Unit -2

THEORY OF DILUTE SOLUTIONS

1) **What is solution?** [1]

A: It is a homogenous mixture of two or more compounds.

2) **What is dilute solution?** [1]

A: It is a solution in which solute concentration is very less.

3) **Give an example for solid-solid solution** [1]

A: Copper dissolved in gold.

4) **Give an example for gas-gas solution** [1]

A: Mixture of oxygen and nitrogen gases.

5) **Give an example for gas-solid solution** [1]

A: Solution of hydrogen in palladium.

6) **Give an example for liquid-solid solution** [1]

A: Amalgam of mercury with sodium.

7) **Give an example for liquid-liquid solution** [1]

A: Ethanol dissolved in water.

8) **Give an example for solid-gas solution** [1]

A: Camphor in nitrogen gas.

9) **Define mole fraction and give the equation to calculate it.** [2]

A:Mole fraction is the ratio of number of moles of one component to the total number of moles of all the components in the solution.

$$X_A = \frac{n_A}{n_A + n_B}$$

$$X_B = \frac{n_B}{n_A + n_B}$$

10) **Define molarity and give the equation to calculate it.** [2]

A: Number of moles of the solute present per liter solution is known as molarity.

$$M = \frac{n_B}{V}$$

11) **Define molality and give the equation to calculate it.** [2]

A: Number of moles of the solute present perkgsolvent is known as molality.

$$M = \frac{n_B}{W_A}$$

12) **Define the term solubility of a substance.** [1]

A: Solubility of a substance is its maximum amount that can be dissolved in a specified amount of solvent at a specified temperature

13) **State Henry's law**. [2]

A: **Henry's Law:** At constant temperature solubility of a gas in a liquid is directly proportional to the partial pressure of gas present above the solution.

OR

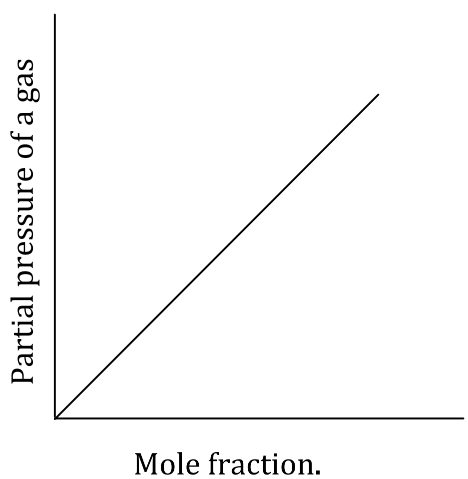
At constant temperature the partial pressure of the gas in vapor phase (p) is proportional to the mole fraction of the gas (x) in the solution.

Mathematically $p \propto x$; $p = K_H x$.

Where K_H is Henry's law constant. K_H depends on the nature of the gas.

14) **Write the plot which shows relation between partial pressure of a gas v/s its mole fraction**. [2]

A:



15) **Mention the factors affecting solubility of a gas in liquid.** [2]

A: 1. Temperature 2. Pressure

16) **Explain how temperatures effect the solubility of a gas in liquid**. [2]

A: Solubility of gases in liquid decreases with rise in temperature. According to Le Chatelier's Principle,as dissolution is an exothermic process, the solubility should decrease with increase of temperature.

17) **Explain how pressure effects the solubility of a gas in liquid.** [1]

A: The solubility of gases increases with increases of pressure.

18) **Mention the applications of Henry's law**. [3]

A: (a) To increase the solubility of CO_2 insoft drink and soda water, the bottle is sealed under high pressure.

(b) To avoid bends, as well, the toxic effects of high concentration of nitrogen in the blood, the tanks used by scuba divers are filled with air dilute with helium.
(c) At high altitudes the partial pressure of oxygen is less than that at the ground level. This leads to low concentrations of oxygen in the blood and tissues of people living at high altitudes or climbers.

19)**State Raoult'slaw of liquid-liquid dilute solutions.** [2]
A: The partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution.
Thus, for component 1
$P_1 \alpha x_1$
And $p_1 = p_1^0 x_1$

20)**What are ideal solutions?** [1]
A: The solution which obey Raoul's law over the entire range of concentration are known as ideal solution

21)**Mention the characters of ideal solutions.** [3]
A:

Ideal

I. It obeys Raoults law is obeyed at all temperature and concentration
$P = P_A + P_B$
II. ΔV_{mix} = O i.e., there is no change in volume on mixing
III. ΔH_{mix} = O i.e., there is no enthalpy change when ideal solution formed
IV. It doesn't form azeotropic mixture
V. Force of attraction between A—A, B—B is similar as A—B

22)**What are non-ideal solutions?** [1]
A: When a solution does not obey Raoult's law over the entire range of concentration, then it is called non-ideal solution.

23)**Mention the types of non-ideal solutions.** [1]
A: There are two types
(a) Non-ideal solution with positive deviation from Raoult's law
(b) Non-ideal solution with negative deviation from Raoult's law

24)**Give an example for non-ideal solution with positive deviation from Raoult's law.** [1]
A: Mixtures of ethanol and acetone

25) **Give an example for non-ideal solution with negative deviation from Raoult's law.** [1]

A: An example of this type is a mixture of phenol and aniline.

26) **What are azeotropes? Give example.** [2]

A: Azeotropes are binary mixtures having the same composition in liquid and vapour phase and boil at a constant temperature.

For example: ethanol-water mixture

27) **State Raoult's law of relative lowering of vapour pressure.** [1]

A: Relative lowering of vapour pressure is equal to the mole fraction of the solute.

28) **Define colligative property.** [1]

A: The properties depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution. Such properties are called colligative properties

29) **Mention four colligative properties of dilute solutions.** [2]

A: Relative lowering of vapour pressure

I. Elevation in Boiling point
II. Depression in Freezing point
III. Osmotic pressure

30) **Define the term relative lowering of vapour pressure.** [2]

A: It is the ratio of lowering of vapour pressure to the vapour pressure of the pure solvent

$$\frac{P^o - P}{P^o} = \text{Relative lowering of V.P}$$

31) **What is elevation in boiling point?** [1]

A: Elevation in boiling point is the difference between the boiling point of the solution containing non-volatile solute and the boiling point of the pure solvent

$\Delta T_b = T - T^o$

32) **Give the relation between elevation in boiling point and molecular mass of solute.** [2]

A:

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

Where w_2 is mass of solute, w_1 is the mass of the solvent; M_2 is molar mass of the solute

33) **Give the S.I.unit of ebullioscopic constant or boiling point elevation constant or molal elevation constant.** [1]

A: The unit of K_b is K kg mol^{-1}

34) **What is depression infreezing point?** [1]

A: It is the decrease in the freezing point of solution when non-volatile solute is added into solvent.

35) **Give the relation between depression infreezing point and molecular mass of solute.** [2]

A:

$$\Delta T_f = K_f \frac{\frac{w_2}{M_2}}{\frac{w_1}{1000}} \qquad \therefore M_2 = \frac{K_f \times 1000 \times w_2}{\Delta T_f \times w_1}$$ where M_2 is molar mass of the solute.

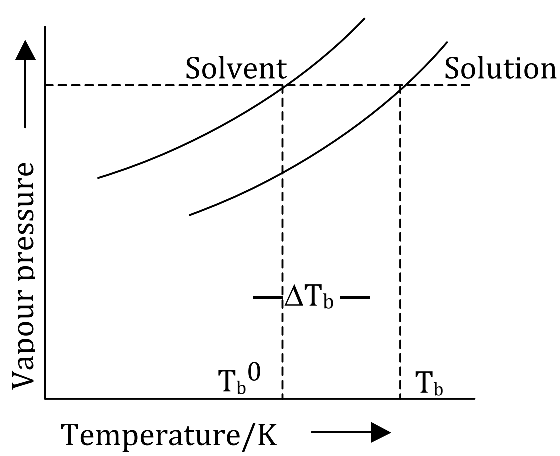
Note: Values of K_f and K_b of the solvent depends on their molecular mass and ΔH_{fusion} and ΔH_{vap} of the solvent respectively.

36) **Give the S.I.unit of cryoscopic constant.** [1]

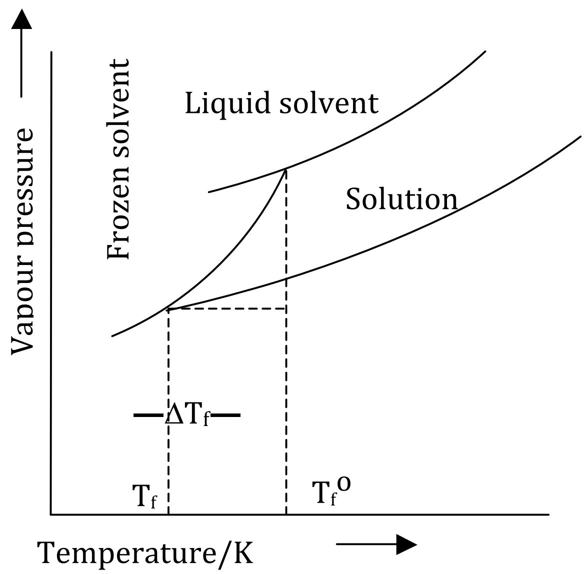
A: The unit of K_f is K kg mol^{-1}

37) **Draw the plot showing elevation in boiling point in a solution.** [2]

A:

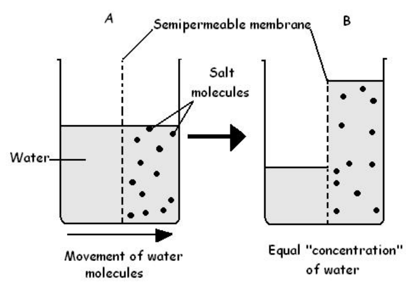


38)**Draw the plot showing depression in freezing point in a solution.** [2]



39)**Define osmosis.** [1]

A: The process of movement of solvent particles from lower concentration to higher concentration through semi-permeable membrane to attain equilibrium is called osmosis.



40)**What is osmotic pressure and give its relation with concentration of solution.** [2]

A: The amount of external pressure required to stop the osmosis.

π = CRT

Where: π= osmotic pressure, R = gas constant, T = temperature, C = concentration of solution.

41) **What are isotonic solutions?** [1]

A: Two different solutions having sameosmotic pressure are called isotonic solutions

42)**What are hypertonic solutions?** [1]

A: The solution having more osmotic pressure than other

43)**What are hypotonic solutions?** [1]

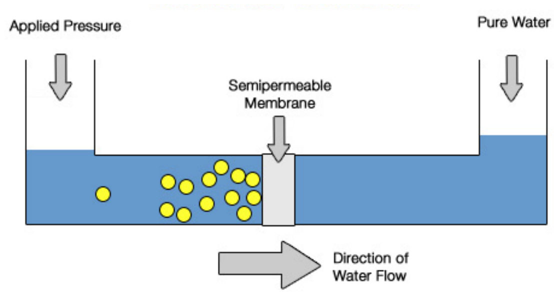
A: The solution having less osmotic pressure than other

44)**Explain the application of reverse osmosis in desalination of water.** [2]

A: When pressure more than osmotic pressure is applied, pure water is squeezed out of the sea water through the membrane. A variety of polymer membranes are available for this purpose.

The pressure required for the reverse osmosis is quite high. A workable porous membrane is a film of cellulose acetate placed over a suitable support. Cellulose acetate is permeable to water but impermeable to impurities and ions present in sea water.

45)**What is reverse osmosis?** [1]



A: Movement of solvent particles from higher concentration to lower concentration through a semi permeable membrane, when pressure is applied greater than osmotic pressure

46)**What is abnormal molar mass?** [1]

A: A molar mass that is either lower or higher than the expected or normal value is called as abnormal molar mass.

47) Define Vant hoff factor

Van't Hoff factor 'i' to account for the extent of association or dissociation of a solute in a solvent is

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

or

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

or

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

48)**What is the value of i for NaCl.** [1]

A: 2

49)**What is the value of i for K_2SO_4.** [1]

A: 3

50)**What is the value of i for sugar.** [1]

A: 1

51)**What is the value of i for glucose.** [1]

A: 1

52)**On what factor the colligative property depends on.** [1]

A: It depends on number of moles of solute particles but not on the nature of the solute.

53)**Write the mathematical equation of Raoults law in case of non-volatile solute.** [1]

A: If one of the components (solute) is non-volatile then the equation of Raoults law is.

$P_B = 0$

$P = P_A + P_B$

$P = P_A + 0$

$P = P_A^0 . X_A$

54)**Write the differentiate between non-ideal solutions with positive deviation and negative deviation from Raoult's law** [2]

Positive deviation	**Negative deviation**
(a)In this solution solvent – solute interaction is weaker than solvent – solvent, solute-solute interactions (b) $P > P_A + P_B$ (c) $\Delta V > 0$ (d) ΔH = positive (e) It forms azeotrope with minimum boiling point	(a) In this solution solvent – solute interaction is stronger than solvent – solvent, solute-solute interactions (b) $P < P_A + P_B$ (c) $\Delta V < 0$ (d) ΔH = negative (e)It forms azeotrope with maximum boiling point

55)**Define lowering of vapour pressure?** [1]

A: It is defined as the difference between the vapor pressure of the solvent in pure state and the vapour pressure of the solution

$\Delta P = P^o – P$

56)**State Roult's law of relative lowering of vapour pressure** [1]

A: It states that the relative lowering of vapour pressure is equal to the mole fraction of the solute

57) **Why sea water freezes below 0^0C?** [1]

A: Sea water freezes below 0^0C due to the presence of the non-volatile solute dissolved in the water.

58) **Derive the equation to calculate molecular mass of unknown solute using Raoult's law of relative lowering of V.P** [3]

A: According to Raoult's law relative lowering of vapour pressure is equal to the mole fraction of the solute.

$$\frac{P^o - P}{P^o} = X_B$$

$$\frac{P^O - P}{P^O} = \frac{n_B}{n_A + n_B}$$

$n_B <<< n_A$ for dilute solution

So we can neglect n_B in denominator

$$\frac{P^O - P}{P^O} = \frac{n_B}{n_A}$$

$$\frac{P^O - P}{P^O} = \frac{\frac{W_B}{M_B}}{\frac{W_A}{M_A}}$$

$$\frac{P^O - P}{P^O} = \frac{W_B}{W_A}\frac{M_A}{M_B}$$

$$M_B = \frac{W_B . M_A}{W_A}\left(\frac{P^O}{P^O - P}\right)$$

Numerical problems

1. ***A solution containing 2.56 g sulphur in 100 g CS_2 gave a freezing point lowering of 0.383 K. Calculate the molar mass of sulphur molecules. Given K_f of CS_2 = 3.83 K kg mol^{-1}.***

Ans. $\Delta T_f = 0.383$ K, $K_f = 3.83$ K kg mol^{-1}

$$\Delta Tf = K_f \times m \quad ; \quad \Delta Tf = K_f \times \frac{\frac{W_2}{M_2}}{\frac{W_1}{1000}}$$

$$M_2 \text{ (molar mass of sulphur molecules)} = \frac{2.56 \times 1000 \times 3.83}{100 \times 0.383} = 256 \text{ g mol}^{-1}$$

2. ***100 g of water has 3g of urea dissolved in it. Calculate the freezing point of the solution. K_f for water = 1.86 K kg mol^{-1}, molar mass of urea = 60 g mol^{-1}, freezing point of water = 273.15 K (0°C)***

Ans. $$\Delta T_f = K_f \times m \quad ; \quad \Delta T_f = 1.86 \times \frac{\frac{W_2}{M_2}}{\frac{W_1}{1000}} \qquad \Delta T_f = 1.86 \times \frac{3 \times 1000}{60 \times 100} = 0.93$$

$$\Delta T_f = T_f^0 - T_f \qquad \therefore T_f = 273.15 - 0.93 = 272.22 \quad \text{or} \quad -0.93°C$$

3. ***Human blood has osmotic pressure of 7.2 atm at body temperature of 37°C. Calculate the molar concentration of solute particles in blood. Given R = 0.0821 L atm K^{-1}.***

Ans. $$\pi = CRT \quad ; \quad C = \frac{\pi}{RT} \qquad T = 273 + 37 = 310 \text{ K}$$

$$C \text{ (molar concentration)} = \frac{7.2}{0.0821 \times 310} = 0.2828 \text{ M}$$

4. ***Vapour pressure of benzene is 200 mm of Hg. 2g of a non-volatile solute in 78 g benzene has vapour pressure of 195 mm of Hg. Calculate the molar mass of the solute. Molar mass of benzene = 78 g mol^{-1}.***

Ans. $$\frac{P° - P}{P°} = \frac{n_2}{n_1} \; ; \quad \frac{P° - P}{P°} = \frac{\frac{W_2}{M_2}}{\frac{W_1}{M_1}} \qquad \frac{200 - 195}{200} = \frac{\frac{2}{M_2}}{\frac{78}{78}} \; ;$$

$$\text{Molar mass of solute } (M_2) = \frac{200 \times 2}{5} = 80 \text{ g mol}^{-1}$$

5. 500 g of water containing 27 g of a non-volatile solute will boil at 100.156°C. Calculate the molar mass of the solute. Given boiling point of water = 100°C, K_b = 0.52 K kg mol^{-1}.

Ans. $\Delta T_b = K_b \times m$; $\Delta T_b = K_b \times \dfrac{\frac{W_2}{M_2}}{\frac{W_1}{1000}}$

Molar mass of solute (M_2) = $\dfrac{0.52 \times 27 \times 1000}{500 \times 0.156}$ = 180 g mol^{-1}.