

SOLUTIONS

Very Short Answer Questions:

***1. State Henry's law?**

Sol. Henry's law states that 'the solubility of a gas in a liquid is directly proportional to the pressure of the gas at a given temperature.'

Or

'The partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution'.

It is expressed as, $p = K_H x$

Where, K_H = Henry's law constant.

p = Partial pressure of the gas in vapour phase.

x = Mole fraction of the gas.

*** 2. What is Ebullioscopic constant?**

Ans. Molal elevation constant or Ebullioscopic constant may be defined as the elevation in boiling point when the molality of the solution is unity, i.e., one mole of the solute is dissolved in 1000g (1kg) of the solvent.

The units of K_b are K/m or $K \text{ kg mol}^{-1}$. $K_b = \frac{RT_b^2}{1000L_v}$ Where R = Gas constant

T_b = boiling point of the solvent in Kelvin and L_v = Latent heat of vapourisation.

***3. What is Cryoscopic constant?**

Ans. Molal depression constant or Cryoscopic constant may be defined as the depression in freezing point when the molality of the solution is unity, i.e., one mole of the solute is dissolved in 1000g (1kg) of the solvent.

The units of K_f are K/m or $K \text{ kg mol}^{-1}$. $K_f = \frac{RT_f^2}{1000L_f}$ Where R = Gas constant

T_f = Freezing point of the solvent in Kelvin and L_f = Latent heat of fusion.

4. Define Osmotic pressure?

Ans. The hydrostatic pressure developed on the diluted aqueous solution at equilibrium state due to inflow of water when the solution is separated from the water by a semipermeable membrane is called osmotic pressure.

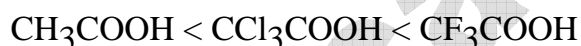
*5. What are isotonic solutions?

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

E.g. Human blood is isotonic with normal saline solution i.e. 0.9% (w/v) sodium chloride solution.

6. The depression in freezing point of water observed for the same amount of acetic acid, trichloroacetic acid and tri fluoroacetic acid increases in the order given above. Explain briefly?

Ans. The depression in freezing point of a solute in water depends upon the number of particles or ions in its aqueous solution or its degree of dissociation (α). Three acids are arranged in the order of their increasing acidic strengths as follows:



Fluorine is more electronegative than chlorine. So, trifluoroacetic acid is stronger acid than trichloroacetic acid which in turn stronger than acetic acid. The order of depression in freezing point is also the same.

7. Calculate the mass percentage of aspirin ($\text{C}_9\text{H}_8\text{O}_4$) in aceto nitrile (CH_3CN) when 6.5 g of $\text{C}_9\text{H}_8\text{O}_4$ is dissolved in 450 g of CH_3CN ?

Ans. Mass of aspirin = 6.5 g

Mass of acetonitrile = 450 g

Mass of solution = (6.5 + 450) g = 456.5 g

$$\text{Mass \%} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$\text{Mass \%} = \frac{(6.5)\text{g}}{(456.5)\text{g}} \times 100 = 1.424\%$$

8. Calculate the amount of benzoic acid (C_6H_5COOH) required for preparing 250 ml of 0.15 M solution in methanol?

Ans. Molarity = 0.15 M or 0.15 mol L^{-1} .

Volume solution = 250 ml = 0.25 L

Molar mass of solute = $(12 \times 6) + (1 \times 5) + (12) + (16 \times 2) + 1 = 122 \text{ g mol}^{-1}$.

$$\text{Molarity} = \frac{\text{Mass}}{\text{Molar mass}} \times \frac{1}{\text{Volume (L)}}$$

$$(0.15 \text{ mol L}^{-1}) = \frac{W}{(122 \text{ g mol}^{-1})} \times \frac{1}{(0.25 \text{ L})}$$

Mass of solute = $(0.15 \times 122 \times 0.25) \text{ g} = 4.575 \text{ g}$.

(Benzoic acid)

*9. What is van'tHoff factor 'i' and how it is related to α in the case of a binary electrolyte (1:1)?

Ans. van't Hoff factor is the ratio of observed and calculated colligative property of a solute undergo either dissociation or association in a solution..

$$\text{van't Hoff's factor (i)} = \frac{\text{observed colligative property}}{\text{calculated colligative property}}$$

For solutes undergo dissociation, $\alpha = \frac{i-1}{n-1}$,

In the case of a binary electrolyte (1:1), $n=2$

$$\therefore \alpha = \frac{i-1}{2-1} = i-1, \therefore i = \alpha + 1$$

*10. Calculate the mole fraction of H_2SO_4 in a solution containing 98% H_2SO_4 by mass?

Ans. 98% by mass means 100gm of solution contains 98gm of H_2SO_4

Wt of H_2SO_4 = 98gm, wt of water = $100 - 98 = 2$ gm

Moles of H_2SO_4 i.e. $n_1 = 98/98 = 1$ and moles of water i.e. $n_2 = 2/18 = 1/9$

$$\text{Mole fraction of } H_2SO_4 = \frac{n_1}{n_1 + n_2} = \frac{1}{1 + \frac{1}{9}} = \frac{9}{10} = 0.9$$

Short Answer Questions

*1. Define the following terms: (i) Mole Fraction (ii) Molality (iii) Molarity of a Solution.

(i) Mole Fraction: Mole fraction may be defined as the ratio of the number of moles of one component (solute or solvent) to the total number of all the components present in the solution.

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

For example, in a binary mixture, if the number of moles of A and B are n_A and n_B respectively, the mole fraction of A and B will be x_A and x_B .

$$x_A = \frac{n_A}{n_A + n_B} \quad ; \quad x_B = \frac{n_B}{n_A + n_B}$$

Mole fraction has no units and is temperature independent.

(ii) Molality: The number of moles of the solute (n) per kilogram (kg) of the solvent is known as molality (m). It is independent of temperature.

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

Unit of molality is **mol kg⁻¹** or **m (molal)**.

(iii) Molarity: Molarity (M) is defined as the number of moles of solute dissolved in one litre (or one cubic decimetre) of solution. It depends on temperature.

$$\text{Molarity (M)} = \frac{\text{Moles of solute}}{\text{Volume of solution in litre}}$$

Unit of molarity is **mol L⁻¹** or **M (Molar)**.

2. Define mass percentage, volume percentage and mass to volume percentage of solutions?

Ans. Mass percentage $\left(\frac{w}{W}\right)$: The mass percentage of a component of a solution is defined as, the amount of solute in grams dissolved in 100g of solution

$$\therefore \text{mass \% of a component} = \frac{\text{mass of the component in the solution}}{\text{total mass of the solution}} \times 100$$

It will not change with temperature

Volume percentage $\left(\frac{v}{V}\right)$: The volume percentage is defined as the volume of a component in ml present in 100 ml of solution

$$\text{Volume \% of a component} = \frac{\text{mass of component}}{\text{total volume of solution}} \times 100$$

It decreases with increase in temperature

Mass by volume percentage (W/V):

It is defined as mass of a component in gms present in 100ml of the solution

$$\text{Mass by volume \% of a component} = \frac{\text{mass of component}}{\text{total volume of solution}} \times 100$$

It decreases with increase in temperature.

****3. State Raoult's law. Calculate the vapour pressure of a solution containing 9 gm of glucose in 162 gm of water at 298K. The vapour pressure of pure water at 298K is 17.535 mm of Hg?**

Ans. Raoult's law states that

“At a given temperature the vapour pressure of solution (P^s) containing non volatile solute is directly proportional to mole fraction of solvent in it”.

Let a solution contains n_A moles of solvent and n_B moles of solute, then according to Raoult's law,

$$P^s \propto X_A, \text{ Where } X_A \text{ is the molefraction of solvent.}$$

(Or) The relative lowering in vapour pressure of a solution containing non –volatile solute is equal to the mole fraction of solute present in it.

i.e. $\frac{P^0 - P^s}{P^0} = X_B$ (mole fraction of solute) Or $\frac{P^0 - P^s}{P^0} = \frac{wM}{Wm}$ where w, W are weights and m, M are molecular weights of solute and solvent respectively.

Solution: According to Raoult's law $\frac{P^0 - P^s}{P^0} = \frac{wM}{Wm}$; $\frac{17.535 - P^s}{17.535} = \frac{9 \times 18}{162 \times 180}$

$$\frac{17.535 - P^s}{17.535} = \frac{1}{180} \Rightarrow P^s = 17.535 - \frac{17.535}{180} = 17.535 - 0.09742 = 17.43758 \text{ mm}$$

4. i. What is an ideal solution?

ii. Heptane and octane form an ideal solution. At 373K the vapour pressure of the two liquid components are $105.2Kp_a$ and $46.8Kp_a$ respectively. What will be the vapour pressure of a mixture of 26.0g heptane and 35g of octane?

Ans. I. A solution which obeys Raoult's law at all conditions of concentration and temperature is called an ideal solution. During the formation of an ideal solution ΔH_{mix} is zero and ΔV_{mix} is zero.

E.g.: A mixture of Benzene and Toluene.

ii. Solution: Heptane (C_7H_{16})

Octane (C_8H_{18})

$$P_A^0 = 105.2Kp_a$$

$$P_B^0 = 46.8Kp_a$$

$$n_A = \frac{wt}{m.wt} = \frac{26}{100} = 0.26$$

$$n_B = \frac{wt}{m.wt} = \frac{35}{114} = 0.3070$$

$$X_A = \frac{n_A}{n_A + n_B} = \frac{0.26}{0.26 + 0.3070} = 0.4585$$

$$X_B = 1 - X_A = 1 - 0.4585 = 0.5415$$

$$\text{Total pressure } (P_T) = P_A^0 \cdot X_A + P_B^0 \cdot X_B = 105.2 \times 0.4585 + 46.8 \times 0.5415 = 73.5764Kp_a$$

5. What is meant by positive deviation from Raoult's law and how is the sign of ΔH_{mix} related to positive deviation from Raoult's law?

Ans. In a solution showing +ve deviation the vapour pressure of the solution is higher than that of an ideal solution of the same composition and in similar conditions. This is because the partial vapour pressure of each liquid is higher than would be expected on the basis of Raoult's law.

In solutions showing +ve deviation, the attractive forces between molecules of A and B is less than between A-A molecules and B-B molecules

For non-ideal solutions show +ve deviation, $\Delta H_{mix} > 0$ i.e +ve and $\Delta V_{mix} > 0$.

6. How is molar mass related to the elevation in boiling point of a solution?

Ans. The increase in the boiling point of a liquid when a non volatile solute is dissolved in it is called elevation of boiling point. Thus boiling point of solution is greater than the boiling point of pure solvent. It is denoted by ΔT_b .

ΔT_b = boiling point of solution - boiling point of pure solvent.

$$\Delta T_b \text{ is proportional to molality, } (\Delta T_b) = K_b \times m = \frac{k_b \times a \times 100}{M \times b}$$

Where K_b = molality elevation constant (or) ebullioscopic constant. a ,b are the weights of solute and solvent in gms. M is the molar mass of solute.

7. What is relative lowering of vapour pressure? How is it useful to determine the molar mass of a solute?

Ans. The ratio of lowering of vapour pressure ($P_0 - p_s$) to the vapour pressure of the pure solvent is known as the relative lowering of vapour pressure. It is denoted by $\left(\frac{P_0 - p_s}{P_0} \right)$

According to Raoult's law the relative lowering of vapour pressure of a dilute solution of non-volatile solute is equal to the mole fraction of the solute. Thus the molecular weight of solute (m) can be calculated as follows.

$$\text{i.e. } \frac{p_0 - p_s}{p_0} = \frac{n_s}{n_s + n_0}; \frac{p^\circ - p^s}{p^\circ} = \frac{wM}{Wm}; m = \frac{w \times W \times p^\circ}{W(p_0 - p_s)}$$

Where w , W are the weights of solute and solvent in gms. m & M are the molar mass of solute and solvent respectively.

****8. A solution of sodium hydroxide in water is labeled as 10% (w/w). What would be the mole fraction of NaOH in the solution?**

Ans. 10 % (w/w) NaOH solution means 10gms of NaOH present in 100gm of solution

\therefore Wt of NaOH (w) = 10gm

NaOH	water
$w_1 = 10$	$w_2 = 90$

$$n_1 = \frac{w_1}{m_1} = \frac{10}{40} = 0.25 \quad n_2 = \frac{w_2}{m_2} = \frac{90}{18} = 5$$

$$\text{Mole fraction NaOH } (X_1) = \frac{n_1}{n_1 + n_2} = \frac{0.25}{0.25 + 5} = \frac{1}{21} = 0.0467$$

9. Calculate the mass of a non-volatile solute (molar mass 40g mol^{-1}) which should be dissolved in 114gm octane to reduce its vapour pressure to 80%.

Ans. Let the vapour pressure of pure octane = 100mm

\therefore Vapour pressure of solution $P = 80\text{mm}$

Solute	solvent (octane)
$w = ?$	$W = 114\text{gm}$
$m = 40$	$M = 114$

$$\therefore \frac{p^o - p^s}{p^o} = \frac{w}{m} \times \frac{M}{W}$$

$$\frac{100 - 80}{100} = \frac{w}{40} \times \frac{114}{114}$$

$$\frac{20}{100} = \frac{w}{40}$$

$$\therefore w = 8\text{g}$$

10. A solution of glucose in water is labeled as 10% w/w. What would be the molarity of the solution?

Ans. 10% $\left(\frac{w}{W}\right)$ glucose solution means 100gms of solution contains 10gm of glucose

\therefore Wt of glucose (w) = 10gms

Wt of water (w) = 90gm

∴ Volume of solution = 90ml (assuming density of solution=1 gm/ml)

$$\begin{aligned}\therefore \text{Molarity} &= \frac{w}{gmw} \times \frac{1000}{v \text{ in ml}} \\ &= \frac{10}{180} \times \frac{1000}{90} = 0.617M\end{aligned}$$

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