Q 1. Define an ideal solution and write one of its characteristics?

A1 The solutions which obey Raoult's law over the entire range of concentration are known as ideal solutions. i.e $P_A = P^oA\ x_A$ and $P_B = P^oB\ x_B$.

For ideal solutions $\Delta H_{mix} = 0$ and $\Delta V_{mix} = 0$.

eg ;- Solution of n – hexane and n- heptane

Q 2. What is meant by reverse osmosis ?

A2 The process in which the solvent flows from the solution into the pure solvent through the semi permeable membrane when a pressure higher than the osmotic pressure is applied on the solution is called reverse osmosis.

Application :- The technique is used in the desalination of sea water.

Q3. Define mole fraction.

A3 The mole fraction of a component is the ratio of the number of moles of that component to the total number of moles of all the components present in the solution.

For a binary solution consisting of 2 components A and B if n_A is the number of moles of A and n_B is the number of moles of B then.

$$x_A = \frac{n_A}{n_A + n_B} \qquad x_B = \frac{n_B}{n_A + n_B}$$

Q 4. Define the term azeotrope?

A4 The constant boiling mixture which distill out unchanged in their composition are called azeotropes.

Eg :- A mixture of ethanol and water containing 95.4% of ethanol forms an azeotrope with boiling point 351.15 K.

Q5. Explain boiling point elevation constant for a solvent / Define ebullioscopic constant?

A5 Since $\Delta T_b = K_b.m$ where m is molality

When m = 1

$$K_b = \Delta T_b$$

Therefore Ebullioscopic constant is defined as the elevation in boiling point of a solution when 1 mole of a solute is dissolved in 1 Kg of solvent .

Q6 What are isotonic solutions ?

A6 The solutions of equimolar concentrations having same osmotic pressure at given temperature are called isotonic solutions.

eg :- A 0.9% solution of pure NaCl is isotonic with human red blood cells.

Q7 Explain why aquatic species are more comfortable in cold water rather than in warm water?

A7 Aquatic species need dissolved oxygen for breathing. As solubility of gases decrease with increase of temperature, less oxygen is available in summers in lakes. Hence they feel more comfortable in winter when the solubility is higher.

OR

Q7 Why do gases nearly always tend to be less soluble in liquid as the temperature is raised?

A7 Dissolution of gas in liquid is an exothermic process. Gas + Solvent Solution $\leftrightarrows$ + heat.

Therefore as per Lechatlier's principle if the temperature is increased, equilibrium shifts backward i.e the solubility decreases.

Q8. Differentiate between molarity and molality for a solution. How does a change in temperature influence their values?

Or

Q8. State the main advantage of molality over molarity as the unit of concentration?

Molarity	**Molality**
It is defined as the number of moles of solute dissolved in one litre of the solution	It is defined as the number of moles of solute dissolved in 1 Kg of the solvent
Mathematically Molarity (M) = $\frac{\text{No of moles of solute x 1000}}{\text{Vol of Solution (ml)}}$	Mathematically Molality (M) = $\frac{\text{No of moles of solute x 1000}}{\text{Mass of Solvent (g)}}$
It decreases with increase in temperature (as $V \alpha T$)	It does not change with change in temperature

Since molality does not change with a change in temperature therefore it is a better method to express the concentration of a solution.

Q9. What is meant by colligative property. List any four factors on which colligative properties of a solution depend?

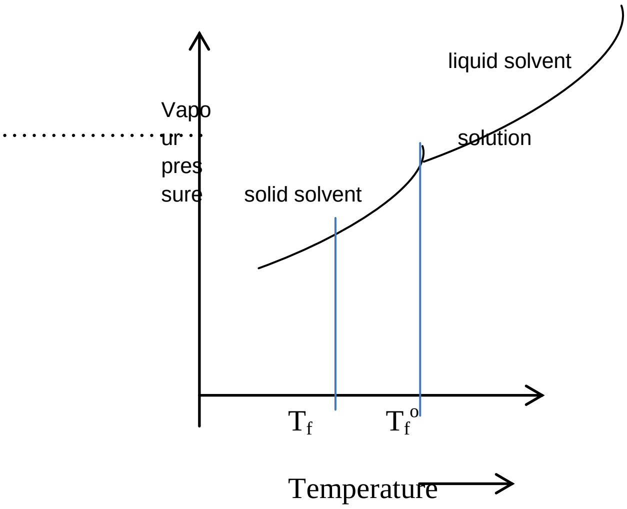
A9. The properties of solutions which depend upon the number of solute particles and not upon the nature of the solute are known as colligative properties eg :- Osmotic pressure.

<u>Factors</u> :-

(i) Number of particles of solute.
(ii) Concentration of solution.
(iii) Temperature.
(iv) Association or dissociation of solute.

Q10. **An aqueous solution of sodium chloride freezes below 273K. Explain the lowering in freezing point of water with the help of a suitable diagram?**

A10. Freezing point of a substance is the temperature at which solid and liquid phases of a substance coexist i.e they have the same vapour pressure. As the vapour pressure of the solution is less than that of pure solvent For solution its vapour pressure will become equal to that of a solid solvent only at a lower temperature.



Q11. A sample of drinking water was found to be severely contaminated with chloroform $CHCl_3$, supposed to be carcinogen. The level of contamination was 15ppm (by mass)?

(i) Express this in percent by mass.

(ii) Determine the molality of $CHCl_3$ in water sample.

A11. 15 ppm means 15 parts in 10^6 parts by mass in the solution.

i.e 10^6 parts by mass of solution= 15 parts of solute.

or 100 parts (Mass %) $= \frac{15}{10^6} \times 100$

$= 15 \times 10^{-4}$

Mass of solvent $= (10^6 - 15)$ g $\approx 10^6$ g

Therefore Molality $= \frac{n_B}{w_A}$ where n_B = no of moles of solute

w_A= Mass of the solvent

Molality $= \frac{15/119.5 \times 1000}{10^6}$

$= 1.25 \times 10^{-4}$m

Q12 State Raoult's law for a solution containing volatile components. How does Raoult's law becomes as special case of Henry's law?

A12 For a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction?

i.e $P_A \alpha\, x_A$ or $P_A = P^0{}_A x_A$
and $P_B \alpha\, x_B$ or $P_B = P^0{}_B x_B$

Where P_A and P_B are the partial pressure of A and B, $P^0{}_A$, $P^0{}_B$ are the vapour pressure of pure component and x_A and x_B are their mole fractions.

If gas is the solute and liquid is the solvent then according to Henry's law

$P_A = K_H x_A$

Thus Raoult's laws and Henry's law become identical except that their proportionality constants are different.

Q13 Some ethylene glycol is added to your car's cooling system along with 5kg of water. If the freezing point of water-glycol solution is -15^{0}c, what is the boiling point of the solution?

$K_b = 0.52$ K Kgmol^{-1} and $K_f = 1.86$ K Kg mol^{-1}

A13 $\Delta T = 15^o c$ $K_f = 1.86$ k/m

$$\text{Molality} = \frac{\Delta T_f}{K_f}$$

= 15/1.86 = 8.06 m

ΔT_b = K_b x m
= 0.52 x 8.06
= 4.19^{0}c

Boiling point of pure water = 100^{o}c
Therefore T_b = Δ_b+ $T\Delta$
T_b = 100 +4.19
= 104.19^{o}C

Q14 Assuming complete dissociation. Calculate the expected freezing point of a solution prepared by dissolving 6g of Glauber's salt, $Na_2SO_4.10\ H_2O$ in 0.1 Kg mol^{-1} of water.K_f of water = 1.86 K Kg mol $^{-1}$.

A 14 K_f = 1.86 K Kgmol^{-1}
W_B = 6g W_A = 0.1 Kg mol^{-1}
M_B = 322 g mol^{-1}

Since there is a complete dissociation
Therefore i = 3

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

$$= \frac{3 \times 1.86 \times 6}{322 \times 0.1}$$

$= 1.04^o$

Q15. Non ideal solutions exhibit either positive or negative deviations from Raoult's law. What are these deviations and why are they caused? Explain with one example for each type?

A15 For non ideal solutions, vapour pressure is either higher or lower than that predicted by Raoult's law. If it is higher the solution exhibits positive deviation and if it is lower it exhibits negative deviation from Raoult's law.

Positive Deviation	**Negative Deviation**
When solute – solvent interactions are weaker than solute – solute or solvent solvent interactions, vapour pressure increases which result in positive deviation.	When solute solvent interactions are stronger than solute – solute or solvent – solvent interactions, vapour pressure decreases which result in negative deviation.
Eg :- Ethanol +Acetone. for a solution showing +ve deviation $P_A > P^o_A X_A$ and $P_B > P^o_B X_B$	eg :- Chloroform + Acetone. for a solution showing –ve deviation $P_A < P^oA X_A$ $P_B < P^0B X_B$
Δ H mix = +ve	Δ H mix = - ve
Δ Vmix = +ve	Δmix = - ve

For plots of non ideal solution showing +ve and –ve deviation refer NCERT pg 56

Q16. (i) What is Van't Hoff factor? What types of values can it have if in forming the solution the solute molecules undergo

(a) Dissociation?

(b) Association?

A16. (i) Van't Hoff factor (i) is defined as the ratio of the experimental value of colligative property to the calculated value of colligativeproperty .

$$i = \frac{\text{Observed Colligative property}}{\text{Calculated Colligative property}}$$

Also, $$i = \frac{\text{Total number of moles of particles after dissociation/ association}}{\text{Number of moles of particles before association/ dissociation}}$$

Therefore , For (a) dissociation i> 1

And (b) Association i< 1

Q 17 (i) Define the terms osmosis and osmotic pressure?

(ii) An aqueous solution containing 12.48g of barium chloride in 1.0 kg of water boils at 373.0832 k. Calculate the degree of dissociation of barium chloride?

(Given K_b for H_2O = 0.52 Km^{-1} molar mass of Ba Cl_2 = 208.34 $gmol^{-1}$)

A17. (i) The net spontaneous flow of the solvent molecules from the solvent to the solution or from a less concentrated solution to a more concentrated solution through a semipermeable membrane is called osmosis.

Osmotic pressure :- The minimum excess pressure that has to be applied on the solution to prevent the entry of the solvent into the solution through the semipermeable membrane is called osmotic pressure.

(ii) Given $W_2 = 12.48g$, $W_1 = 1$ Kg = 1000g
(iii)

T_b (solution) = 373.0832 K

K_b for $H_2O = 0.52\ Km^{-1}$ and M_2 = (Ba Cl_2) = 208.34

$\Delta T_b = T_b - T_b^o = 373.0832 - 373 = 0.0832$ K

$$M_2 \text{ (Observed)} = \frac{K_b \times W_2 \times 1000}{\Delta T_b \times W_1}$$

$$= \frac{0.52 \times 12.48 \times 1000}{0.0832 \times 1000}$$

$$= 78 \text{ g mol}^{-1}$$

$$i = \frac{M_2 \text{ (calculated)}}{M_2 \text{ (observed)}} = \frac{208.34}{78} = 2.67$$

For $BaCl_2$ m = 3 as it gives 3 ions on dissociation

$$\alpha = \frac{i-1}{m-1} = \frac{2.67 - 1}{3-1} = \frac{1.67}{2} = 0.835$$

= 83.5%

Q18. (a) What type of deviation is shown by a mixture of ethanol and acetone? Give reason.

(b) What do you expect to happen when RBC's are placed in

(i) 1% NaCl solution (ii) 0.5 % NaCl solution

(c) Calculate the molarity of 68% (w/w) solution of nitric acid , if the density of the solution is 1.504 g ml^{-1}

A18. (a) Ethanol and acetone shows positive deviation because on mixing the two the forces of attraction decreases and the vapour pressure increases.

(b) Since RBC's are isotonic with 0.9% NaCl solution therefore

(i) In 1% solution of NaCl they will shrink due to plasmolysis

(ii) In 0.5% solution of NaCl they will swell or may even burst.

(c) Molarity = $\frac{\% \text{ x density x } 10}{\text{Molar mass}}$

Mass % = 68 , d = 1.504 Molar mass of HNO_3 = 63 $gmol^{-1}$

Therefore Molarity = $\frac{68 \text{ x } 1.504 \text{ x } 10}{63}$

= 16.23 M

Q19. (a) State Henry's law and mention two of its important applications

(b) The partial pressure of ethane over a saturated solution containing 6.56 x 10^{-2}g of ethane is 1bar. If the solution were to contain 5 x 10^{-2} g of ethane, then what will be the partial pressure of the gas.

A19. (a) Henry's law states that at a constant temperature , the solubility $x$of a gas in a liquid is directly proportional to the pressure of the gas

$P = K_H x$

<u>**Applications**</u> :-

- To increase thje solubility of CO_2 in soda water, the bottle is sealed under high pressure
- There is a low concentration of oxygen in the blood and tissues of the people living at high altitudes due to which they feel weak and are unable to think clearly (anoxia).
- (b) $M = K_H$ x P

  For the 1st case 6.56 x 10^{-2} = K_H x 1 bar or K_H = 6.56 x 10^{-2} g bar^{-1}

  In the 2nd case 5 x 10^{-2} = (6.56 x 10^{-2}) x P

  or P = $\frac{5 \text{ x } 10^{-2}}{6.56 \text{ x } 10^{-2}}$

  P = 0.762 bar

20. **Concentrated nitric acid used in 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 mL^{-1}?**

Concentrated nitric acid used in laboratory work is 68% nitric acid by mass in an aqueous solution. This means that 68 g of nitric acid is dissolved in 100 g of the solution.

Molar mass of nitric acid (HNO_3) = 1 × 1 + 1 × 14 + 3 × 16 = 63 g mol^{-1}

Then, number of moles of HNO_3 $= \frac{68}{63}$ mol

$= 1.079 \text{ mol}$

Given,

Density of solution = 1.504 g mL^{-1}

$\therefore$ Volume of 100 g solution = $\frac{100}{1.504} \text{mL}$

$= 66.49 \text{ mL}$
$= 66.49 \times 10^{-3} \text{ L}$

Molarity of solution $= \frac{1.079 \text{ mol}}{66.49 \times 10^{-3} \text{ L}}$

$= 16.23 \text{ M}$

21. What role does the molecular interaction play in a solution of alcohol and water?

In pure alcohol and water, the molecules are held tightly by a strong hydrogen bonding. The interaction between the molecules of alcohol and water is weaker than alcohol−alcohol and water−water interactions. As a result, when alcohol and water are mixed, the intermolecular interactions become weaker and the molecules can easily escape. This increases the vapour pressure of the solution, which in turn lowers the boiling point of the resulting solution.

22. Why do gases always tend to be less soluble in liquids as the temperature is raised?

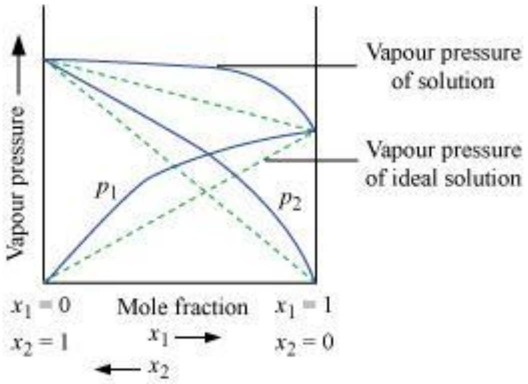
Solubility of gases in liquids decreases with an increase in temperature. This is because dissolution of gases in liquids is an exothermic process.

$$\text{Gas} + \text{Liquid} \longrightarrow \text{Solution} + \text{Heat}$$

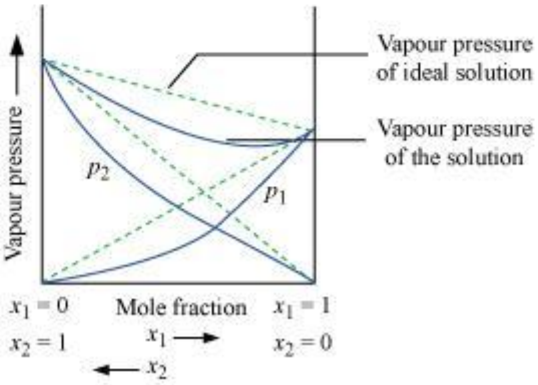
Therefore, when the temperature is increased, heat is supplied and the equilibrium shifts backwards, thereby decreasing the solubility of gases.

23. What is meant by positive and negative deviations from Raoult's law and how is the sign of $\Delta_{sol}H$ related to positive and negative deviations from Raoult's law?

According to Raoult’s law, the partial vapour pressure of each volatile component in any solution is directly proportional to its mole fraction. The solutions which obey Raoult’s law over the entire range of concentration are known as ideal solutions. The solutions that do not obey Raoult’s law (non-ideal solutions) have vapour pressures either higher or lower than that predicted by Raoult’s law. If the vapour pressure is higher, then the solution is said to exhibit positive deviation, and if it is lower, then the solution is said to exhibit negative deviation from Raoult’s law.



Vapour pressure of a two-component solution showing positive deviation from Raoult’s law



Vapour pressure of a two-component solution showing negative deviation from Raoult’s law

In the case of an ideal solution, the enthalpy of the mixing of the pure components for forming the solution is zero.

$\Delta_{sol}H = 0$

In the case of solutions showing positive deviations, absorption of heat takes place.

$\therefore \Delta_{sol}H$ = Positive

In the case of solutions showing negative deviations, evolution of heat takes place.

$\therefore \Delta_{sol}H$ = Negative

24. 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 of AB_2 lowers the freezing point by 2.3 Kwhereas 1.0 g of AB_4 lowers it by 1.3 K. The molar depression constant for benzene is 5.1 Kkg mol^{-1}. Calculate atomic masses of A and B.

We know that,

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

Then, $M_{AB_2} = \frac{1000 \times 1 \times 5.1}{2.3 \times 20}$

= 110.87 g mol^{-1}

$M_{AB_4} = \frac{1000 \times 1 \times 5.1}{1.3 \times 20}$

= 196.15 g mol^{-1}

Now, we have the molar masses of AB_2 and AB_4 as 110.87 g mol^{-1} and 196.15 g mol^{-1} respectively.

Let the atomic masses of A and B be *x* and *y* respectively.

Now, we can write:

$$x + 2y = 110.87 \qquad (i)$$

$$x + 4y = 196.15 \qquad (ii)$$

Subtracting equation (i) from (ii), we have

$2y = 85.28$

$\Rightarrow y = 42.64$

Putting the value of '*y*' in equation (1), we have

$x + 2 \times 42.64 = 110.87$

$\Rightarrow x = 25.59$

Hence, the atomic masses of A and B are 25.59 u and 42.64 u respectively.

25. Determine the amount of CaCl2 (*i* = 2.47) dissolved in 2.5 litre of water such that its osmotic pressure is 0.75 atm at 27°C.

We know that,

$$\pi = i\frac{n}{V}RT$$

$$\Rightarrow \pi = i\frac{w}{MV}RT$$

$$\Rightarrow w = \frac{\pi MV}{iRT}$$

$\pi = 0.75\,\text{atm}$
$V = 2.5\,\text{L}$
$i = 2.47$
$T = (27+273)\,\text{K} = 300\,\text{K}$

Here,

R = 0.0821 L atm $K^{-1}mol^{-1}$

M = 1 × 40 + 2 × 35.5

= 111g mol^{-1}

Therefore, $w = \dfrac{0.75\times111\times2.5}{2.47\times0.0821\times300}$

= 3.42 g

Hence, the required amount of $CaCl_2$ is 3.42 g.

26. Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 liter of water at 25° C, assuming that it is completely dissociated.

When K_2SO_4 is dissolved in water, K^+ and SO_4^{2-} ions are produced.

$$K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}$$

Total number of ions produced = 3

$\therefore i = 3$

Given,

w = 25 mg = 0.025 g

V = 2 L

$T = 25^0C = (25 + 273)\,K = 298\,K$

Also, we know that:

R = 0.0821 L atm $K^{-1}mol^{-1}$

$M = (2 \times 39) + (1 \times 32) + (4 \times 16) = 174\ g\ mol^{-1}$

Appling the following relation,

$$
\begin{aligned}
\pi &= i\frac{n}{v}\mathrm{R}T \\
&= i\frac{w}{M}\frac{1}{v}\mathrm{R}T \\
&= 3\times\frac{0.025}{174}\times\frac{1}{2}\times 0.0821\times 298 \\
&= 5.27\times 10^{-3}\,\mathrm{atm}
\end{aligned}
$$