

**Unit 9: Solutions****31. Define (i) molality (ii) Normality**

(i) **molality:** Molarity is defined as the number of moles of the solute per kilogram of the solvent

$$\text{Molality} = \frac{\text{No. of moles of solute}}{\text{Mass of the solvent (in kg)}}$$

(ii) **Normality:** Normality is defined as number of gram equivalents of solute present in one litre of solution.

$$\text{Normality} = \frac{\text{No. of gram equivalent of solute}}{\text{Volume of solution (in L)}}$$

**32. What is a vapour pressure of liquid? What is relative lowering of vapour pressure?****Vapour pressure of liquid :**

The pressure of the vapour in equilibrium with its liquid is called vapour pressure of the liquid at the given temperature.

**Relative lowering of vapour pressure:**

The ratio of lowering of vapour pressure to vapour pressure of pure solvent.

$$\text{Relative lowering of vapour pressure} = \frac{P^\circ_{\text{solvent}} - P_{\text{solution}}}{P^\circ_{\text{solvent}}}$$

**33. State and explain Henry's law**

Henry's law states that, "the partial pressure of the gas in vapour phase is directly proportional to the mole fraction(x) of the gaseous solute in the solution at low concentrations".

Henry's law can be expressed as,  $P_{\text{solute}} \propto X_{\text{solute in solution}}$

$$P_{\text{solute}} = K_H X_{\text{solute in solution}}$$

$X_{\text{solute in solution}}$

**34. State Raoult law and obtain expression for lowering of vapour pressure when nonvolatile solute is dissolved in solvent.**

Raoult law states that "in the case of a solution of volatile liquids, the partial vapour pressure of each component (A & B) of the solution is directly proportional to its mole fraction".

According to Raoult's law

$$P_A \propto x_A ; P_A = k x_A$$

$$\text{when } x_A = 1, k = P^\circ_A$$

where  $P^\circ_A$  is the vapour pressure of pure component 'A' at the same temperature.

$$\text{Therefore, } P_A = P^\circ_A x_A$$

When a nonvolatile solute is dissolved in a pure solvent, the vapour pressure of the pure solvent will decrease.

Volatile solvent Particles

Nonvolatile solute particles

$P_{\text{solution}} \propto x_A$  ; Where  $x_A$  is the mole fraction of the solvent

$$P_{\text{solution}} = k x_A \text{ When } x_A = 1, K = P^\circ_{\text{solvent}}$$

( $P^\circ_{\text{solvent}}$  is the partial pressure of pure solvent)

$$P_{\text{solution}} = P^\circ_{\text{solvent}} x_A$$

$$\frac{P_{\text{solution}}}{P^\circ_{\text{solvent}}} = x_A$$

$$1 - \frac{P_{\text{solution}}}{P^\circ_{\text{solvent}}} = 1 - x_A$$

$$\frac{P^\circ_{\text{solvent}} - P_{\text{solution}}}{P^\circ_{\text{solvent}}} = x_B$$

Where  $x_B$  is the fraction of the solute

$$(\therefore x_A + x_B = 1, x_B = 1 - x_A)$$

The above expression gives the relative lowering of vapour pressure. Based on this expression, Raoult's Law can also be stated as "the relative lowering of vapour pressure of an ideal solution containing the nonvolatile

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solute is equal to the mole fraction of the solute at a given temperature”

**35. What is molal depression constant?**

**Does it depend on nature of the solute ?**

$$\Delta T_f = K_f \cdot m$$

If  $m=1$  then  $\Delta T_f = K_f$

The molal depression constant  $K_f$  is equal to the depression in freezing point for 1 molal solution.

Depression constant **does not depend on the nature of the solute.** (but depends on the number of solution particles in the solution solvent).

**36. What is osmosis?**

Osmosis is a spontaneous process by which the solvent molecules pass through a semi permeable membrane from a solution of lower concentration to a solution of higher concentration.

**37. Define the term ‘isotonic solution’.**

Two solutions having same osmotic pressure at a given temperature are called isotonic solutions.

**38. You are provided with a solid ‘A’ and three solutions of A dissolved in water – one saturated, one unsaturated, and one super saturated. How would you determine which solution is which ?**

**Saturated Solution:** It can dissolve salt an additional to it.

(A Solution in which no more solute can be dissolved in a definite amount of solvent at a given temperature is called a saturated solution.)

**Unsaturated solution:** Further solubility of salt do not takes place but solubility can takes place on heating.

(A solution which has more of solute than the saturated at a given temperature is called super saturated solution.)

**Super saturated solution:** Solubility of salt do not takes place on even an further heating.

(A Solution which has more of solute than the saturated solution at a given temperature is called super saturated solution.)

**39. Explain the effect of pressure on the solubility.**

The change in pressure does not have any significant effect in the solubility of solids and liquids as they are not compressible. However, **the solubility of gases generally increases with increase of pressure.**

Consider a saturated solution of a gaseous solute dissolved in a liquid solvent in a closed container. In such a system, the following equilibrium exists.

**Gas (in gaseous state)  $\rightleftharpoons$  Gas (in solution)**

According to Le-Chatelier principle, the increase in pressure will shift the equilibrium in the direction which will reduce the pressure. Therefore, more number of gaseous molecules dissolves in the solvent and the solubility increases.

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**40. A sample of 12 M Concentrated hydrochloric acid has a density  $1.2 \text{ gL}^{-1}$ . Calculate the molality**

Molarity = 12 M HCl

Density of the solution =  $1.2 \text{ gL}^{-1}$

In 12 M HCl solution, there are 12 moles of HCl in 1 litre of the solution

$$\text{Molarity} = \frac{\text{No. of moles of solute}}{\text{Mass of the solvent (in kg)}}$$

Calculate mass of water (solvent)

Mass of 1 litre HCl solution = density  $\times$  volume

$$= 1.2 \text{ g mL}^{-1} \times$$

1000 mL

$$= 1200 \text{ g}$$

Mass of HCl = No. of moles of HCl  $\times$  molar mass of HCl

$$= 12 \text{ mol} \times 36.5 \text{ g mol}^{-1}$$

$$= 438 \text{ g}$$

Mass of water = mass of HCl solution – mass of HCl

Mass of water =  $1200 - 438 = 762 \text{ g}$

$$\text{Molarity} = \frac{12}{0.762} = 15.75 \text{ m}$$

**41. A 0.25 M glucose solution at 370.28 K has approximately the pressure as blood does what is the osmotic pressure of blood?**

$$C = 0.25 \text{ M}; T = 370.28 \text{ K}$$

$$(\pi)_{\text{glucose}} = CRT$$

$$(\pi) = 0.25 \text{ mol L}^{-1} \times 0.082 \text{ L atm K}^{-1} \text{ mol}^{-1} \times 370.28 \text{ K}$$

$$(\pi) = 7.59 \text{ atm}$$

**42. Calculate the molality of a solution containing 7.5 g of glycine ( $\text{NH}_2\text{-CH}_2\text{-COOH}$ ) dissolved in 500 g of water.**

$$\text{Molarity} = \frac{\text{No. of moles of solute}}{\text{Mass of the solvent (in kg)}}$$

$$\text{No. of moles of glycine} = \frac{\text{mass of glycine}}{\text{molar mass of glycine}}$$

$$= \frac{7.5}{75} = 0.1$$

$$\text{Molarity} = \frac{0.1}{0.5 \text{ Kg}} = 0.2 \text{ m}$$

**43. Which solution has the lower freezing point? 10 g of methanol ( $\text{CH}_3\text{OH}$ ) in 100 g of water (or) 20 g of ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ) in 200 g of water.**

$$\Delta T_f = K_f m$$

i.e.,  $\Delta T_f \propto m$

$$m_{\text{CH}_3\text{-OH}} = \frac{\left(\frac{10}{32}\right)}{0.1} = 3.125 \text{ m}$$

$$m_{\text{C}_2\text{H}_5\text{-OH}} = \frac{\left(\frac{20}{46}\right)}{0.2} = 2.174 \text{ m}$$

$\therefore$

Depression in freezing point is more in methanol solution and it will have lower freezing point.

**44. How many moles of solute particles are present in one litre of  $10^{-4}$  M potassium sulphate?**

In  $10^{-4}$  M  $\text{K}_2\text{SO}_4$  solution, there are  $10^{-4}$  moles of potassium sulphate.

$\text{K}_2\text{SO}_4$  molecule contains 3 ions ( $2\text{K}^+$  and  $1\text{SO}_4^{2-}$ )

1 mole of  $\text{K}_2\text{SO}_4$  contains  $3 \times 6.023 \times 10^{23}$  ions

$10^{-4}$  mole of  $\text{K}_2\text{SO}_4$  contains  $3 \times 6.023 \times 10^{23} \times 10^{-4}$  ions

$$= 18.069 \times 10^{19} \quad [\text{therefore } n_1$$

$$>> n_2; n_1 + n_2 \approx n_1]$$

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**45. Henry's law constant for solubility of methane in benzene is  $4.2 \times 10^{-5}$  mm Hg at a particular constant temperature. At this temperature. Calculate the solubility of methane at**

**i) 750 mm Hg**

**ii) 840 mm Hg**

$$(K_H)_{\text{benzene}} = 4.2 \times 10^{-5} \text{ mm Hg}$$

Solubility of methane = ? ;  $P = 750 \text{ mm Hg}$  ;  $P = 840 \text{ mm Hg}$

According to Henry's Law,

$$P = K_H \cdot X_{\text{in solution}}$$

$$750 \text{ mm Hg} = 4.2 \times 10^{-5} \text{ mm Hg} \cdot X_{\text{in solution}}$$

$$\rightarrow X_{\text{in solution}} = \frac{750}{4.2 \times 10^{-5}}$$

i.e, solubility =  $178.5 \times 10^5$

similarly at  $P = 840 \text{ mm Hg}$

$$\text{solubility} = \frac{840}{4.2 \times 10^{-5}} = 200 \times 10^5$$

**46. The observed depression in freezing point of water for a particular solution is  $0.093^\circ\text{C}$ . Calculate the concentration of the solution in molality. Given that molal depression constant for water is  $1.86 \text{ K Kg mol}^{-1}$**

$$\Delta T_f = 0.093^\circ\text{C} = 0.093\text{K}; m = ?$$

$$K_f = 1.86^\circ\text{C kg mol}^{-1}$$

$$\Delta T_f = K_f \cdot m$$

$$m = \frac{0.093 \text{ K}}{1.86 \text{ K kg mol}^{-1}} = 0.05 \text{ mol kg}^{-1} = 0.05m$$

**47. The vapour pressure of pure benzene ( $\text{C}_6\text{H}_6$ ) at a given temperature is  $640 \text{ mm Hg}$ .  $2.2 \text{ g}$  of non-volatile solute is added to  $40 \text{ g}$  of benzene. The vapour pressure of the solution is  $600 \text{ mm Hg}$ . Calculate the molar mass of the solute?**

$$P^\circ_{\text{C}_6\text{H}_6} = 640 \text{ mm Hg}$$

$W_2 = 2.2 \text{ g}$  (non volatile solute);  $W_1 = 40 \text{ g}$  (benzene)

$$P_{\text{solution}} = 600 \text{ mm Hg}; M_2 = ?$$

$$\frac{P^\circ - P}{P^\circ} = x_2; \quad \frac{640 - 600}{640} = \frac{n_2}{n_1 + n_2}; \quad \frac{40}{640} = \frac{n_2}{n_1}$$

$$0.0625 = \frac{W_2 \times W_1}{M_2 \times M_1}$$

$$M_2 = \frac{2.2 \times 78}{0.0625 \times 40} = 68.64 \text{ g mol}^{-1}$$