Class : 12

2023 – 24

Board : PU BOARD KARNATAKA

SOLUTIONS

Types of Solutions :

- Solutions are homogeneous mixtures of two or more than two components. Its composition and properties are uniform throughout the mixture, component that is present in the largest quantity is known as solvent. One or more components present in the solution other than solvent are called solutes,

TYPES OF SOLUTIONS :

Type of Solution	Solute	Solvent	Common Examples
Gaseous Solutions	Gas	Gas	Mixture of oxygen and nitrogen gases
	Liquid	Gas	Chloroform mixed with nitrogen gas
	Solid	Gas	Camphor in nitrogen gas
Liquid Solutions	Gas	Liquid	Oxygen dissolved in water
	Liquid	Liquid	Ethanol dissolved in water
	Solid	Liquid	Glucose dissolved in water
Solid Solutions	Gas	Solid	Solution of hydrogen in palladium
	Liquid	Solid	Amalgam of mercury with sodium
	Solid	Solid	Copper dissolved in gold

EXPRESSING CONCENTRATION OF SOLUTIONS :

- **Mass percentage (w/w) :**
  Mass % of a component
  $$=\frac{\text{Mass of the component in the solution}}{\text{Total mass of the solution}}\times 100$$

- **Volume percentage (V/V) :**
  Volume % of a component
  $$=\frac{\text{Volume of the component in the solution}}{\text{Total volume of the solution}}\times 100$$

- **Mass by volume percentage (w/V) :**
  It is the mass of solute dissolved in 100 mL of the solution.

- **Parts per million :**
  Parts per million
  $$=\frac{\text{Number of parts of the component}}{\text{Total number of parts of all component of the solution}}\times 10^{6}$$

- Mole fraction:
  Mole fraction of a component
  $$= \frac{\text{Number of moles of the component}}{\text{Total number of moles of all the component}}$$

- Molarity:
  $$\text{Molarity} = \frac{\text{Mole of solute}}{\text{Volume of solution in litre}}$$

- Molality:
  $$\text{Molality(m)} = \frac{\text{Mole of solute}}{\text{Mass of solvent in kg}}$$

SOLUBILITY

- Solubility of a substance is its maximum amount that can be dissolved in specified amount of solvent at a specified temperature. It depends upon the nature of solute and solvent as well as temperature and pressure.
- Solubility of a Solid in a Liquid :
  - Polar solutes dissolve in polar solvents and non polar solutes in nonpour solvents.
  - Such a solution in which no more solute can be dissolved at the same temperature and pressure is called a saturated solution. An unsaturated solution is one in which more solute can be dissolved at the same temperature.

EFFECT OF TEMPERATURE

- In general, if in a nearly saturated solution, the dissolution process is endothermic ($\Delta_{sol} H > 0$), the solubility should increase with rise in temperature, and it is exothermic ($\Delta_{sol} H < 0$) the solubility should decrease.

EFFECT OF PRESSURE

- Pressure does not have any significant effect on solubility of solids in liquids. It is so because solids and liquids are highly incompressible.

SOLUBILITY OF A GAS IN A LIQUID

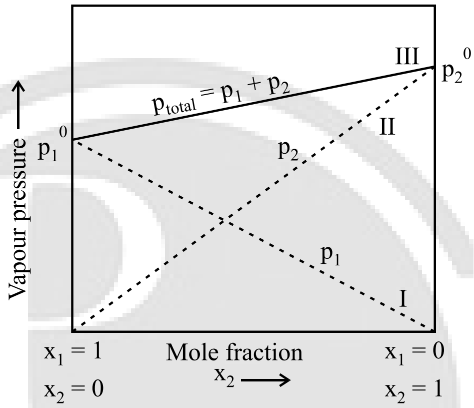
- Solubility of gases in liquids is greatly affected by pressure and temperature. The solubility of gases increase with increase of pressure.
- **Henry's** law: The law states that at a constant temperature, **the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of liquid or solution.**
- The partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.
  $$p = K_H x$$
- Higher the value of K_H at a given pressure, the lower is the solubility of the gas in the liquid. The solubility of gases increases with decrease of temperature. It is due to this reason that aquatic species are more comfortable in cold waters rather than in warm waters.
- To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.
- Scuba divers must cope with high concentrations of dissolved gases while breathing air at high pressure underwater. Increased pressure increases the solubility of atmospheric gases in blood.

EFFECT OF TEMPERATURE

- Solubility of gases in liquids decreases with rise in temperature.

VAPOUR PRESSURE OF LIQUID SOLUTIONS

- Vapour Pressure of Liquid-Liquid Solutions :
    - **Raoult's law** which states that for a solution of volatile liquids, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution.
    - For component I
        - $P_1 \propto x_1$
        - and
        - $p_1 = p_1^0 x_1$
    - p_1^0 is the vapour pressure of pure component 1 at the same temperature.
        - For component 2
    - $p_2 = p_2^0 x_2$
    - p_2^0 represents the vapour pressure of the pure component 2.
    - Dalton's law of partial pressures, the total pressure(p_{total}) over the solution phase in the container will be the sum of the partial pressures of the components of the solution and is given as $p_{total} = p_1 + p_2$



The plot of vapour pressure and mole fraction of an ideal solution at constant temperature. The dashed lines I and II represent the partial pressure of the components.

RAOULT'S LAW AS A SPECIAL CASE OF HENRY'S LAW:

- According to Raoult's law, the vapour pressure of a volatile component in a given solution is given by $p_i = x_i p_1^0$. In the solution of a gas in a liquid, one of the components is so volatile that it exists as a gas and we have already seen that its solubility is given by Henry's law which states that
  $p = K_H x$.
- The partial pressure of the volatile component or gas is directly proportional to its mole fraction in solution. Only the proportionality constant K_H differs from p_1^0. Thus, Raoult's law becomes a special case of Henry's law in which K_H becomes equal to p_1^0.

VAPOUR PRESSURE OF SOLUTIONS OF SOLIDS IN LIQUIDS

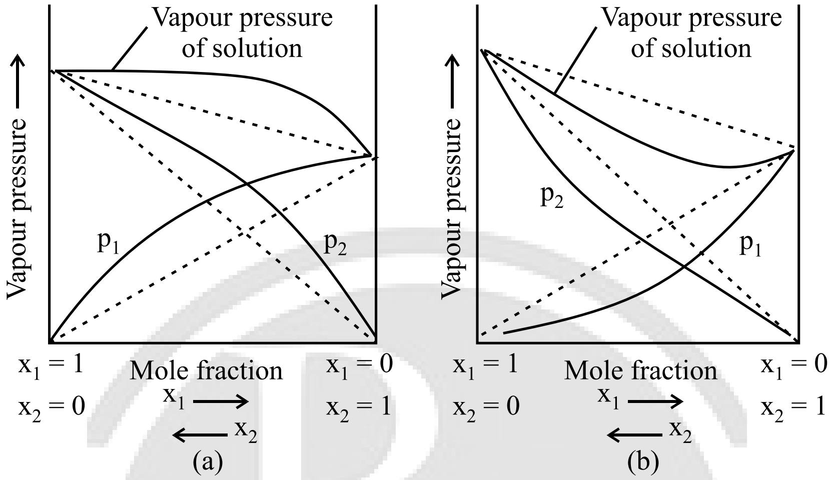
- Vapour pressure of the solution at a given temperature is found to be lower than the vapour pressure of the pure solvent at the same temperature.
- The decrease in the vapour pressure of solvent depends on the quantity of non-volatile solute present in the solution, irrespective of its nature.
- For any solution the partial vapour pressure of each volatile component in the solution is directly proportional to its mole fraction.

IDEAL AND NON-IDEAL SOLUTIONS

- Ideal Solutions: The solutions which obey Raoult's law over the entire range of concentration are known as ideal solutions.
  $\Delta_{mix} H = 0, \Delta_{mix} V = 0$

NON-IDEAL SOLUTIONS

- When a solution does not obey Raoult's law over the entire range of concentration, then it is called non-ideal solution.
- If it is higher, the solution exhibits positive deviation and if it is lower, it exhibits negative deviation from Raoult's law.
- In case of positive deviation from Raoult's law, A-B interactions are weaker than those between A-A or B-B.
- Mixtures of ethanol and acetone behave in this manner.
- Carbon disulphide to acetone also shows positive deviation.
- In case of negative deviations from Raoult's law, the intermolecular attractive forces between A-B and B-B are weaker than those between A-B and leads to decrease in vapour pressure resulting in negative.
- A mixture of chloroform and acetone forms a solution with negative deviation from Raoult's law.



- Some liquids on mixing, formazeotropes which are binary mixtures having the same composition in liquid and vapour phase and boil at a constant temperature.
- Minimum boiling azeotrope and maximum boiling azeotrope. The solutions which show a large positive deviation from Raoult's law form minimum boiling azeotrope at a specific composition.
- For example, ethanol-water mixture.
- The solutions that show large negative deviation from Raoult's law form maximum boiling azeotrope at a specific composition. Nitric acid and water is an example of this class of azeotrope.

COLLIGATIVE PROPERTIES AND DETERMINATION OF MOLAR MASS

- All these properties depend on the number of solute particles irrespective their nature of parties depend on the number of particles present in the solution. Such properties are called colligative properties.
- These are: (1) relative lowering of vapour pressure of the solvent(2) depression of freezing point of the solvent (3) elevation of boiling point of the solvent and (4) osmotic pressure of the solution.
- Relative lowering of Vapour Pressure : The vapour pressure of a solvent in solution is less than that of the pure solvent. Relative lowering of vapour pressure and is equal to the mole fraction of the solute.

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{n_2}{n_1 + n_2}\left(\text{since } x_2 = \frac{n_2}{n_1 + n_2}\right)$$

- Elevation of Boiling Point : Let T_b^0 be the boiling point of pure solvent and T_b be the boiling point of solution. The increase in the boiling point $\Delta T_b = T_b - T_b^0$ is known as elevation of boiling point.

$$\Delta T_b \propto m \quad \text{or} \quad \Delta T_b = K_b m.$$

K_b is called Boiling Point Elevation constant or Molal Elevation Constant (Ebullioscopic Constant).

$$m = \frac{w_2 / M_2}{w_1 / 1000} = \frac{1000 \times w_2}{M_2 \times w_1}; \Delta T_b = \frac{K_b \times 1000 \times w_2}{M_2 \times w_1}$$

- Depression of Freezing Point : Let T_f^0 be the freezing point of pure solvent decrease in freezing point.

$\Delta T_f = T_f^0 - T_f$ is known as depression in freezing point.

$$\Delta T_b \propto m \quad \text{or} \quad \Delta T_b = K_b m.$$

- The proportionality constant, K, which depends on the nature of the solvent is known as Freezing Point Depression Constant or Molal Depression Constant or Cryoscopic Constant.

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

$$\Delta T_f = \frac{K_f \times w_2 / M_2}{w_1 / 1000} \Rightarrow \Delta T_f = \frac{K_f \times w_2 \times 1000}{M_2 \times w_1}$$

OSMOSIS AND OSMOTIC PRESSURE

- If this membrane is placed between the solvent and solution solvent molecules will flow through the membrane from pure solvent to the solution. This process of flow of the solvent is called osmosis.
- Pressure that just stops the flow of solvent is called osmotic presume of solution.
- Osmotic pressure is proportional to the molarity, C of the solution at a given temperature T.

  $\Pi = CRT$
- Two solutions having same osmotic pressure at a given temperature are called isotonic solutions.
- If we place the cells in a solution containing more than 0.9% (mass/ volume) sodium chloride, water will flow out of the cells and they would shrink. Such a solution is called hypertonic. If the salt concentration is less than 0.9% (mass/volume), the solution is said to be hypotonic.
- People taking a lot of salt or salty food experience water retention in tissue cells and intercellular spaces because of osmosis. The resulting puffiness or swelling is called edema.

REVERSE OSMOSIS AND WATER PURIFICATION

- The direction of osmosis can be reversed if a pressure larger than the osmotic pressure is applied to the solution side. That is, now the pure solvent flows out of the solution through the semi permeable membrane. This phenomenon is called reverse osmosis.
- Reverse osmosis is used in desalination of sea water.

ABNORMAL MOLAR MASSES

- A molar mass that is either lower or higher than the expected or normal value is called as abnormal molar mass.
- In 1880 van't Hoff introduced a factor i, known as the van't Hoff factor.

$$i = \frac{\text{Normal molar mass}}{\text{Abnormal molar mass}} = \frac{\text{Observed colligative property}}{\text{Calculated colligative property}}$$

$$i = \frac{\text{Total number of moles of particles after association/dissociation}}{\text{Number of moles of particles before association/dissociation}}$$

- Inclusion of van’t Hoff factor modifies the equations for colligative properties as follows :

  Relative lowering of vapour pressure of solvent.

$$\frac{p_1^0 - p_1}{p_1^0} = i.\frac{n_2}{n_1}$$

Elevation of Boiling Point, $\Delta T_b = iK_b m$

Depression of Freezing point, $\Delta T_f = iK_f m$

Osmotic pressure of solution, $\Pi = in_2RT / V$

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