text{mass of the solution}} \times 100$$

→ denoted by w/w.

(ii) Volume percentage :-

→ Volume % of a component (solute/solvent)

$$\Rightarrow \frac{\text{volume of the component}}{\text{Total volume of the solution}} \times 100$$



→ denoted by (v/v).

(iii) Mass by Volume Percentage:-  $\%$

→ Mass of solute dissolved in 100 mL of the solution.

→ denoted by (w/v).

(iv) Parts per million (ppm):- When a solute is present in a trace quantities, it is convenient to express concentration in Parts (Per Million) (ppm).

$$\text{Parts per million} = \frac{\text{no. of parts of the component} \times 10^6}{\text{Total no. of parts of all component of the solution.}}$$

→ ex - The concentration of pollutants in water or atmosphere is often expressed in terms of  $\mu\text{g mL}^{-1}$  or ppm.

(v) Mole Fraction:-

→ Mole fraction of a component =

$$\frac{\text{no. of moles of the component}}{\text{Total no. of moles of the component}}$$

→ Denoted by a greek letter  $\chi$  (chi) or Roman  $x$ .

→ In binary solution some of mole fraction will be equal to 1.

$$\chi_A + \chi_B = 1.$$

(vi) Molarity:- Molarity (M) is defined as number of moles solute dissolved in one litre (or one cubic decimetre) of solution.

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



→ Unit of Molarity: M (molar).

Example:-

\* Calculate the molarity of a solution containing 5g of NaOH in 450 ml solution.

Sol:- 
$$\text{Molarity} = \frac{\text{no. of moles of Solute}}{\text{Volume of solution in litre}}$$

No. of moles of NaOH =  $\frac{\text{Given mass}}{\text{Molar mass}}$

$$= \frac{5}{40}$$

$$[\text{NaOH} = 23 + 16 + 1 = 40 \text{ g/mol}]$$

$$= 0.125 \text{ moles}$$

Volume of solution = 450 ml =  $\frac{450}{1000}$  L

$$\text{Molarity} = \frac{0.125 \times 1000}{450} = 0.278 \text{ M} \quad \underline{\text{Ans}}$$

Molality:-

Molality (m) is defined as the no. of moles of the solute per kg of the solvent.

→ denoted by m.

→ Unit is m or mol/kg.

Ex:- Calculate molality of 2.5g of ethanoic acid ( $\text{CH}_3\text{COOH}$ ) in 75g of benzene.

Sol:- 
$$\text{Molality} = \frac{\text{no. of moles of Solute}}{\text{mass of solvent}}$$

$$\text{No. of moles of } \text{CH}_3\text{COOH} = \frac{2.5}{60}$$

$$= 0.417 \text{ moles}$$

$$[\text{CH}_3\text{COOH} = 12 + 1 \times 3 + 12 + 16 \times 2 + 1 = 60 \text{ g/mol}]$$



$$\text{mass of } C_6H_6 = \frac{75}{1000} \text{ kg}$$

$$\text{Molality} = \frac{0.0417}{75} \times 1000$$

$$= \text{Ans } 0.556 \text{ mol/kg}$$

Some important facts:- [Molality vs Molarity]

- Molality is a function of temperature.
- Volume depends on temperature.
- Molality are independent of temperature.
- Mass does not depends on temperature.

Solubility:- Solubility of a substance is its maximum amount that can be dissolved in a specified amount of solvent.

- Fixed amount of solvent
- Temperature also fixed
- fixed Pressure

Solubility depends upon:-

- Nature of solute and solvent
- Temperature
- Pressure

Solubility in liquid:-

- solubility of solid in a liquid
- solubility " liquid in a liquid
- " " Gas in a liquid

(i) Solubility of solid in liquid:- When a solid solute is added to the solvent, some solute dissolves



and its concentration increases in solution. This process is known as dissolution.

→ Some solute particles in solution collide with the solid solute particles and get separated out of solution. This process is known as crystallisation.

→ At this stage, the concentration of solute in solution will remain constant under the given conditions, i.e. temperature and pressure. [dynamic equilibrium].

→  $\text{solute} + \text{solvent} \rightleftharpoons \text{solution}$

Saturated & Unsaturated solution:-

→ Saturated:- no more solute can be dissolved at the same temperature and pressure.

→ Unsaturated:- more solute can be dissolved at same temperature.

Solid in liquid: Temperature effect

→ Follow Le chatelier's principle

→ If the dissolution process is endothermic ( $\Delta_{\text{sol}} H > 0$ ), the solubility should increase with rise in temperature.

→ If the dissolution process is exothermic ( $\Delta_{\text{sol}} H < 0$ ), the solubility should decrease with rise in temperature.

Solid in liquid: Pressure effect

→ Pressure does not have any significant impact on solubility of solids in liquids.



Solubility of Gas in liquid :-

- HCl (gas) is highly soluble in water.
- O<sub>2</sub> " " less " " " "

Pressure effect :-

- Solubility of gases increases with increase in pressure.

Henry's law :- Solubility of a gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of liquid or solution.

$$p \propto k_H \chi$$

$$p = k_H \chi$$

where  $p$  = partial pressure

$\chi$  = Mol fraction

$k_H$  = Henry's law constant

- $k_H$  value for O<sub>2</sub> increases with increase in temp., so solubility decreases with increase in temperature.

→ Henry's law Application: Soda bottles

→ " " " " : Scuba divers

Ques 1: - Henry's law constant for CO<sub>2</sub> in water is  $1.67 \times 10^8$  Pa at 298 K. Calculate the quantity of CO<sub>2</sub> in 500ml of soda water when packed under 2.5 atm CO<sub>2</sub> pressure at 298 K.

Sol :-  $k_H = 1.67 \times 10^8$  Pa  
 $p = 2.5$  atm

$$= 2.5 \times 1.01 \times 10^5 \text{ Pa}$$

$$= 2.525 \times 10^5 \text{ Pa}$$



Using Henry's law  
 $P_{CO_2} = K_H X$

$$X = \frac{P}{K_H}$$

$$X = \frac{2.533 \times 10^5}{1.67 \times 10^8} = 0.00152$$

$X$  also write  $\frac{\text{no. of } CO_2}{\text{no. of } CO_2 + n_{H_2O}} = 0.00152$

$$= \frac{\text{no. of moles } CO_2}{n_{H_2O}} = 0.00152$$

$n_{H_2O} = \frac{\text{given mass of water}}{\text{the molar mass of water}}$

[ Given = 500 mL  
we know  $d = \frac{m}{V}$   
 $d = 1$  ]

$$= \frac{500}{18}$$

$$n_{CO_2} = 0.00152 \times \frac{500}{18} = 0.042$$

We know that;  $\text{no. of moles} = \frac{\text{given amount}}{\text{molar mass}}$

$$\begin{aligned} \Rightarrow \text{amount of } CO_2 &= n_{CO_2} \times 44 \\ &= 0.042 \times 44 \\ &= 1.848 \text{ gram } \underline{\underline{Ans}} \end{aligned}$$

Vapour pressure of liquid solution:-

→ Pressure exhibited by vapour present above a liquid surface is known as vapour pressure.



→ Only in closed container.

### Raoult's law:-

→ For a solution of volatile liquids, the partial vapour pressure of each component of the sol<sup>n</sup> is directly proportional to its mole fraction present in sol<sup>n</sup>.

$$P_1 \propto X_1 \text{ or } P_1 = P_1^{\circ} X_1 \quad [\text{Pure form}]$$

$$P_2 \propto X_2 \text{ or } P_2 = P_2^{\circ} X_2 \quad [ \text{ " " } ]$$

where  $P_1$  = partial pressure of first liquid substance

$P_2$  = " " " 2<sup>nd</sup> " "

$X_1$  = mole fraction of 1<sup>st</sup> " "

$X_2$  = " " " 2<sup>nd</sup> " "

$P_i^{\circ} = p_i^{\circ}$  is the vapour pressure of pure component 1 at the same temp.

Dalton's law of Partial pressures:- Total pressure is equal to the sum of the partial pressure of the component.

$$P_{\text{total}} = P_1 + P_2 \quad [\text{when two components}]$$

### Total Vapour Pressure: Calculation

→ Raoult's law:  $P_1 = P_1^{\circ} X_1$

$$P_2 = P_2^{\circ} X_2$$

$$\begin{array}{l} \text{Binary sol}^n \\ [X_1 + X_2 = 1] \\ [X_1 = 1 - X_2] \end{array}$$

Dalton's law:  $P_{\text{total}} = P_1 + P_2$

$$\Rightarrow P_1^{\circ} X_1 + P_2^{\circ} X_2$$

$$= P_1^{\circ} (1 - X_2) + P_2^{\circ} X_2$$

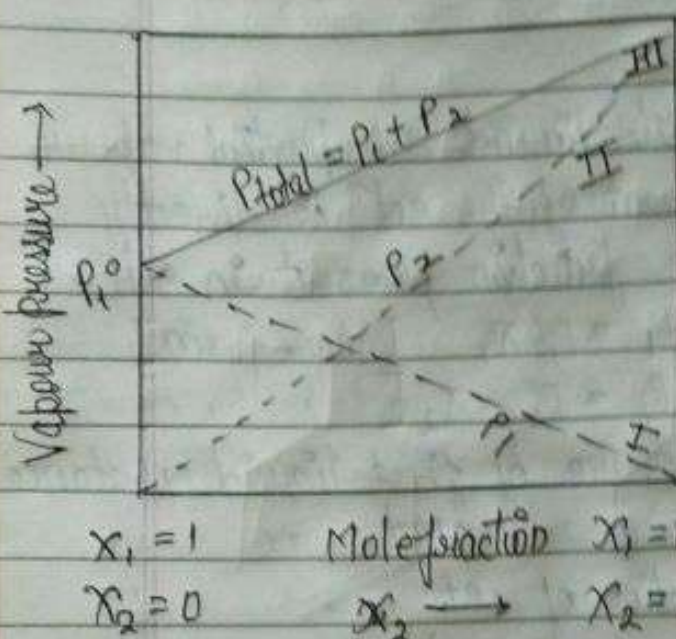
$$= P_1^{\circ} - P_1^{\circ} X_2 + P_2^{\circ} X_2$$

$$P_{\text{total}} = P_1^{\circ} + (P_2^{\circ} - P_1^{\circ}) X_2$$

→ Total vapour pressure depends upon only one component mole fraction.



## Vapour pressure & Mole fraction: Plot



According to Raoult's law:-

1st Component	2nd Component
$P_1 = X_1 P_1^\circ$	$P_2 = X_2 P_2^\circ$
1st component minimum	max
$X_1 = 0$	$X_2 = 1$
$P_1 = 0$	$P_2 = P_2^\circ$

$\downarrow$   
 Minimum                      max.  
 $X_2 = 0$                        $X_2 = 1$   
 $P_2 = 0$                        $P_2 = P_2^\circ$

$\rightarrow Y_1 = \frac{P_1}{P_{total}}$       [where Y is mole fraction in vapour phase]  
 $Y_2 = \frac{P_2}{P_{total}}$

### Raoult's law: Special case of Henry's law:-

$\rightarrow$  Henry's law:-  $P = k_H X$   
 Raoult's law:-  $P_1 = X_1 P_1^\circ$

### Vapour Pressure: Solid in Liquid solutions

(i) Pure solvent [only]:- when add Non-Kalalite solute on surface also covered solute.



(2) When we add volatile solute its also covered in the surface of solution.

### Raoult's law General form:-

→ For any sol<sup>n</sup> the partial vapour pressure of each volatile component in the sol<sup>n</sup> is directly proportional to its mole fraction.

### Ideal & Non-Ideal Solution:-

→ Ideal  
obeys Raoult's law

→ Non-Ideal Sol<sup>n</sup>  
Do not obeys Raoult's law

### Characteristics :-

→ No heat is absorbed/ evolved when components are mixed.

$$\Delta H_{mix} = 0$$

$$\Delta_{mix} V = 0$$

Volume of sol<sup>n</sup> = sum of volumes of the component.

Non-Ideal :- \* If its V.P. is lower than the predicted by Raoult's law. This is called and if its v.p. is lower than that predicted by Raoult's law. [negative deviation lower] and [positive deviation higher].

### Why positive deviation:-

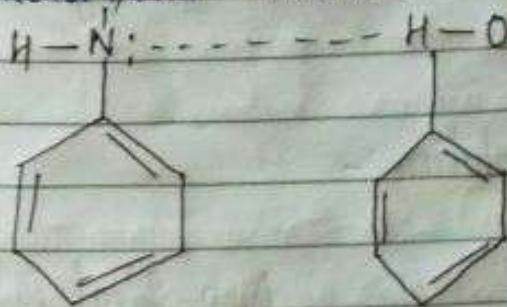
→ Molecules of A (or B) will find it easier to escape than in pure state. This increases in vapour pressure.

Ex:- Ethanol and Acetone



### Why Negative deviation?

- A-B interactions are stronger than those between A-A or B-B.
  - Molecules of A (or B) will find it difficult to escape. This decreases the vapour pressure.
- Ex: Phenol and Aniline



### Azeotropes:-

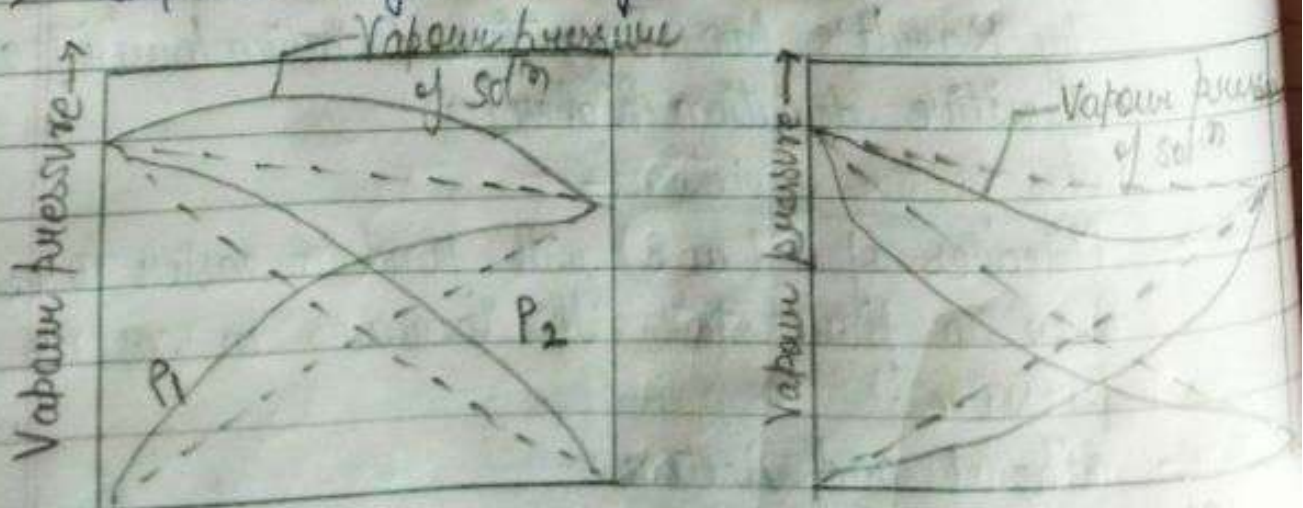
- Binary mixtures
- boils at a constant temperature at a certain composition.

### Minimum Boiling Azeotropes:-

- Which non-ideal solutions shows positive deviation is called minimum boiling azeotropes because when we draw constant pressure phase diagram then temperature plot is goes through minimum.

### Maximum Boiling Azeotropes:-

- temperature goes through maximum.



Positive deviation

negative deviation



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

Sol<sup>n</sup>

$$P_A^\circ = 450 \text{ mm Hg}$$

$$P_B^\circ = 700 \text{ mm Hg}$$

$$P_{\text{total}} = 600 \text{ mm Hg}$$

$$\text{we know, } \boxed{P_{\text{total}} = P_A + P_B}$$

$$\Rightarrow P_A^\circ x_A + P_B^\circ x_B$$

$$P_{\text{total}} \Rightarrow P_A^\circ x_A + P_B (1 - x_A)$$

$$600 = 450 x_A + 700 (1 - x_A)$$

$$600 = 450 x_A + 700 - 700 x_A$$

$$x_A = 0.4$$

$$x_B = 1 - x_A = 1 - 0.4 = 0.6$$

composition of liquid mixture.

$$P_A = P_A^\circ x_A = 450 \times 0.4 = 180 \text{ mm Hg}$$

$$P_B = P_B^\circ x_B = 700 \times 0.6 = 420 \text{ mm Hg}$$

So, vapour pressure

$$x_A = \frac{P_A}{P_B} \quad ; \quad x_B = \frac{P_B}{P_B + P_A}$$

$$= \frac{180}{180 + 420} = 0.3$$

$$= 1 - 0.3 = 0.7$$