# **UNIT 9.SOLUTIONS**

# **BOOK BACK QUESTION AND ANSWERS:**

**31.Define (i) molality (ii) Normality** 

(i) molality

Number of moles of solute

 $Molality(m) = \frac{1}{Mass of the solvent(in Kg)}$ 

(ii) Normality

Number of gram equivalengt of solute Normality(N) =Volume of solution(in L)

# **32.What is a 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.

# 33. State and explain Henry's law.

# Henry's law.

"The partial pressure of the gas in vapour phase (vapour pressure of the solute) 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,

 $P_{solute} \alpha X_{solute in solution}$ 

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p_{solute} = K_H X_{solute} in solution
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Here.

P<sub>solute</sub> represents the partial pressure of the gas in vapour state which is commonly called as vapour pressure.

X<sub>solute</sub>in solution represents the mole fraction of solute in the solution.

KH is a empirical constant with the dimensions of pressure. The value of 'KH' depends on the nature of the gaseous solute and solvent. The above equation is a straight-line in the form of y=mx. The plot partial pressure of the gas against its mole fraction in a solution will give a straight line as .The slope of the straight line gives the value of KH.



# 34. State Raoult law and obtain expression for lowering of vapour pressure when non volatile solute is dissolved in solvent.

"The relative lowering of vapour pressure of an ideal solution containing the non volatile solute is equal to the mole fraction of the solute at a given temperature".

Psolution  $X_A$ -----(1)

Where  $x_A$  is the mole fraction of the solvent

Psolution= k  $X_A$ -----(2)

When  $x_A = 1$ ,

 $K = P^0$  solvent ( $P^0$  solvent is the partial pressure of pure solvent)

Psolution =  $P^0$  solvent  $X_A$ ------(3)

Psolution /  $P^0$ solvent = xA-----(4)

$$1-$$
Psolution /P<sup>0</sup>solvent =  $1-X_{A-}$ 

 $P^0$  solvent – P solution/  $P^0$  solvent =  $X_B$ ----(6)

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.

### **35.** What is molal depression constant? Does it depend on nature of the solute ?

Molal freezing point depression constant or cryoscopic constant (K<sub>f</sub>) is defined as the depression in

freezingpoint produced when one mole of solute is dissolved in one Kg of solvent .

It does not depend on the nature the solute but depends on the number of solute particles .

#### 36. What is osmosis?

which is a spontaneous process by which the solvent molecules pass through a semipermeable 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 :**A solution containing the maximum amount of solute that can be dissolved in a particular solvent at a particular temperature

**Unsaturated solution :** A solution into which more solute can be dissolved.

<b>Super saturated</b> : A solution in which more solute is dissolved than in a saturated solution.
<b>39.</b> Explain the effect of pressure on the solubility.
Effect of pressure: Generally 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) ≒ 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.
40. A sample of 12 M Concentrated hydrochloric acid has a density 1.2gL <sup>-1</sup> Calculate the molality. Given
Molarity = 12 M HCl
density of the solution = $1.2 \text{ g } \text{L}^{-1}$
In 12M HCl solution, there are 12 moles of HCl in 1 litre of the solution. Molality = no. of moles of solute mass of solvent (in Kg) calculate mass of water (solvent)
mass of 1 litre HCl solution
$= 1.2 \text{ gm} \text{J}^{-1} \times 1000 \text{ m} \text{J}$
$= 1.2 \text{ gmL}  \land 1000 \text{ mL}$ $= 1200 \text{ g}$
mass of Hcl = no. of moles of HCl $\times$ molar mass of HCl
$= 12 \text{ mol} \times 36.5 \text{g mol}^{-1}$
= 438  g
mass of water = mass of HCl solution – mass of HCl
mass of water = 1200 - 438 = 762 g
$molality = \frac{12}{0.762}$ $= 15.75m$
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 ?

41. C = 0.25 M

T = 370.28 K

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

 $(\pi)=0.25$  molL<sup>-1</sup>×0.082L atm K<sup>-1</sup>mol<sup>-1</sup> × 370.28K

= 7.59 atm

42. Calculate the molality of a solution containing 7.5 g of glycine (NH<sub>2</sub>-CH<sub>2</sub>-COOH) dissolved in 500 g of water.

 $molality = \frac{no. \text{ of moles of solute}}{mass \text{ of solvent (in Kg)}}$ no. of moles of glycine =  $\frac{mass \text{ of glycine}}{molar \text{ mass of glycine}}$   $= \frac{7.5}{75} = 0.1$   $molality = \frac{0.1}{0.5 \text{ Kg}}$  = 0.2 m

43. Which solution has the lower freening point?10 g of methanol (CH<sub>3</sub>OH) in 100g of water (or) 20 g of ethanol (C<sub>2</sub>H<sub>5</sub>OH) in 200 g of water.

 $\Delta T_{f} = K_{f} m$ 

ie  $\Delta T_f \alpha m$ 

$$m_{CH_3-OH} = \frac{\left(\frac{10}{32}\right)}{0.1} = 3.125m$$
$$m_{C_2H_5-OH} = \frac{\left(\frac{20}{46}\right)}{0.2} = 2.174m$$

: 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<sup>-4</sup> M potassium sulphate?

44. In  $10^{-4}$ M K<sub>2</sub>SO<sub>4</sub> solution, there are  $10^{-4}$  moles of potassium sulphate.

K<sub>2</sub>SO<sub>4</sub> molecule contains 3 ions (2K<sup>+</sup> and 1So<sub>4</sub><sup>2-</sup>)

1 mole of  $K_2SO_4$  contains  $3 \times 6.023 \times 10^{23}$  ions

 $10^{-4}$  mole of K<sub>2</sub>SO<sub>4</sub> contains  $3 \times 6.023 \times 10^{23} \times 10^{-4}$  ions

 $= 18.069 \times 10^{19}$ 

45. Henry's law constant for solubility of methane in benzene is 4.2x10<sup>-5</sup> mm Hg at a particular constant temperature At this temperature. Calculate the solubility of methane at i) 750 mm Hg ii) 840 mm Hg

 $(k_{\rm H})_{\rm bonzene} = 4.2 \times 10^{-5} \text{ mm Hg}$ 

Solubility of methane = ?

P = 750mm Hg \_\_\_\_ P = 840 mm Hg

According to Henrys Law,

 $\mathbf{P} = \mathbf{K}_{\mathrm{H}} \cdot \mathbf{x}_{\mathrm{in \ solution}}$ 

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

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

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

similarly at P = 840 mm Hg

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°C. Calculate the concentration of the solution in molality. Given that molal depression constant for water is 1.86 KKg mol<sup>-1</sup>

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 $\Delta T_{f} = 0.093^{\circ}C = 0.093K$ 

m = ?

 $K_{f} = 1.86K \text{ Kg mol}^{-1}$ 

 $\Delta T_f = K_f \cdot m$ 

 $\therefore m = \frac{\Delta T_f}{K_f}$  $= \frac{0.093 K}{1.86 K Kgmol^{-1}}$  $= 0.05 mol Kg^{-1}$ = 0.05m

47. The vapour pressure of pure benzene ( $C_6H_6$ ) at a given temperature is 640 mm Hg. 2.2 g of nonvolatile solute is added to 40 g of benzene. The vapour pressure of the solution is 600 mm Hg. Calculate the molar mass of the solute?

$$P_{C_{6}H_{6}}^{0} = 640 \text{mm Hg}$$

$$W_{2} = 2.2 \text{ g (non volabile solute)}$$

$$W_{1} = 40 \text{ g (benzene)}$$

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

$$M_{2} = ?$$

$$\frac{P^{o} - P}{P^{0}} = x_{2}$$

$$\frac{640 - 600}{640} = \frac{n_{2}}{n_{1} + n_{2}} \quad [\because n_{1} >> n_{2}; n_{1} + n_{2} \approx n_{1}]$$

$$\frac{40}{640} = \frac{n_{2}}{n_{1}}$$

$$0.0625 = \frac{W_{2} \times M_{1}}{M_{2} \times W_{1}}$$

$$M_{2} = \frac{2.2 \times 78}{0.0625 \times 40}$$

$$= 68.64 \text{ g mol}^{-1}$$

## **OTHER IMPORTANT QUESTION AND ANSWERS**

# 1.What are aqueous and non- aqueous solutions? **Aqueous solution:** If the water is used as the solvent, the resultant solution is called as an aqueous solution. **Non-Aqueous solution:** If solvents (Benzene, CCl<sub>4</sub>, ether etc.,) other than water is used, then the resultant solution is called as a non-aqueous solution. 2.Define the following concentration units. a) Molarity b) Formality c) Mole fraction. a) Molarity: $Molarity(M) = \frac{Number of moles of solute}{Volume of solution (in L)}$ **b)** Formality Number of formula weight of solute Formality(F) = Volume of solution (in L) c) Mole fraction. $Mole fraction(X) = \frac{Number of moles of the component}{Total number of moles of all the components present in solution}$ **3.Define the following terms.** a) Mass percentage(%w/w) b) Volume percentage(%v/v) c) Mass by volume percentage(%w/v) d) parts per million (ppm) a) Mass percentage(%w/w) Mass percentage = $\frac{\text{Mass of solute(in g)}}{\text{Mass of the solution(in g)}} \times 100$ b) Volume percentage(%v/v) Volume percentage = $\frac{\text{Volume of the solute(in mL)}}{\text{Volume of the solution(in mL)}} X 100$ c) Mass by volume percentage(%w/v) Mass by volume percentage = $\frac{\text{Mass of solute(in g)}}{\text{Volume of the solution(in mL)}} X100$ d) parts per million (ppm) Parts per million = $\frac{\text{Mass of the solute}}{\text{Mass of the solution}} \times 100$

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## 4.Define standard solutions

A standard solution or a stock solution is a solution whose concentration is accurately known.

## 5. Define working standards.

At the time of experiment, the solution with required concentration is prepared by diluting the stock solution. This diluted solution is usually called working standard.

## 6. Write the advantages of using standard solutions.

1. The error due to weighing the solute can be minimised by using concentrated stock solution that requires large quantity of solute.

2. We can prepare working standards of different concentrations by diluting the stock solution, which is more efficient since consistency is maintained.

3. Some of the concentrated solutions are more stable and are less likely to support microbial growth than working standards used in the experiments.

## 7.Explain the limitations of Henry's law.

1.Henry's law is applicable at moderate temperature and pressure only.

2. Only the less soluble gases obeys Henry's law

3. The gases reacting with the solvent do not obey Henry's law. For example, ammonia or HCl reacts with water and hence does not obey this law.  $NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$ 

4. The gases obeying Henry's law should not associate or dissociate while dissolving in the solvent.

#### 8. Define solubility

The solubility of a substance at a given temperature is defined as the amount of the solute that can be dissolved in 100 g of the solvent at a given temperature to form a saturated solution.

#### 9.What are ideal and non ideal solutions?

#### **Ideal solution**

An ideal solution is a solution in which each component i.e. the solute as well as the solvent obeys the Raoult's law over the entire range of concentration. Example: benzene and toluene

#### Non-ideal solution

The solutions which do not obey Raoult's law over the entire range of concentration, are called nonideal solutions. Example: Benzene and acetone.

#### 10. Define colligative properties.

The properties which do not depend on the chemical nature of the solute but depends only on the number of solute particles (ions/molecules) present in the solution.

- Relative lowering of vapour pressure
- Elevation of boiling point,
- Depression in freezing point
- Osmotic pressure

#### 11.Define relative lowering of vapour pressure

The vapour pressure of a solution containing a non volatile, non-electrolyte solute is always lower than the vapour pressure of the pure solvent.

 $\frac{P0 \text{ solvent} - Psolution}{P0 \text{ solvent}} = X_B(\text{mole fraction of the solute})$ 

#### **12.Define elevation of boiling point.**

When a non volatile solute is added to a pure solvent at its boiling point, the vapour pressure of the solution is lowered below 1 atm. To bring the vapour pressure again to 1 atm, the temperature of the solution has to be increased. As a result, the solution boils at a higher temperature (Tb) than the boiling point of the pure solvent ( $T_b^\circ$ ). This increase in the boiling point is known as elevation of boiling point.

#### The elevation of boiling point ( $\Delta T_b$ )= $T_b$ - $T_b^{\circ}$

#### **13.Define Depression in freezing point.**

The lowering of the freezing point of the solvent when a solute is added is called depression in freezing point ( $\Delta T_f$ ).

The depression in freezing temperature  $(\Delta T_f)$  can be expressed as,  $\Delta T_f = T_f^0 - T_f$ 

#### 14.Define Osmotic pressure.

The pressure that must be applied to the solution to stop the influx of the solvent (to stop osmosis) through the semi permeable membrane.

#### 15.What is meant by Reverse Osmosis (RO)?

It can be defined as a process in which a solvent passes through a semi permeable membrane in the opposite direction of osmosis, when subjected to a hydrostatic pressure greater than the osmotic pressure.

#### 16. What are abnormal molar mass?

The value of the molar mass of the solute determined using colligative properties would be different from the actual molar mass, and it is called abnormal molar mass.

### 17. Define Van't Hoff factor.

It is defined as the ratio of the actual molar mass to the abnormal(calculated) molar mass of the solute.

Normal( actual) molar mass

Observed (abnormal)molar mass

Observed colligative property Calculated colligative property

## 18. Write the relation between Van't Hoff factor and Degree of dissociation or association.

Relation between Van't Hoff factor and Degree of dissociation:

$$\alpha$$
 dissociation =  $\frac{i-1}{n-1}$ 

Relation between Van't Hoff factor and Degree of association:

$$\alpha$$
 association =  $\frac{(1-i)n}{n-1}$ 

#### 19.Explain the determination of molar mass weights from relative lowering of vapour pressure.

The measurement of relative lowering of vapour pressure can be used to determine the molar mass of a non volatile solute. For this purpose, a known mass of the solute is dissolved in a known quantity of solvent. The relative lowering of vapour pressure is measured experimentally.

According to Raoult's law the relative lowering of vapor pressure is,

 $\frac{Po \text{ solvent - Psolution}}{Posolvent} = X_B(\text{mole fraction of the solute}) ------(1)$ 

 $n_A \,$  and  $n_B \,$  are the moles of the solvent and solute For dilute solutions  $n_A >> n_B$  . Hence  $n_A + n_B$  =  $n_A$ 

$$X_{\rm B} = \frac{n{\rm B}}{n{\rm A}} \qquad (3)$$

 $n_A = W_A \ / \ M_A \quad \text{and} \ \ n_B = W_B \ \ / \ M_B \label{eq:nA}$  Equation 3 becomes

 $X_B = W_B / M_B / W_A / M_A$  (4)

$$\frac{P0 \text{ solvent - Psolution}}{P0 \text{ solvent}} = W_B / M_B / W_A / M_A$$

Relative lowering of vapour pressure  $(\Delta p/p^0_A) = W_B \times M_A / W_A \times M_B$  ------(5)

From eqn 5 the molar mass of the solute  $(M_B)$  can be calculated using the known values of  $W_A$ ,  $W_B$ ,  $M_A$  and the measured  $\Delta p/p^0{}_A$ .

Therefore;

#### molar mass of the solute $M_B = p_A^0 x W_B x M_A / \Delta p x W_A$

**20.Explain the determination of molar mass of solute from depression in freezing point.** If the solution is prepared by dissolving  $W_B g$  of solute in  $W_A g$  of solvent, then the molality is,

$$m = \frac{\text{Number of moles of solute x1000}}{\text{Weight of solvent in grams}}$$
(1)

Number of moles of solute =  $W_B / M_B$  -----(2)

Where M<sub>B</sub> is molar mass of solute

Therefore,

 $m = W_B x \ 1000 / M_B x W_A$  -----(3)

We know that, Depression in freezing point is

 $\Delta T_{\rm f} = K_{\rm f} \ m \ -----(4)$ 

Substituting eqn 3 into eqn 4

 $\Delta T_{\rm f} = K_{\rm f} x W_{\rm B} x 1000 / M_{\rm B} x W_{\rm A}$  -----(5)

Molar mass can be calculated using eqn 5,

#### $\mathbf{M}_{\mathbf{B}} = \mathbf{K}_{\mathbf{f}} \mathbf{x} \mathbf{W}_{\mathbf{B}} \mathbf{x} \mathbf{1000} / \Delta \mathbf{T}_{\mathbf{f}} \mathbf{x} \mathbf{W}_{\mathbf{A}}$

21.Explain the determination of molar mass from Osmotic pressure.

According to Van't Hoff equation

 $\Pi = cRT -----(1)$ 

c = n / V -----(2)

Here,

n = number of moles of solute dissolved in 'V' litre of the solution

Therefore

 $\pi = n R T / V$  -----(3)

If the solution is prepared by dissolving  $W_B$  g of non volatile solute in  $W_A$  g of solvent, then the number of moles 'n' is,

 $n = W_B / M_B$  -----(4)

 $M_B$  = molar mass of the solute

Substituting the (eqn 4) in eqn (3)

 $\mathbf{H} = \mathbf{W}_{\mathbf{B}} \mathbf{R} \mathbf{T} / \mathbf{V} \mathbf{M}_{\mathbf{B}}$  $\mathbf{M}_{\mathbf{B}} = \mathbf{W}_{\mathbf{B}} \mathbf{R} \mathbf{T} / \mathbf{V}_{\mathbf{B}} \mathbf{H}$ 

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