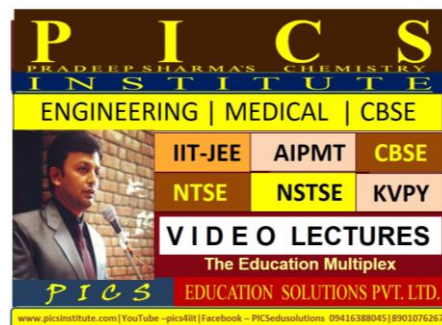


SOLUTIONS

Section A : LEARNING POINTS:



Units of concentration of Solution :

(i) Mass Percentage(w/w): Amount of solute present in grams dissolved per 100g of solution.

Ex : 10% (w/w) glucose in water by mass, it means that 10 g of glucose is dissolved in 90 g of water resulting in a 100 g solution.

(ii) Volume percentage (v/v): Volume of solute present in 100ml of solution.

Ex : 10%(v/v) Alcohol in water by volume, it means that 10 ml of alcohol present in a 100 ml of solution.

(iii) Parts per million (ppm)- Amount of substance present in grams in 10^6 gm of solution.

(iv) Mole fraction (X) -It is the ratio of number of mole of a particular component to the total number of moles of all the components present in the solution.

$$X_A = n_A / (n_A + n_B), \quad X_B = n_B / (n_A + n_B),$$

Where X_A & X_B are the mole fractions of Solvent and Solute respectively. n_A & n_B are the number of moles of Solvent and Solute respectively.

(v) Molarity (M) - No. of mole of solute present per litre of solution.

$$M = (n_B / V) \times 1000$$

Where

$m = \frac{w_B \times 1000}{M_B \times V}$	n_B - No. of moles of solute V - Volume of solution in ml. w_B - amount of solute M_B - Molar Mass of solute
--	---

(vi) Molality :- (m) No. of moles of solute present per 1000 g or 1. kg solvent.

Where

$m = \frac{w_B \times 1000}{M_B \times w_A}$	n_B - No. of moles of solute w_A - amount of solvent in gm. w_B - amount of solute M_B - Molar Mass of solute
--	--



Solubility:

1) Solubility of a Solid in Liquids: It is observed that polar solutes dissolve in polar solvents and non polar solutes in nonpolar solvents.

Ex: Sodium chloride and sugar dissolve readily in water. Naphthalene and anthracene dissolve readily in benzene.

In general, a solute dissolves in a solvent if the intermolecular interactions are similar in the two.

Dissolution: When a solid solute is added to the solvent, some solute dissolves and its concentration increases in solution. This process is known as dissolution.

Crystallisation: Some solute particles in solution collide with the solid solute particles and get separated out of solution. This process is known as crystallisation.

A stage is reached when the two processes occur at the same rate. Under such conditions, number of solute particles going into solution will be equal to the solute particles separating out and a state of dynamic equilibrium is reached.



Effect of temperature:

The solubility of a solid in a liquid is significantly affected by temperature changes.

According to **Le Chateliers Principle**, the dissolution process is endothermic ($\Delta_{\text{sol}} H > 0$), the solubility should increase with rise in temperature and if it is exothermic ($\Delta_{\text{sol}} H < 0$) the solubility should decrease. These trends are also observed experimentally.

Effect of pressure:

Pressure does not have any significant effect on solubility of solids in liquids.

2. Solubility of gases in Liquids:

- 1) Oxygen dissolves only to a small extent in water. It is this dissolved oxygen which sustains all aquatic life.
- 2) Hydrogen chloride gas (HCl) is highly soluble in water.

Solubility of gases in liquids is greatly affected by pressure and temperature. The solubility of gases increase with increase of pressure.

Henry was the first to give a quantitative relation between pressure and solubility of a gas in a solvent which is known as

Henry's law: The law states that at a constant temperature, **the solubility of a gas in a liquid is directly proportional to the pressure of the gas.**

The solubility of a gas in a liquid solution is a function of partial pressure of the gas. If we use the mole fraction of a gas in the solution as a measure of its solubility, then it can be said that

"The mole fraction of gas in the solution is proportional to the partial pressure of the gas over the solution." $p = K_H \times$

Here K_H → is the Henry's law constant.

X → is mole fraction of gas in the solution.

P → partial pressure of the gas.

Henry's law & its applications:

- 1) Solubility of a gas 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.
- 2) To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.

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- 3) 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. When the divers come towards surface, the pressure gradually decreases. This releases the dissolved gases and leads to the formation of bubbles of nitrogen in the blood. This blocks capillaries and creates a medical condition known as bends, which are painful and dangerous to life.

To avoid bends, as well as, the toxic effects of high concentrations of nitrogen in the blood, the tanks used by scuba divers are filled with air diluted with helium (11.7% helium, 56.2% nitrogen and 32.1% oxygen).

- 4) 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. Low blood oxygen causes climbers to become weak and unable to think clearly, symptoms of a condition known as anoxia.

Effect of Temperature:

Solubility of gases in liquids decreases with rise in temperature. The dissolution of a gas in liquid is an exothermic process involves dynamic equilibrium and thus must follow Le Chatelier's Principle. As the temperature increases the solubility of gas decreases.

From Henry's law:

As the temperature increases the value of K_H increases, we know that K_H is inversely proportional to Mole fraction of the gas i.e solubility of the gas (From Henry's law). So, as the temperature increases the solubility of a gas decreases.

Vapour Pressure and Raoult's law :-

a) Raoult's law for binary solutions of volatile liquids: At a given temperature, for a solution of volatile liquids, the partial vapour pressure of each component is equal to the product of the vapour pressure of the pure component and its mole fraction .

If the solution contains A & B are two volatile liquids, then

$$\text{i.e.} \quad P_A = p_A^0 X_A \quad \& \quad P_B = p_B^0 X_B$$

Where \rightarrow p_A and p_B are the vapour pressures of A and B in solution respectively. p_A^0 & p_B^0 are the vapour pressures of A and B in their pure state respectively.

x_A and x_B are the molefractions of A and B in solution respectively.

b) Raoult's law for solution containing Non - volatile solute: At a given temperature, the relative lowering vapour pressure of a solution is equal to the mole fraction of the solute.

Derivation :

We know that, from Raoult's law,

$$P_{\text{solution}} = p_A + p_B$$

$$P_{\text{solution}} = p_A^0 X_A + p_B^0 X_B$$

$$P_{\text{solution}} = p_A^0 X_A + 0 \quad (\text{Since } p_B^0 = 0, \text{ because B is a non-volatile solute})$$

$$P_{\text{solution}} = X_A P_A^0$$

□

$$P_{\text{solution}} = (1 - X_B) P_A^0 \quad (\text{Since } X_A + X_B = 1)$$

□

$$(P_{\text{solution}} - P_A^0) = -X_B P_A^0 \quad \square$$

$$(P_A^0 - P_{\text{solution}}) / X_B = P_A^0$$

$$\text{Where, } (P_A^0 - P_{\text{solution}}) \rightarrow \text{Lowering of vapour pressure}$$

$$(P_A^0 - P_{\text{solution}}) / P_A^0 \rightarrow \text{Relative lowering of vapour pressure.}$$

$$X_B \rightarrow \text{Mole fraction of Solute.}$$

Ideal and Non-Ideal Solutions :

a) Ideal Solutions : The solution which obeys Raoult's law exactly at all concentration and all temperatures.

The ideal solution also have following characteristics:

i) It should obey the Raoult's law (Total pressure, $P = p_A^0 X_A + p_B^0 X_B$) ii)

Heat exchange on mixing is zero ($\Delta H_{\text{mix}} = 0$) iii) Volume exchange on mixing is zero

($\Delta V_{\text{mix}} = 0$)

b) Non ideal solutions:

The solution which do not obey Raoult's law are called non ideal solutions. For these solutions

$$\text{i) } p_A \neq p_A^0 x_A \quad \text{and} \quad p_B \neq p_B^0 x_B, \quad \text{ii) } \Delta H_{\text{mixing}} \neq 0, \quad \text{iii) } \Delta V_{\text{mixing}} \neq 0$$

Types of non ideal Solutions :

A) Non ideal solution showing positive deviation from Raoult's law :

→ The Mixture contains two components namely A and B, **If the interaction between A-B molecules is weaker than the interactions between A-A or B-B or both**, then the solution deviate from the ideal behavior and Each component of solution has a partial vapour pressure greater than expected on the basis of Raoult's law .

→ The total vap. Pressure will be greater than corresponding Vap. Pressure expected in case of ideal solution of the same composition

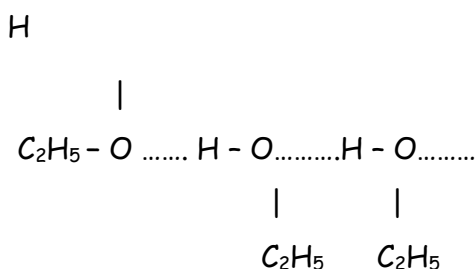
$$p_A > p_A^0 x_A \quad \text{and} \quad p_B > p_B^0 x_B$$

$$\text{Total Vapour pressure } P, \quad P = (p_A + p_B) > (p_A^0 x_A + p_B^0 x_B)$$

→ Example: Mixture of Ethyl alcohol and Cyclohexane.

→ Explanation for positive deviation:

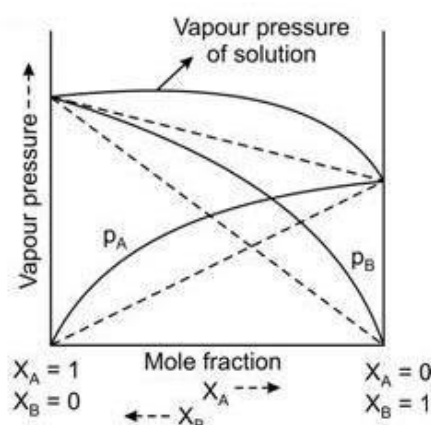
→ In ethyl alcohol the molecules are held together by hydrogen bonding.



→ When Cyclohexane is added to ethyl alcohol, the Cyclohexane molecules occupy spaces between ethyl alcohol molecules. As a result , some hydrogen bonds in alcohol molecules break. The escaping tendency of alcohol and Cyclohexane molecules from solution increases. So there is increase in vapour pressure. In

$$\text{such case} \quad \text{i) } \Delta H_{\text{mixing}} > 0, \quad \text{ii) } \Delta V_{\text{mixing}} > 0$$

Graph of a Positive deviation:



B) Non ideal solution showing negative deviations from Raoult's law:

→ The Mixture contains two components namely A and B, **If the interaction between A-B molecules is stronger than the interactions between A-A or B-B or both**, then the solution deviate from the ideal behavior and Each component of the solution has a partial vapour pressure less than from pure liquids. As a result, each component of solution has a partial vapour pressure less than expected on the basis of Raoult's law.

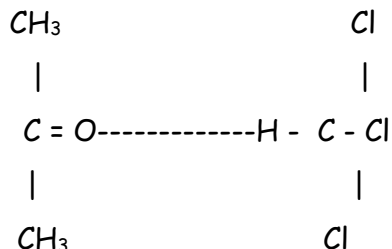
Hence total vap.pressure becomes less than the corresponding vap. pressure expected in case of ideal solution $p_A < p_A^0 x_A$ and $p_B < p_B^0 x_B$

$$\text{Total Vapour pressure } P, P = (p_A + p_B) < (p_A^0 x_A + p_B^0 x_B)$$

→ Example: Mixture of Acetone and Chloroform

→ Explanation for negative deviation:

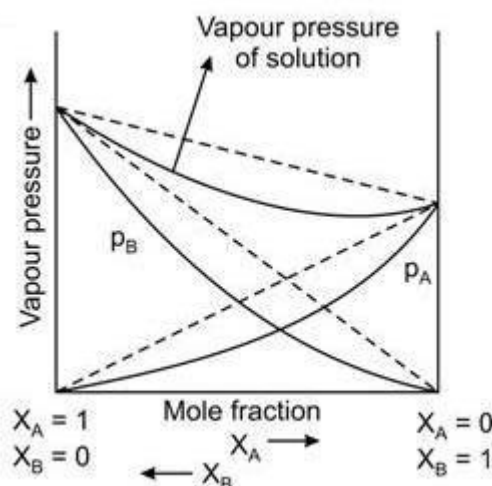
→ By Mixing Acetone and chloroform, a new attractive forces are formed due to in intermolecular hydrogen bonding. Hence the attractive forces become stronger and the escaping tendency of each liquid from the solution decreases.



→ So, the Vapour pressure of the solution is less than expected for an ideal solution . In such case

- (i) $\Delta H_{\text{mixing}} < 0$
- (ii) $\Delta V_{\text{mixing}} < 0$

Graph of a Negative deviation:



Azeotropes:

The binary mixtures having the same composition in liquid and vapour phase and boil at a constant temperature.

Types of Azeotropes:



i) Minimum boiling azeotropes:

.

The solutions which show a large **positive deviation from Raoult's law** form **minimum boiling azeotrope** at a specific composition.

Example: Ethanol-water mixture (obtained by fermentation of sugars) on fractional distillation gives a solution containing approximately 95% by volume of ethanol. Once this composition, known as azeotrope composition, has been achieved, the liquid and vapour have the same composition, and no further separation occurs.

ii) Maximum boiling azeotropes:

The solutions that show large negative **deviation from Raoult's law** form **maximum boiling azeotrope** at a specific composition.

Example: Nitric acid and water is an example of this class of azeotrope. This azeotrope has the approximate composition, 68% nitric acid and 32% water by mass, with a boiling point of 393.5 K.

Colligative Properties:

The properties of the solutions which depends only on the number of the solute particles but not on the nature of the solute are called Colligative properties.

Four important Colligative properties are:

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

a) Relative lowering of vapour pressure:

According to Raoult's law, At a given temperature, the relative lowering vapour pressure of a solution is equal to the mole fraction of the solute.

$$\frac{(P_{0A} - P_{\text{solution}})}{P_{0A}} = X_b$$

$$\frac{n_B}{n_A + n_B} (P_A^0 - P_{\text{solution}}) = \frac{n_B}{n_A} P_A^0$$

$$\frac{n_B}{n_A} (P_A^0 - P_{\text{solution}}) = \frac{n_B}{n_A} P_A^0$$

(since for dilute solutions $n_A \gg n_B$)

Where, $n_A \rightarrow$ No. of moles of solvent in solution
 $n_B \rightarrow$ No. of moles of solute in solution

$$\frac{w_B/M_B}{w_A/M_A} (P_A^0 - P_{\text{solution}}) = \frac{n_B}{n_A} P_A^0$$



$$M_B = \frac{w_B \times P_A^0 \times M_A}{(P_A^0 - P_{\text{solution}}) \times w_A}$$

Where, w_A and w_B are the Mass of solvent and solute respectively.

M_A and M_B are the Molar mass of Solvent and Solute respectively.

P_A^0 and P_{solution} are the vapour pressure of pure solvent and solution respectively.

Thus, molar mass of the solute can be determined if the other quantities w_A , w_B , M_A and relative lowering of vapour pressure ($P_A^0 - P_{\text{solution}}$) are known.

The composition of vapour phase in equilibrium with the solution is determined by the partial pressures of the components. If y_1 and y_2 are the mole fractions of the components 1 and 2 respectively in the vapour phase then, using Dalton's law of partial pressures:

$$p_1 = y_1 p_{\text{total}} \quad \& \quad p_2 = y_2 p_{\text{total}}$$

In general, $p_i = y_i p_{\text{total}}$

b) Elevation of boiling point:

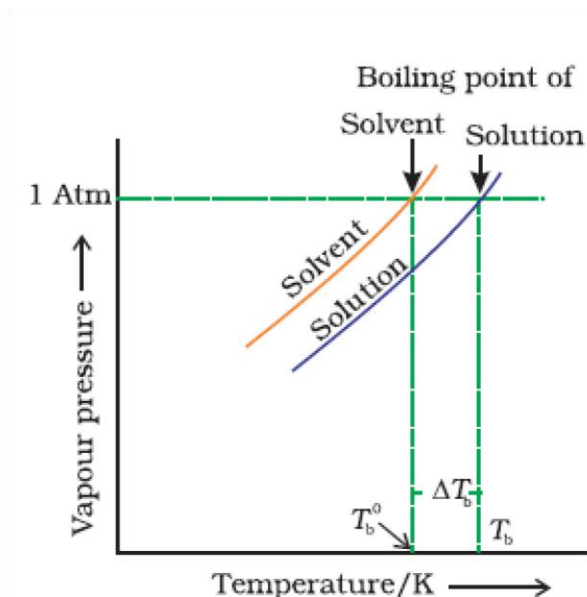
This vapour pressure of the solution at a given temperature is found to be lower than the vapour pressure of the pure solvent at the same temperature. In the solution, the non volatile solute particles obstruct the escaping of solvent molecules from the surface, thus, the vapour pressure is also reduced.



As you know that, as the temperature increases, the vapour pressure also increases.

The temperature at which the vapour pressure of the solvent/solution is equal to the atmospheric pressure, the solvent/solution boils.

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 $\Delta T_b = T_b^0 - T_b$ is known as elevation of boiling point.



$$\Delta T_b = K_b \cdot m$$

$$(T_2 - T_1) = K_b \cdot m \text{ -----} \rightarrow \text{Eq (1)}$$

Where T_1 = Boiling point of Solvent in absolute temperature T_2
 = Boiling point of Solution in absolute temperature m = Molality of
 the solution.

$$\Delta T_b = \frac{1000 \times K_b \times w_B}{M_b \times w_A}$$

Where W_B gram of a non volatile solute dissolved in W_A grams of the solvent and M_b is the Molar mass of the solute .

$$M_b = \frac{1000 \times K_b \times w_B}{\Delta T_b \times w_A}$$

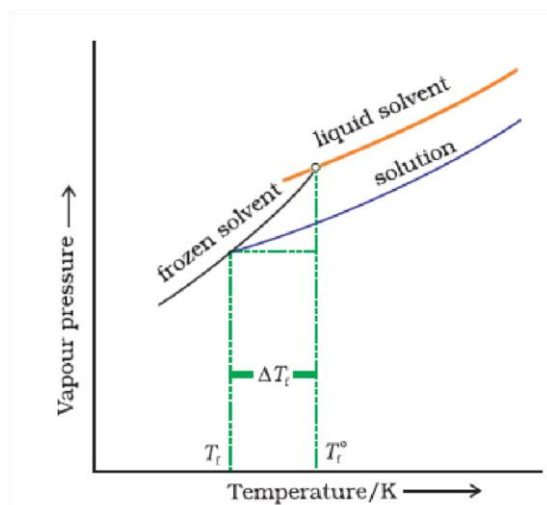
Thus using the above equation, **molar mass of the solute** is calculated.

c) Depression of freezing point:

The lowering of vapour pressure of a solution causes a lowering of the freezing point compared to that of the pure solvent.

A solution will freeze when its vapour pressure equals the vapour pressure of the pure solid solvent.

According to Raoult's law, when a non-volatile solid is added to the solvent its vapour pressure decreases and now it would become equal to that of solid solvent at lower temperature. Thus, the freezing point of the solvent decreases.



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



$$(T_1 - T_2) = K_f \cdot m \longrightarrow \text{Eq (1)}$$

Where T_1 = Freezing point of Solvent in absolute temperature

T_2 = Freezing point of Solution in absolute temperature

m =

Molality of the solution.

$$\Delta T_f = \frac{1000 \times K_f \times w_B}{M_b \times w_A}$$

Where w_B gram of a non volatile solute dissolved in w_A grams of the solvent and M_b is the Molar mass of the solute .

$$M_b = \frac{1000 \times K_f \times w_B}{\Delta T_f \times w_A}$$

Thus using the above equation, **molar mass of the solute** is calculated.

d) Osmotic pressure:

Osmosis:

The phenomenon of the flow of solvent through a semi permeable membrane from pure solvent (low concentration) to the solution (high concentration) is called osmosis.

Osmotic Pressure:

The pressure applied on a solution to prevent the passage of solvent into the pure solvent through a semi permeable membrane is called osmotic pressure.

Reverse Osmosis:

The phenomenon of the flow of solvent through a semi permeable membrane from solution to pure solvent is called Reverse osmosis.

This process occurs, when the pressure applied on the solution is more than the Osmotic pressure.

Reverse Osmosis is used for the purification of Water.

semi Permeable Membrane:

The membrane which allows only the solvent and not the solute to pass through it. E.g. Parch meat, cellophane membrane etc.

Van't Hoff observed that for dilute solutions, the osmotic pressure (π) is given as :-

$$\pi = C R T$$

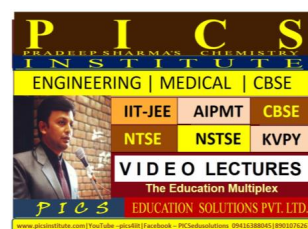
Where

π = Osmotic Pressure of the solution in atm

C = Molar concentration of the solution in mol/lit

R = Gas constant = 0.0821 lit-atm-mol⁻¹-K⁻¹

T = Absolute Temperature in K



According to Van't Hoff equation

$$\Pi = CRT, \text{ where } \Pi = \text{Osmotic pressure of the solution}$$

$$\text{But Concentration, } C = n / V$$

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

$$\Pi = (n / V) \times (RT) \text{ -----} \rightarrow \text{Eq (1)}$$

Again, $n = W_B / M_B$ Where
the molar mass of the

solute.

W_B is the mass of solute and M_B is

$$= \frac{W_B \times R \times T \Pi}{W_B \times V}$$

Substituting 'n' in the Eq(1)

$$\text{Molecular mass of Solute} = \frac{W_B \times R \times T}{\Pi \times V}$$

Thus using the above equation, **molar mass of the solute** is calculated.

Advantage :

- The osmotic pressure method has the advantage over other methods **as pressure measurement is around the room temperature** and the **molarity of the solution is used instead of molality**.

b) For determination of molar mass of solutes is particularly **useful for biomolecules as they are generally not stable at higher temperatures**.and **polymers have poor solubility**.

Isotonic Solutions: Two solutions having same osmotic pressure at a given temperature are called isotonic solutions. When such solutions are separated by semipermeable membrane no osmosis occurs between them.

Example: The osmotic pressure associated with the fluid inside the blood cell is equivalent to that of 0.9% (mass/volume) sodium chloride solution, called normal saline solution and it is safe to inject intravenously.

Hypertonic : If the salt concentration is more than 0.9% (mass/volume), the solution is said to be hypertonic. In this case, water will flow out of the cells if placed in this solution and they would shrink.

Hypotonic: If the salt concentration is less than 0.9% (mass/volume), the solution is said to be hypotonic. In this case, water will flow into the cells if placed in this solution and they would swell.

Application of Osmosis:

- 1) A raw mango placed in concentrated salt solution loses water via osmosis and shrivel into pickle.
- 2) Wilted flowers revive when placed in fresh water.
- 3) Water will move out of the blood cells through osmosis, when placed in water containing more than 0.9% (mass/volume) salt, blood cells collapse due to loss of water by osmosis.
- 4) 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**.
- 5) Water movement from soil into plant roots and subsequently into upper portion of the plant is partly due to osmosis.
- 6) The preservation of meat by salting and of fruits by adding sugar protects against bacterial action. Through the process of osmosis, a bacterium on salted meat or candid fruit loses water, shrivels and dies.

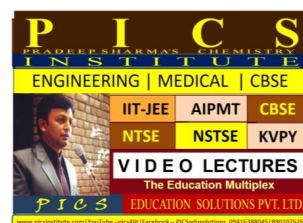
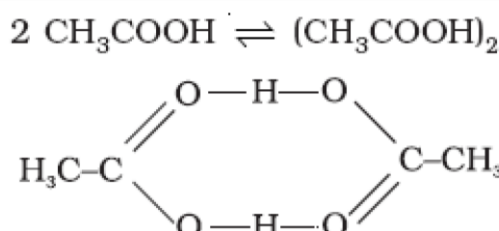
Abnormal Molar Masses:

In some cases, the molar masses determined by colligative properties do not agree with the expected or theoretical values . This may be due to the **association or the dissociation** of the solute molecule in the solution. The two changes are being discussed below:

1) Association of solute particles: - In certain polar solvents, the solute molecules undergo association i.e. two three or even more molecules exists in combination with each other to form bigger molecules .

Total no. of molecules in solution become less than the no. of molecules of the substance added and, therefore colligative properties will be lower, since colligative properties inversely proportional to the molar mass will be greater than theoretical values in such cases.

Example: Acetic acid CH_3COOH exist in dimer by hydrogen bond.



2) Dissociation of solute particles: Molecules of some substance dissociate or ionize in a solvent to give two or more particles.

The total no. of particles increases in solution and consequently colligative properties of such solution will be larger so the molar mass will be less than theoretical values in such cases.

Example: KCl , $\text{KCl} = \text{K}^+ + \text{Cl}^-$

Van't hof factor (i):

It is defined as

<p>Normal molar mass i</p> <p>= -----</p> <p>Observed molar mass</p>

In case of association, the observed molar mass more than the normal, so the factor " $i < 1$ "

In case of dissociation, the observed molar mass has a lesser value, so " $i > 1$ ".

In case of solute where neither association nor dissociation in solvent, the Van't factor " $i = 1$ "

In terms of colligative property 'i' may be defined as :

<p>Observed value of colligative property i</p> <p>= -----</p> <p>Normal value of colligative property</p>

Inclusion of Van't Hoff Factor 'i' modifies the equations for colligative properties as follows:-

<p>Elevation of boiling point, $\Delta T_b = i K_b m$</p>
--

Depression of Freezing point, $\Delta T_f = i K_f m$

Osmotic Pressure $\Pi = i C R T$

Section - B : Important Conceptual Questions and Answers:

1Q) A solution of glycol containing 1.82 gm/litre has an osmotic pressure of 51.8 cm of mercury at 10°. What is the molecular weight of glycol? (1 Mark)

(Ans) $M_2 = \frac{w R T}{P V} = \frac{1.82 \times 0.0821 \times 2.83}{(51.8/76) \times 1} = 62.04$

2Q) Which one of the following salts will have the same value of van't Hoff factor (i) As that of $K_4[Fe(CN)_6]$. (1 Mark)

(Ans) $Al_2(SO_4)_3$

Explanation :

each $K_4[Fe(CN)_6]$ and $Al_2(SO_4)_3$ dissociates to give 5 ions or $i = 5$
 $K_4[Fe(CN)_6] \rightleftharpoons 4K^+ + [Fe(CN)_6]^-$

3Q) A 5% solution of cane sugar (mol. wt. = 342) is isotonic with 1% solution of a substance X. Calculate the molecular weight of X. (2 Mark)

(Ans) Osmotic pressure of 5% cane sugar solution (p_1) = $\frac{50 \text{ g/L}}{342} \times 0.0821 \times T$ $C \times R \times T =$

Osmotic pressure of 1% solution of substance (p_2) = $\frac{10 \text{ g/L}}{M} \times 0.0821 \times T$ =

Both are isotonic, So $p_1 = p_2$

$$\frac{50}{342} \times 0.0821 \times T = \frac{10}{M} \times 0.0821 \times T$$

Hence, M (mol. wt. of X) = $342/5 = 68.4$

4Q) During osmosis, Mention the flow of solvent through a semipermeable membrane. (1 Mark)

(Ans) During osmosis solvent flows through semipermeable membrane from lower concentration to higher concentration.

5Q) A solution containing 10 g per dm³ of urea (molecular mass = 60 g mol⁻¹) is isotonic with a 5 % solution of a non-volatile solute. The molecular mass of this non-volatile solute is (2 Mark)

(Ans) Osmotic pressure of urea from the formula , $= \frac{5}{M \times 1} \times 0.082 \times T$

$$\pi V = nRT \Rightarrow \pi = \frac{nRT}{V}$$

$$\Rightarrow \pi = \frac{10}{60} \times 0.082 \times T \quad [1 \text{ dm} = 1 \text{ litre}]$$

Osmotic pressure of solution having non-volatile solute Equating these



pressures,

$$\frac{10}{60} \times 0.082 \times T = \frac{5}{M \times 1} \times 0.082 \times T$$

$$M = 300 \text{ gm mol}^{-1}$$

6Q) Vapour pressure of CCl_4 at 25°C is 143 mm Hg. 0.5 g of a non-volatile solute (mol. wt. 65) is dissolved in 100 ml of CCl_4 . Find the vapour pressure of the solution. (Density of $\text{CCl}_4 = 1.58 \text{ g/cm}^3$) (2 Mark)

(Ans) Relative lowering of V.P. = mole fraction of Solute

$$\frac{p^\circ - p_s}{p^\circ} = X_2$$

Density of $\text{CCl}_4 = \frac{\text{Mass of } \text{CCl}_4}{\text{Volume}}$

Mass of $\text{CCl}_4 = \text{Density} \times \text{Volume}$

$$= 1.58 \times 100$$

$$= 158 \text{ g}$$

$$\frac{143 - p_s}{143} = \frac{0.5/65}{158/154}; \quad p_s = 141.93 \text{ mm}$$

7Q) The relationship between osmotic pressure at 273 K when 10g glucose (P_1), 10 g urea (P_2), and 10g sucrose (P_3) are dissolved in 250 ml of water is (2 Mark)

(Ans) Moles of glucose = $\frac{10}{180} = 0.05$, Urea = $\frac{10}{60} = 0.16$, Sucrose = $\frac{10}{342} = 0.029$
Hence osmotic pressure $p_2 > p_1 > p_3$

8Q) Two elements A and B form compounds of formula AB_2 and AB_4 . When dissolved in 20.0 g of benzene 1.0 g of AB_2 lowers freezing point by 2.3°C whereas 1.0 g of AB_4 lowers freezing point by 1.3°C . The K_f for benzene is 5.4. The atomic masses of A and B will be (3 Mark)

(Ans) Let the masses of A and B be a and b. The molecular mass of AB_2 will be $(a + 2b) \text{ mol}^{-1}$ g and AB_4 will be $(a + 4b) \text{ g mol}^{-1}$

$$\text{For } \text{AB}_2, 2.3 = (5.1 \times 1 \times 1000)/[(a+2) \times 20]$$

$$\text{or } a + 2b = \frac{5.1 \times 1 \times 1000}{20 \times 2.3} \quad \dots \text{(I)}$$

$$\text{For } \text{AB}_4, 1.3 = (5.1 \times 1 \times 1000)/[(a+4b) \times 20]$$

$$\text{or } a + 4b = \frac{5.1 \times 1000}{20 \times 1.3} \dots \text{(II) On}$$

solving (I) and (II),

$$a = 25.49 \text{ and } b = 42.64$$



9Q) 250 ml of sodium carbonate solution contains 2.65gm of sodium carbonate. If 10 ml of this solution is diluted to one litre, What is the concentration of resultant solution?
(mol. Wt. of sodium carbonate=106) (2 Mark)

(Ans) Initial concentration = $2.65 \text{ gm} / 250 \text{ cc} = 10.60 \text{ gm/L} = (10.6/106) = 0.1\text{M}$.

When 10 ml is diluted to one litre solution = 100 times.

Hence final conc. = $0.1/100 = 0.001\text{M}$.

10Q) Write Henry's law. (1 Mark)

(Ans) The solubility of a gas in a liquid is directly proportional to the partial pressure of the gas at a given temperature.

11Q) What happens when blood cells are placed in pure water? (1 Mark)

(Ans) Water molecules move into blood cells through the cell walls. So, blood cells swell and may even burst.

12Q) Two liquids A and B boil at 120°C and 160°C respectively. Which of them has higher vapour pressure at 70°C ? (1 Mark)

(Ans) Lower the boiling point, more volatile it is. So liquid A will have higher vapour pressure at 70°C .

13Q) A solution of 1.25gm of a non-electrolyte in 20gm of water freezes at 271.94 K. If $K_f = 1.86\text{K/m}$, then calculate the molar mass of the solute. (2 Mark)

(Ans) According to depression of freezing point.

$$M_b = \frac{1000 \times K_f \times w_B}{\Delta T_f \times w_A}$$

$$= (1000 \times 1.86 \times 1.25) / ((273 - 271.94) \times 20)$$

$$= 109.67\text{gm/mol.}$$

14Q) Osmotic pressure of a solution is 0.0821 atm at a temperature of 300 K. The concentration in mole/litre is: (1 Mark)

(Ans) $C = \pi/RT = 0.0821/(0.0821 \times 300) = 0.003$

15Q) A solution of ethanol in water is 1.6 molal. How many grams of ethanol are present in 500g of the solution. (2 Marks)

(Ans) Mass of ethanol = $\text{Molality} \times \text{M.wt.}$
 $1.6 \times 46 = 73.6g$

Total of mass of solution = $73.6 + 1000 = 1073.6g$

\therefore 1073.6g of solution contain 73.6g of ethanol.

\therefore Mass of ethanol in 500g of solution = $\frac{73.6}{1073.6} \times 500$
 $= 34.28g$



16Q) On a hill station pure water boils at 99.82°C . The K_b of water is $0.513^{\circ}\text{C Kg mol}^{-1}$. Calculate the boiling point of 0.69m solution of urea. (1 Marks)

(Ans)

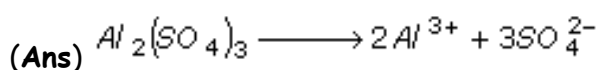
$$\begin{aligned}\Delta T_b &= K_b m \\ &= 0.513 \times 0.69 \\ &= 0.3539^{\circ}\text{C}\end{aligned}$$

Boiling point of solution = Boiling point of water + ΔT_b

$= 99.82 + 0.3539$

$= 100.17^{\circ}\text{C}$

17Q) Find the vant Hoff factor for $\text{Al}_2(\text{SO}_4)_3$ (1 Marks)



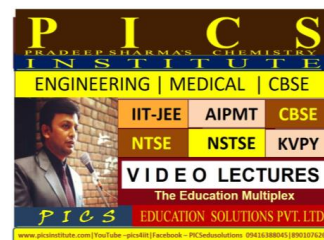
Total ions produced = $2 + 3 = 5$

$i = \frac{\text{observed no. of ions}}{\text{Normal no. of ions}} = \frac{5}{1} = 5$

18Q) Ethylene glycol solution having molality 0.5 is used as coolant in a car. Calculate the freezing point of solution (given $K_f = 1.86 \text{ K Kg/mole}$) (2 Marks)

(Ans)

$$\begin{aligned}
 \Delta T_f &= k_f \times m \\
 &= 1.86 \times 0.5 \\
 &= 0.93^\circ\text{C}. \\
 \Delta T_f &= T_f^\circ - T_f \\
 \text{or } T_f &= T_f^\circ - \Delta T_f \\
 &= 0 - 0.93 \\
 &= -0.93^\circ\text{C}
 \end{aligned}$$



19Q) An aqueous solution freezes at -0.186°C . $K_f = 1.86^\circ\text{C}$, $K_b = 0.512$. Find elevation in boiling point. (2 Marks)

(Ans) $\Delta T_f = 0 - (-0.186) = 0.186^\circ\text{C}$

$$\Delta T_f = K_f \times m$$

Or $m = \frac{\Delta T_f}{K_f} = \frac{0.186}{1.86} = 0.1$

$$\Delta T_b = K_b \times m$$

$$= 0.512 \times 0.1 = 0.0512^\circ\text{C}$$

20Q) Density of 1 M solution of glucose 1.18g/cm^3 . K_f for H_2O is 1.86°C . Find freezing point of solution. (2 Marks)

(Ans) Mass of solution = Volume \times Density

$$= 1000 \times 1.18 = 1180\text{g}$$

$$\text{Mass of water} = 1180 - 180 = 1000\text{g}$$

$$\therefore 1\text{M } \text{C}_2\text{H}_5\text{OH} = 1\text{ m}$$

$$\Delta T_f = K_f \times m$$

$$= 1.86 \times 1 = 1.86$$

$$T_f = T_f^\circ - \Delta T_f$$

$$= 0 - 1.86$$

$$= -1.86^\circ\text{C}$$

21Q) Vapour pressure of two liquid A and B are 120 and 180mm Hg at a given temperature. If 2 mole of A and 3 mole of B are mixed to form an ideal solution, calculate the vapour pressure of solution at the same temperature. (2Marks)

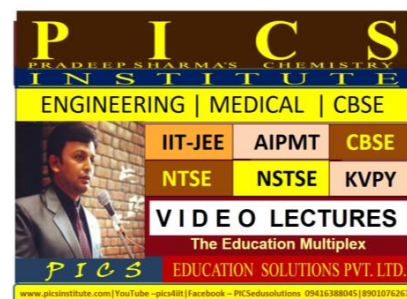
(Ans) Total moles = 2 + 3 = 5

$$P_{\text{solution}} = P_{0A} X_A + P_{0B} X_B$$

$$= (120 \times 2/5) + (180 \times 3/5)$$

$$= 48 + 108$$

$$= 156\text{mm.}$$



22Q) The Osmotic pressure of human blood is 7.65 atm at 37°C. For injecting glucose solution it is necessary the glucose solution has same osmotic pressure as of human blood. Find the molarity of glucose solution having same osmotic pressure as of human blood. (2 Marks)

(Ans) $\pi = CRT = (n/v) RT$

$$7.65 = (n/v) \times 0.0821 \times 310$$

$$n/v = 7.65 / (0.0821 \times 310)$$

$$= 0.30\text{mol/lit}$$

$$\text{Molarity} = 0.30\text{M}$$

23Q) A solution contains 25% water, 25% ethanol and 50% acetic acid by mass. Find mole fraction of each of the component. (3 Marks)

(Ans) Moles of water = $n_1 = \frac{25}{18} = 1.39$
Moles of C_2H_5OH = $n_2 = \frac{25}{46} = 0.54$
Moles of CH_3COOH = $n_3 = \frac{50}{60} = 0.83$

$$\text{Total moles in solution} = n_1 + n_2 + n_3 = 1.39 + 0.54 + 0.83 = 2.76$$

$$\text{Mole fraction of water} = \frac{n_1}{n_1 + n_2 + n_3} = \frac{1.39}{2.76} = 0.503$$

$$\text{Mole fraction of } C_2H_5OH = \frac{n_2}{n_1 + n_2 + n_3} = \frac{0.54}{2.76} = 0.196$$

$$\text{Mole fraction of } CH_3COOH = \frac{n_3}{n_1 + n_2 + n_3} = \frac{0.83}{2.76} = 0.301$$

24Q) Conc. H_2SO_4 has a density 1.9g/ml and is 99% H_2SO_4 by weight. Find molarity of solution. (3 Marks)

(Ans) Mass of 1000 ml of H_2SO_4 = density \times volume

$$= 1.9 \times 1000$$

$$= 1900 \text{ g}$$

Mass of H_2SO_4 present in 1900 g (1L) of H_2SO_4

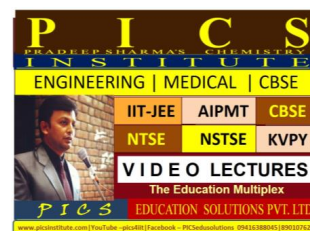
$$= (99/100) \times 1900$$

$$= 1881 \text{ g}$$

Mole of H_2SO_4 present in 1L = Molarity = mass / molar mass

$$= 1881 / 98$$

$$= 19.197 \text{ M}$$



25Q) Vapour pressure of pure water is 40mm. If a non-volatile solute is added to it, vapour pressure falls by 4 mm. Calculate molality of solution. (3 Marks)

(Ans)
$$\frac{\Delta p}{p^\circ} = x_B = \frac{4}{40} = 0.1$$

\therefore The solution has 0.1 moles of solute in 0.9 moles of water.

Mass of water = $\text{Moles} \times \text{M.wt.} = 0.9 \times 18 = 16.2 \text{ g}$

Molality of solution =
$$\frac{\text{Moles of solute}}{\text{Mass of solvent in kg}} = \frac{0.1}{16.2/1000}$$

$$= 6.17 \text{ m}$$

26Q) The vapour pressure of benzene at certain temperature is 640mm Hg. To 39.08 of benzene, non-volatile and non-electrolyte solid-weighing 2.175g was added. The vapour pressure of solution was 600mm of Hg. Find the mass of the solute? (3 Marks)

(Ans)

$$\frac{p^\circ - p}{p^\circ} = x_B$$

$$\frac{p - p}{p^\circ} = \frac{w/m}{W/M} = \frac{w \times M}{m \times W}$$

$$\frac{640 - 600}{640} = \frac{2.175 \times 78}{m \times 39.08}$$

$$\frac{40}{640} = \frac{2.175 \times 78}{39.08 m}$$

$$m = \frac{2.175 \times 78}{39.08} \times \frac{640}{40} = 69.60 \text{ g}$$



27Q) An aqueous solution of a non-volatile and non-electrolyte substance boils at 100.5°C . Calculate osmotic pressure of this solution at 27°C . K_b (for water) per 1000g = 0.50.

(3 Marks)

(Ans) $\Delta T_b = T_b - T_b^*$

$$100.5 - 100 = 0.5^{\circ}\text{C}$$

$$\Delta T_b = K_b m \quad \text{or} \quad m = \frac{\Delta T_b}{K_b} = \frac{0.5}{0.50} = 1$$

∴ Molality of solution = 1, (∵ Solvent is water)

∴ density of solution = 1

Volume of solution = volume of solvent = $1000/1 = 1000\text{ml} = 1\text{ L}$

$$T = 27^{\circ}\text{C} = 27 + 273 = 300\text{K}, n = 1 \quad \pi =$$

$$nRT$$

$$\pi = \frac{nRT}{V} = \frac{1 \times 0.0821}{1} \times 300 = 24.63\text{atm}$$

28Q) A decimolar solution of NaCl exerts osmotic pressure of 4.6 atm at 300K. Find the degree of dissolution. (3 Marks)



Initial moles: 1 0 0

Moles at Equilibrium: 1- α α α

Equilibrium

$$\text{Total moles at equilibrium} = 1 - \alpha + \alpha + \alpha = 1 + \alpha$$

$$i = \frac{\text{Moles in solution}}{\text{Actual moles}} = \frac{1 + \alpha}{1} = 1 + \alpha$$

$$\pi V = i CRT$$

$$\pi = 4.6\text{ atm}, V = 1\text{ L} \quad P = 300\text{K}, C = 0.1$$

$$4.6 \times 1 = (1 + \alpha) \times 0.1 \times 0.0821 \times 300$$

$$\therefore \alpha = \left(\frac{4.6}{0.1 \times 0.0821 \times 300} \right) - 1$$

$$= 0.868 = 86.8\%$$



29Q) One litre sample of seawater is found to contain 5.8×10^{-3} g of dissolved oxygen.

Calculate the concentration of dissolved oxygen in seawater in ppm. (3 Marks)

(Density of seawater = 1.03 g/cc).

(Ans) Mass $\frac{\text{volume} \times \text{density}}{\text{volume}} =$

$$\frac{1000 \times 1.03}{1000} =$$

$$= 1030\text{g}$$

Mass of oxygen present in 10^6 (one million) gm of seawater

$$= \frac{\text{Mass of oxygen}}{\text{Total mass of sea water}} \times 10^6$$

$$= \frac{5.8 \times 10^{-3}}{1030} \times 10^6 = 5.63 \text{ ppm}$$

When chloroform and acetone are mixed, they form intermolecular hydrogen bonds. The hydrogen bonds are strong forces of attraction. As a result, volume of the solution will be less than 100ml.

30Q) Which will have more osmotic pressure and why? Solution prepared by dissolving 6g/L of CH_3COOH or Solution prepared by dissolving 7.45g/L of KCl (3 Marks)

(Ans) Moles of $\text{CH}_3\text{COOH} = \frac{\text{Mass}}{\text{M.wt.}} = \frac{6}{60} = 0.1$

$$\text{Moles of KCl} = \frac{\text{Mass}}{\text{M.wt.}} = \frac{7.45}{74.5} = 0.1$$

\therefore Molar concentration of both the solutions is same.

KCl ionizes into K^+ and Cl^- where as CH_3COOH does not ionize:

\therefore Osmotic pressure is colligative property.

\therefore Its value depend on number of particles.

Since, KCl produces more ions so, osmotic pressure of KCl will be more than that of CH_3COOH .

31Q). What is meant by positive and negative deviation from Raoult's law and how is the sign ΔH related to positive & negative deviation from Raoult's Law? (2Marks)

Ans: When a solution is formed from "A" and "B" , there will be three types of interaction, A-A,

B-B, A-B . If A-B interaction is more than A-A or B-B interaction, observed vapour pressure will be more and this type of deviation is called positive deviation.

In the case of negative deviation, during formation of solution heat will be released to the surrounding, ie, ΔH will be negative.

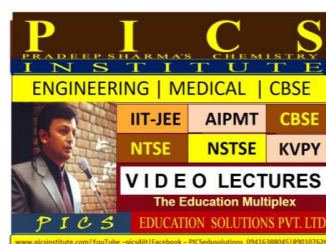
In the case of positive deviation, interaction between molecules decreases and there will be increase in energy of solution or ΔH will be +ve.

32Q). Concentrated nitric acid used in the laboratory work is 68% nitric acid by mass in aqueous solution. What should be the molarity of such a sample of the acid if the density of the solution is 1.504 g/cm^3 . (3Marks)

Ans: density = 1.504 g/cm^3
68% means 68g in 100g solution.
Volume of solution = $100\text{g}/1.504\text{g/cm}^3$
Wt of Nitric acid in 66ml solution = 68g
Wt of nitric acid in 1000ml solution = $(68/66) \times 1000 \text{ g}$
Molarity = $(68 \times 1000)/(66 \times 63) = \underline{16.35M}$

33Q) A solution of glucose in water is labeled as 10% w/w, what would be the molality and mole fraction of each component in solution? If the density of solution is 1.2 g/ml , then what will be the molarity of solution? (3Marks)

Ans: 10% w/w means
10g glucose in 100g solution
10g glucose in 90g water
1000g water contains $(10/90) \times 1000 \text{ g}$ glucose.



Molality = wt per 1000g/mol wt of glucose
 $= 1000/9 \times 180 = 0.617m$

Mole fraction = no of moles of glucose / no. of glucose + no of moles of water
 $= (10/180) / (10/180 + 90/18) = 1/91 = 0.010$ density
 $= 1.2 \text{ g/cm}^3$

Volume of solution = $100 \text{ g}/1.2 \text{ g/cm}^3 = 100\text{g}/1.2 \text{ ml}$

Weight of glucose in 100/1.2 ml = 10g

Weight of glucose in 1000 ml = $10 \times 1.2 \times 1000/100 \text{ g}$

No. of moles of glucose = $120/180$

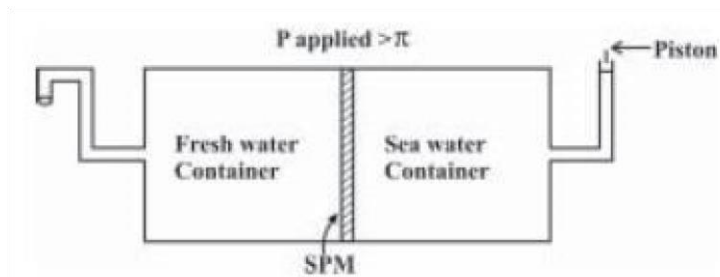
Molarity = $2/3 = 0.66M$



Section C : CBSE SAMPLE PAPERS: Question and answers:

Q1) Given below is the sketch of a plant for carrying out a process.

(CBSE –Samp -1 – 2M)



- Name the process occurring in the above plant.
- To which container does the net flow of solvent take place?
- Name one SPM which can be used in this plant.
- Give one practical use of the plant.

Ans: (i) Reverse osmosis

(ii) Fresh water container

(iii) Cellulose acetate placed on a suitable support (iv)
Desalination of sea water.

Q2) Heptane and octane form an ideal solution at 373 K, The vapour pressures of the pure liquids at this temperature are 105.2 KPa and 46.8 KPa respectively. If the solution contains 25g of heptane and 28.5g of octane, calculate

- vapour pressure exerted by heptane
- vapour pressure exerted by solution
- mole fraction of octane in the vapour phase. (CBSE –Samp -1 – 3M)

Ans:

$$\text{Moles of heptane} = \frac{\text{mass of heptane}}{\text{Molar mass of heptane}} = \frac{25\text{g}}{100\text{g mol}^{-1}} = 0.25 \text{ moles}$$

$$\text{moles of octane} = \frac{\text{mass of octane}}{\text{molar mass of octane}} = \frac{28.5\text{g}}{114\text{g mol}^{-1}} = 0.25 \text{ moles}$$

$$\text{Total moles} = 0.25 + 0.25 = 0.50 \text{ moles}$$

$$\text{Mole fraction of heptane} = \frac{0.25}{0.50} = 0.5$$

$$\text{Mole fraction of octane} = \frac{0.25}{0.50} = 0.5$$

$$\begin{aligned} \text{i) partial pressure of heptane } p &= P_{\text{heptane}}^0 \times X_{\text{heptane}} \\ &= 105.2 \text{ K Pa} \times 0.5 \\ &= 52.6 \text{ K Pa} \end{aligned}$$

$$\begin{aligned} \text{ii) partial pressure of octane } p &= P_{\text{octane}}^0 \times X_{\text{octane}} \\ &= 46.8 \text{ K Pa} \times 0.5 \\ &= 23.4 \text{ K Pa} \end{aligned}$$

$$\begin{aligned} P_{\text{solution}} &= P_{\text{heptane}} + P_{\text{octane}} \\ &= 52.6 \text{ K Pa} + 23.4 \text{ K Pa} \\ &= 76.0 \text{ K Pa} \end{aligned}$$

$$\begin{aligned} \text{iii) mole fraction of octane in vapour phase} &= \frac{P_{\text{octane}}}{P_{\text{solution}}} = \frac{23.4 \text{ K Pa}}{76.0 \text{ K Pa}} \\ &= 0.31 \end{aligned}$$

Q3) Ethylene glycol (molar mass = 62g/mol) is a common automobile antifreeze. Calculate the freezing point of a solution containing 12.4g of this substance in 100g of water. What it be advisable to keep this substance in the car radiator during summer? (For water $K_f = 1.86\text{K Kg/mol}$, $K_b = 0.512\text{K Kg/mol}$) (CBSE –Samp -2 – 2M)

Ans. Moles of ethylene glycol = $\frac{12.4}{62} = 0.2 \text{ mol}$

$$\text{Molality} = \frac{0.2}{100} \times 1000 = 2 \text{ m}$$

$$\text{Freezing point depression} = 2 \times 1.86 = 3.72 \text{ K}$$

$$\begin{aligned} \text{Freezing point of aqueous solution} &= 273.15 - 3.72 \\ &= 269.43 \text{ K} \end{aligned}$$

$$\text{Boiling point elevation of solution} = 2 \times 0.52 = 1.04 \text{ K}$$

$$\text{Boiling point of solution} = 373.15 + 1.04 = 374.19 \text{ K}$$

Since boiling point is higher than room temperature in summer, it is advisable to keep this substance in the car radiator during summer.

Q4). Give reasons for the following :

- At higher altitudes, people suffer from a disease called anoxia. In this disease, they become weak and cannot think clearly.
- When mercuric iodide is added to an aqueous solution of KI, the freezing point is raised.

(CBSE –Samp -2 – 2M)

Ans: (a) At higher altitudes, partial pressure of oxygen is less than that at ground level, so that oxygen concentration becomes less in blood or tissues. Hence people suffer from anoxia.
 (b) Due to the formation of complex $\text{K}_2(\text{Hg I}_4)$, number of particles in the solution decreases and hence the freezing point is raised.

Q5) What is the Van't Hoff factor for a compound which undergoes tetramerization in an organic solvent? (CBSE –Samp -2 – 1M)

Ans: $i = \frac{1}{4}$

Q6) (a) Derive the relationship between relative lowering of vapour pressure and mole fraction of the volatile liquid.

(b) (i) Benzoic acid completely dimerises in benzene. What will be the vapour pressure of a solution containing 61g of benzoic acid per 500g benzene when the vapour pressure of pure benzene at the temperature of experiment is 66.6 torr?

(ii) What would have been the vapour pressure in the absence of dimerisation?

(c) Derive a relationship between mole fraction and vapour pressure of a component of an ideal solution in the liquid phase and vapour phase. (CBSE –Samp -3 – 5M)

solule? Give reason.

$$(a) \frac{\Delta P}{P^0} = i X_B$$

$$i = \frac{1}{2}$$

$$X_B = \frac{n_B}{n_A + n_B} = \frac{61/122}{61/122 + \frac{500}{78}} = \frac{0.5}{0.5 + 6.41} = \frac{0.5}{6.91}$$

$$\frac{\Delta P}{66.6} = \frac{1}{2} \times \frac{50}{691}$$

$$\Delta P = \frac{50 \times 66.6}{691 \times 2} = 2.41$$

$$P^0 - P = 2.41 \\ P = 66.6 - 2.40 \\ = 64.20 \text{ torr}$$

b) In the absence of dimerisation

$$i = 1$$

$$\frac{\Delta P}{P^0} = X_B$$

$$\Delta P = \frac{50}{691} \times 66.6 = 4.82$$

$$P = 66.6 - 4.82 = 61.78 \text{ torr}$$

(c) From Raoult's law $P_1 = x_1 P_1^0$
 x_1 = mole fraction of liquid 1 $P_2 = x_2 P_2^0$
 x_2 = mole fraction of liquid 2

y_1 = Mole fraction of component - 1 in vapour phase.

y_2 = Mole fraction of component - 2 in vapour phase.

$$y_1 = \frac{P_1}{P_{\text{total}}} = \frac{P_1}{P_1 + P_2}$$

$$y_2 = \frac{P_2}{P_{\text{total}}} = \frac{P_2}{P_1 + P_2}$$

$$y_1 = \frac{x_1 P_1^0}{x_1 P_1^0 + x_2 P_2^0} = \frac{x_1 P_1^0}{x_1 P_1^0 + (1 - x_1) P_2^0}$$

$$y_2 = \frac{x_2 P_2^0}{x_1 P_1^0 + x_2 P_2^0}$$

Q7) (a) Which aqueous solution has higher concentration - 1 molar or 1 molal solution of the same

(b) 0.5g KCl was dissolved in 100g water and the solution originally at 20°C, froze at - 0.24°C.

Calculate the percentage ionization of salt. K_f per 1000g of water = 1.86K.

(CBSE –Samp -3 – 5M) Ans;

(a) 1 M has higher concentration than 1m.

1 m solution = 1 mole in 1000 g solvent

or

1 mole in 1000 cm³ of solvent if $d = 1 \text{ g / cm}^3$

But 1 M solution = 1 mole in 1000 cm³ of solution i.e. solvent is less here,

(b) $\Delta T_f = 0 - (-0.24) = +0.24^\circ \text{C}$

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

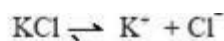
$$= \frac{1000 \times 1.86 \times 5}{0.24 \times 100} \text{ g mol}^{-1}$$

$$= 38.75 \text{ g mol}^{-1}$$

Theoretical mol mass of KCl

$$= 39 + 35.5 = 74.5 \text{ g mol}^{-1}$$

$$i = \frac{\text{calculated mol mass}}{\text{Theoretical mol mass}} = \frac{74.5}{38.75} = 1.92$$



Initial moles 1 mole 0 0

After dissociation 1 - α α α

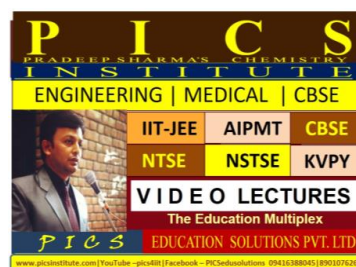
Total no. of moles after dissociation

$$= 1 - \alpha + \alpha + \alpha = 1 + \alpha$$

$$i = \frac{1 + \alpha}{1}$$

$$\alpha = i - 1 = 1.92 - 1 = 0.92$$

Percentage dissociation = 92%



Q8) State Raoult's law for solutions of volatile liquid components. Taking a suitable example, explain the meaning of positive deviation from Raoult's law. (CBSE –2008–2M)

Ans: At a given temperature, for a solution of volatile liquids, the partial vapour pressure of each component is equal to the product of the vapour pressure of the pure component and its mole fraction .

If the solution contains A & B are two volatile liquids, then

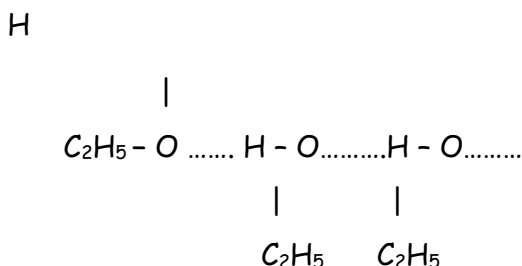
$$\text{i.e.} \quad P_A = p_A^0 X_A \quad \& \quad P_B = p_B^0 X_B$$

The Mixture contains two components namely A and B, **If the interaction between A-B molecules is weaker than the interactions between A-A or B-B or both**, then the solution deviate positively from the ideal behavior. and

Example: Mixture of Ethyl alcohol and Cyclohexane.

→Explanation for positive deviation:

→In ethyl alcohol the molecules are held together by hydrogen bonding.



→When Cyclohexane is added to ethyl alcohol, the Cyclohexane molecules occupy spaces between ethyl alcohol molecules. As a result, some hydrogen bonds in alcohol molecules break. The escaping tendency of alcohol and Cyclohexane molecules from solution increases. So there is increase in vapour pressure.

Q9) Define the term 'Osmotic pressure'. Describe how the molecular mass of a substance can be determined on the basis of Osmotic pressure measurement. (CBSE –2008 – 2M)

Ans: The pressure applied on a solution to prevent the passage of solvent into the pure solvent through a semi permeable membrane is called osmotic pressure.

According to Van't Hoff equation

$$\Pi = CRT, \text{ where } \Pi = \text{Osmotic pressure of the solution}$$

$$\text{But Concentration, } C = n / V$$

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

$$\Pi = (n / V) \times (RT) \text{ -----} \rightarrow \text{Eq (1)}$$

Again, $n = W_B / M_B$ Where W_B is the mass of solute and M_B is the molar mass of the solute..

$$\begin{array}{c}
 W_B \times R \times T \Pi \\
 = \text{-----} \\
 W_B \times V
 \end{array}$$

Substituting 'n' in the Eq(1)

$$\text{Molecular mass of Solute} = \frac{w_B \times R \times T}{\pi \times V}$$

Thus using the above equation, **molar mass of the solute** is calculated.

Q10) A solution containing 8gm of a substance in 100gm of diethylether boils at 36.86°C, whereas pure ether boils at 35.60°C. Determine the molecular mass of the solute. ($K_b = 2.02 \text{ K kg mol}^{-1}$)

(CBSE –2008 – 3M)

Ans: Amount of solute = 8gm

Amount of solvent = 100gm

Boiling point of pure solvent = $T_1 = 35.60^\circ\text{C} = 35.60 + 273.15 = 308.75\text{K}$

Boiling point of solution = $T_2 = 36.86^\circ\text{C} = 36.86 + 273.15 = 310.01\text{K}$

Elevation of boiling point = $\Delta T_b = T_2 - T_1 = 310.01 - 308.75 = 1.26\text{K}$

As you know that $\Delta T_b = K_b \times m$

$$\begin{aligned} \text{Molar mass of the solute} &= \frac{1000 \times K_b \times w_B}{\Delta T_b \times w_A} \\ &= (1000 \times 2.02 \times 8) / (1.26 \times 100) \\ &= 128.25 \text{ gm/mol.} \end{aligned}$$

Q11) Calculate the temperature at which a solution containing 54g of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$, in 250gm of water will freeze. (K_f for water = $1.86 \text{ K kg mol}^{-1}$) **(CBSE –2008 – 3M)**

Ans: Amount of solute = 54gm

Molar mass of Glucose($\text{C}_6\text{H}_{12}\text{O}_6$) = 180gm/mol

Amount of solvent = 100gm

Freezing point of pure solvent = $T_1 = 0^\circ\text{C} = 273.15\text{K}$

Elevation of boiling point = $\Delta T_f = T_1 - T_2 = 273.15 - T_2$

As you know that $\Delta T_f = K_f \times m$

$$273.15 - T_2 = (1.86 \times 54 \times 1000) / (180 \times 100)$$

$$273.15 - T_2 = 5.58\text{K}$$

Freezing point of solution = $T_2 = 273.15 - 5.58 = 267.57\text{K}$.

Q12) What are non-ideal solutions? Give one example. Explain as to why non-ideal solutions deviate from Raoult's law. **(CBSE –Supply-2008 – 2M)**

Ans: The solution which do not obey Raoult's law are called non ideal solutions. For these solutions

$$\text{i) } p_A \neq p_A^0 \times x_A \quad \text{and} \quad p_B \neq p_B^0 \times x_B, \quad \text{ii) } \Delta H_{\text{mixing}} \neq 0, \quad \text{iii) } \Delta V_{\text{mixing}} \neq 0$$

Example: Mixture of Ethyl alcohol and Cyclohexane

Assume in the mixture A and B are two components, If the **A-B interactions are stronger or weaker than A-A and B-B interactions**, then the mixture deviates from the ideal behavior and does not obey Raoult's law.

Q13) Calculate the amount of KCl which must be added to 100gm of water so that water freezes at -2.00°C . Assume that KCl undergoes complete dissociation. ($K_f = 1.86\text{K}\cdot\text{kg}\cdot\text{mol}^{-1}$, $K_b = 39.0$, $i = 2$)
(CBSE –Supply-2008 – 3M)



Ans: Amount of KCl = W_b
Molar mass of KCl = 74.5g/mol
Amount of solvent = 100g
Freezing point of pure solvent = $T_1 = 0^{\circ}\text{C} = 273.15\text{K}$
Freezing point of solution = $T_2 = -2^{\circ}\text{C} = -2 + 273.15 = 271.15\text{K}$
Elevation of boiling point = $\Delta T_f = T_1 - T_2 = 273.15 - 271.15 = 2\text{K}$
KCl completely dissociates = $i = 2$
As you know that $\Delta T_f = i \times K_f \times m$
 $2 = 2 \times (1.86 \times W_b \times 1000) / (74.5 \times 100)$
Amount of KCl = $(74.5 \times 100 \times 2) / (1.86 \times 1000 \times 2)$
 $= 4\text{g}$

Q14) Explain the following

(i) People taking a lot of salt in their diet suffer from edema.

(ii) Equimolar solutions of glucose and KCl are not isotonic. (CBSE –Samp -4 – 2M)

Ans. (i) Water retention in tissue cells and intercellular spaces is very high for people taking a lot of salt in their diet. This results in puffiness or swelling which is called edema.

(ii) KCl dissociates into two ions (K^+ and Cl^-) and exerts double the pressure as compared to glucose (which is non-electrolyte). Therefore, equimolar solutions of glucose and KCl are not isotonic.

Q15) Calculate the freezing point of a solution containing 50.0 g of ethylene glycol (Molecular weight = 62) dissolved in 600 g of water. (K_f for water = $1.86\text{K}\cdot\text{kg}\cdot\text{mol}^{-1}$)

(CBSE –Samp -4 – 2M)

Ans.

$$\Delta T_f = \frac{1000 \times K_f \times w_B}{M_B \times w_A} = \frac{1000 \times 1.86 \times 50}{62 \times 600} = 2.5\text{K}$$

Freezing point of aqueous solution = Freezing point of water - ΔT_f
 $= 273 - 2.5 = 270.5\text{K}$

Q16) Give one use of reverse osmosis.

(CBSE –Samp -4 – 1M)

Ans. Desalination of sea water.

Q17) (i) What would be the value of van't Hoff factor for dilute solution of K_2SO_4 ?

(ii) Which will have higher boiling point—0.1 molar solution of glucose or 0.1 molar solution of NaCl in water? Which of the following is not a colligative property—Osmotic pressure or freezing point? (CBSE –Samp -5 – 3M)

Ans. (i) $K_2SO_4 \rightarrow 2K^+ + SO_4^{2-}$

$$\begin{aligned}\text{Vant' Hoff factor} &= \text{Observed number of ions/Normal number of ions} \\ &= 3/1 = 3\end{aligned}$$

(ii) Elevation in boiling point is colligative property. NaCl is an electrolyte and it dissociates into Na^+ and Cl^- ions whereas glucose does not dissociate in the solution. Since NaCl produces more ions than glucose, the elevation in boiling point is greater in NaCl solution. Hence boiling point of 0.1 molar NaCl solutions is more than 0.1 molar glucose solution.

(iii) Osmotic pressure is colligative property because its value depends on number of particles and not on their nature. Freezing point is not a colligative property.

Q18) State Henry's law. Give its two applications also.

(CBSE –Samp -5 – 2M)

Ans. According to Henry's law the mass of a gas dissolved per unit volume of the solvent at a given temperature is proportional to the pressure of the gas in equilibrium with the solution. This law is useful in (i) Production of carbonated beverages. (ii) In deep sea diving.

Q19) 2 g benzoic acid (C_6H_5COOH) dissolved in 25 g of benzene shows a depression in freezing point equal to 1.62 K. Molal depression constant for benzene is 4.9 K.kg.mol⁻¹. What is the percentage associated of acid if it forms dimer in solution?

(CBSE –Samp -6 – 3M)

Ans.

Mass of benzoic acid (w_B) = 2g

Mass of benzene (w_A) = 25g

Depression in freezing point (ΔT_f) = 1.62K

Molal depression constant (K_f) = 4.9K.kg.mol⁻¹

Normal molar mass of benzoic acid (M_B) = 122g.mol⁻¹

Abnormal molar mass of benzoic acid (M'_B) = ?

$$M'_B = \frac{K_f \times w_B \times 1000}{\Delta T_f \times w_A}$$

$$M'_B = \frac{4.9 \times 2 \times 1000}{1.62 \times 25}$$

$$M'_B = 241.98 \text{ g.mol}^{-1}$$

$$\begin{aligned}\text{Vant' Hoff factor (i)} &= \frac{\text{Normal molar mass}}{\text{Abnormal molar mass}} \\ i &= \frac{122}{241.98}\end{aligned}$$



Initial no.

of mols 1 mol 0

At equilibrium (1-x) $\frac{x}{2}$

Therefore, total number of moles of benzoic acid at equilibrium

$$1 - x + \frac{x}{2} = 1 - \frac{x}{2}$$

$$i = 1 - \frac{x}{2}$$

$$\frac{122}{241.98} = 1 - \frac{x}{2}$$

$$\frac{x}{2} = 1 - \frac{122}{241.98}$$

$$x = 2 \times 0.496$$

$$x = 0.992$$

therefore, degree of association of benzoic acid in benzene is 99.2%



Q20) A solution is made by dissolving 30 g of a non-volatile solute in 90 g of water. It has a vapour pressure of 2.8 kPa at 298 K. At 298 K, vapour pressure of pure water is 3.64 kPa. Calculate the molar mass of the solute. CBSE –Samp -6 – 3M)

Ans.

Mass of non-volatile solute(W_B) = 30g

Mass of solvent(W_A) = 90g

Vapour pressure of solution(P_s) = 2.8kPa

Vapour pressure of pure solvent(P_A^0) = 3.64kPa

Molecular mass of solvent(water)(M_A) = 18g.mol⁻¹

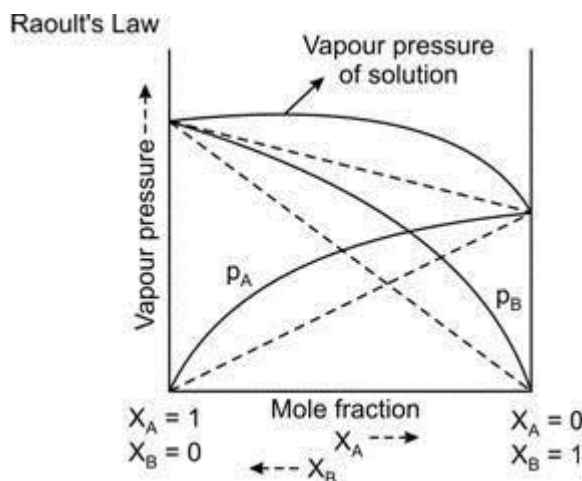
Molecular mass of non-volatile solute(M_B) = ?

$$\begin{aligned} M_B &= \frac{W_B \times M_A}{\left(\frac{P_s - P_A^0}{P_A^0} \right) \times W_A} \\ &= \frac{30 \times 18}{\left(\frac{3.64 - 2.8}{3.64} \right) \times 90} \\ &= \frac{540}{20.76} = 26.01 \\ &= 26 \text{ g.mol}^{-1} (\text{approx.}) \end{aligned}$$

Q21) What is meant by positive and negative deviations from Raoult's law and how is the sign $\Delta_{\text{mix}}H$ related to positive and negative deviation from Raoult's law?

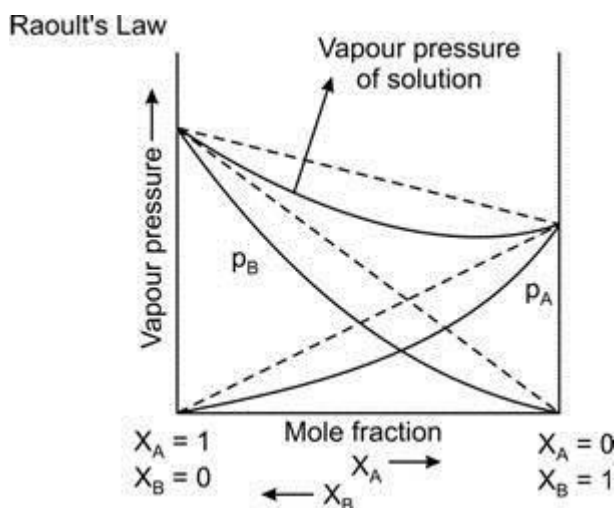
(CBSE –Samp -7 – 3M)

Ans. Positive deviation:- The solution whose vapour pressure is higher than that of an ideal solution of the same composition is said to show positive deviations.



The sign $\Delta_{\text{mix}}H$ for the positive deviation is positive. of

Negative deviation:- The solution whose vapour pressure is less than that of an ideal solution of the same composition is said to show negative deviations.



The sign of $\Delta_{\text{mix}}H$ for the negative deviation is negative.

Q22) (a) Define the abnormal molecular mass.

(b) Calculate the mass of ascorbic acid (Vitamin C, $C_6H_8O_6$) to be dissolved in 75 g of acetic acid to lower its melting point by 1.50°C . $K_f = 3.9 \text{ K.kg.mol}^{-1}$.

(CBSE –Samp -7 – 3M)

Ans. (a) Abnormal molecular mass:- The molar mass values higher or lower than the normal values are termed as the abnormal molar masses.

(b)

Mass of acetic acid (W_B) = 75g

Depression in freezing point (ΔT_f) = 1.5°C

Molar mass of ascorbic acid (M_B) = 176 g.mol^{-1}

$K_f = 3.9 \text{ K.kg.mol}^{-1}$

Mass of ascorbic acid (W_B) = ?

$$\Delta T_f = K_f \times m$$

$$\Delta T_f = K_f \times \frac{W_B \times 1000}{M_B \times W_A}$$

$$W_B = \frac{\Delta T_f \times M_B \times W_A}{K_f \times 1000}$$

$$W_B = \frac{1.5 \times 176 \times 75}{3.9 \times 1000}$$

$$W_B = 5.076\text{g}$$

Q23) (a) (i) Define mole fraction.

(ii) Which term affected by temperature molality or molarity .

(b) Two elements A and B form compounds having formula AB_2 and AB_4 . When dissolved in 20 g of benzene(C_6H_6), 1 g AB_2 lowers the freezing point by 2.3 K whereas 1.0 g of AB_4 lowers it by 1.3 K. The molar depression constant for benzene is $5.1 \text{ K.kg.mol}^{-1}$. Calculate atomic masses of A and B. (CBSE –Samp -8 – 5M)

Ans. (a) (i) Mole fraction:- It is defined as ratio of number of moles one component and total number of moles of solution. It is denoted by X. The value of mole fraction is always 1 for any type of solution.

(ii) Molarity is effected because the value of molarity is depend upon the temperature.

(b)

For compound AB_2 ,

$$\text{Molecular weight of } AB_2 = \frac{1000 \times K_f \times w_B}{\Delta T_f \times w_A} = \frac{1000 \times 5.1 \times 1.0}{2.3 \times 20.0} = 110.87$$

For compound AB_4 ,

$$\text{Molecular weight of } AB_4 = \frac{1000 \times K_f \times w_B}{\Delta T_f \times w_A} = \frac{1000 \times 5.1 \times 1.0}{1.3 \times 20.0} = 196.15$$

Let atomic weight of A = x and that of B = y

$$\text{Molecular weight of } AB_2 = x + 2y = 110.87 \text{-----(1)}$$

$$\text{Molecular weight of } AB_4 = x + 4y = 196.15 \text{-----(2)}$$

Solving eq (1) and (2) we get x = 25.59 and y = 42.64

Atomic weight of A = 25.59 and Atomic weight of B = 42.64

Section -D: Higher Order Questions for high achievers:

(1Q) The heat of vaporisation of benzene is $7353 \text{ cal mol}^{-1}$. The approximate bpt. of benzene is

(Hint) Trouton's rule is $\Delta H_{\text{vap}} / T_b = 21 \text{ cal}$.

(2Q) Camphor is often used in molecular mass determination because

(Hint) Camphor has a very high cryoscopic constant (39.7°). Hence it gives a large depression in melting point when an organic solute is dissolved in it.

3Q) Why cutting onions taken from the fridge is more comfortable than cutting onions lying at room temperature?

(Hint) The vapour pressure is low at lower temperature. So, less vapours of tear - producing chemicals are produced.

4Q) A solution is prepared by dissolving 30g of non-volatile non-electrolyte solute in 90g water. The vapour pressure of solution was 2.8 k Pa at 298K. When 18g of water was further added to it, the vapour pressure became 2.9 k Pa at 298K. Calculate molar mass of solute.

5Q) 9.45 grams of oxalic acid is dissolved in 250 ml of solution. How much water is to be added to make the solution exactly decinormal ?

6Q) Find the quantity of water to change the structure of 25 ml of 0.15 M hydrochloric acid to 0.1 M.

7Q) Find the weight of anhydrous sodium carbonate required to prepare 250 ml of 0.1 N solution.

8Q) Find the volume of 0.25 M- H_3PO_4 required to neutralize 25 ml of 0.03 M- $\text{Ca}(\text{OH})_2$.

9Q) 0.25 gram of acid A was exactly neutralised by 40 ml of 0.125 N base. Find the equivalent weight of acid A.

10Q) If 250 ml of a solution contains 2.45 grams of H_3PO_4 , find its normality? The density of 98% sulphuric acid is 1.8 gram/c.c. Calculate its normality.

11Q) 4.5 grams of an acid of molecular weight 90 was exactly neutralised by 200 ml of 0.5 N- NaOH solution. Find the basicity of the acid.

12Q) Find the weight of ferrous ammonium sulphate needed to prepare 100 ml of 0.1 normal solution.

13Q) If 5.85 grams of common salt is dissolved in water and the solution is made upto 500 ml, find the molarity.



- 14Q) 1.5 litres of a solution of normality x and 2.5 litres of 2 M - HCl are mixed. If the resultant solution has a normality 5, find the value of x .
- 15Q) 20 ml of 0.02 M - KMnO_4 was required to completely oxidise 10 ml of oxalic acid solution. Calculate the molarity of the oxalic acid solution.
- 16Q) An aqueous solution of glucose is 10% in strength. Find the volume in which one gram mole of it is dissolved.
- 17Q) A 500 grams tooth paste sample has 0.2 gram fluoride concentration. What is the concentration of fluoride in terms of ppm level?
- 18Q) 5 ml of N - HCl, 20 ml of N/2 - H_2SO_4 and 30 ml of N/3 - HNO_3 are mixed and volume is made upto one litre. Find the normality of the resultant solution.
- 19Q) If 20 ml of 0.4 N - NaOH solution completely neutralizes 40 ml of a dibasic acid, find the molarity of the acid solution.
- 20Q) If 1000 grams of aqueous solution of CaCO_3 contains 10 grams of carbonate, find the concentration of the solution in ppm.
- 21Q) A solution contains 25% H_2O , 25% $\text{C}_2\text{H}_5\text{OH}$ and 50% CH_3COOH by mass. Find the mole fraction of H_2O .
- 22Q) A solution of a substance containing 1.05 grams per 100 ml was found to be isotonic with 3% glucose solution. Find the molecular weight of the substance.
- 23Q) The solubility of potassium iodate in water is 0.0919 moles/litre. If the specific gravity of the solution is 1.016, find out its molality.
- 24Q) A solution contains 92 grams of ethyl alcohol and 72 grams of water. Find the ratio of mole fractions of alcohol to water.
- 25Q) Crystallisation of solute A is done after saturated solution is allowed to cool. Solubility of a solute A is 12 g per 100 g H_2O at 27°C . 15 g of this solute was dissolved in 50 g H_2O at 70°C and solution cooled to 27°C . How much solute A does crystallise?
- 26Q) The vapour pressure of benzene at 80°C is lowered by 10 mm by dissolving 2 g of a nonvolatile substance in 78g of benzene. The vapour pressure of pure benzene at 80°C is 750 mm. Calculate the molecular weight of the substance.
- 27Q) A 6% glucose solution and 2% solution of X show same relative lowering of vapour pressure. Assuming X to be a non - electrolyte calculate the molecular weight of X.
- 28Q) Vapour pressure of a solution of 5 g of non -electrolyte in 100g of water at particular temperature is 2985 N/m². The vapour pressure of pure water is 3000 N/m². Calculate the molecular weight of solute.



