Methods of Expressing Concentrations

Normality (g. equiv. per litre of solution)

$$N = \frac{\text{Weight of solute (g)}}{\text{Eq. weight of solute} \times \text{Volume of solution (L)}}$$

Molarity (Moles per litre of solution)

$$M = \frac{\text{Weight of solute (g)}}{\text{Molar mass of solute} \times \text{Volume of solution (L)}}$$

Molality (Moles per kg of solvent)

$$m = \frac{\text{Weight of solute (g)}}{\text{Molar mass of solute} \times \text{Mass of solvent (kg)}}$$

Mole fraction

$$x_A = \frac{n_A}{n_A + n_B}; x_B = \frac{n_B}{n_A + n_B} = 1 - x_A$$

Relation

$$N = M \times \frac{\text{Molar mass}}{\text{Equivalent mass}}$$

Relation

$$m = \frac{M}{\frac{d - M \times M_B}{1000}}$$

Relation

$$x_B = \frac{MM_A}{M(M_A - M_B) + 1000\,d}$$

M_A = Molar mass of solvent

M_B = Molar mass of solute

Concentration in percentage

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

$$\text{Volume Percentage} = \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100$$

$$\text{Mass by volume Percentage} = \frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$$

Solubility of Gases

Solubility of gases is the volume of the gas dissolved per unit volume of solvent at 1 atm pressure and specific temperature.

Solubility depends on :

- Temperature
- Nature of gas
- Nature of solvent
- Pressure of the gas

Henry's law : "The solubility of a gas in a liquid at a particular temperature is directly proportional to the pressure of the gas in equilibrium with the liquid at that temperature." *i.e.*, $p \propto x$, $p = K_H x$, x = mole fraction (solubility of gas is expressed in mole fraction).

Raoult's Law

Raoult's law

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

For volatile solute

The total vapoure pressure P of a solution containing two components A and B is

$$p_A = p_A^\circ \times x_A \; ; \; p_B = p_B^\circ \times x_B$$

$$P = p_A + p_B = p_A^\circ x_A + p_B^\circ x_B \; (\because x_A = 1 - x_B)$$

$$= (p_B^\circ - p_A^\circ)\, x_B + p_A^\circ$$

For non-volatile solute

Relative lowering of vapour pressure of a solution containing a non-volatile solute is equal to the mole fraction of solute in the solution.

$$\text{Relative lowering of V.P.} = \frac{P^\circ - P_s}{P^\circ} = \frac{n_B}{n_A + n_B} = x_B$$

Ideal and Non-ideal Solutions

Ideal solutions	Non-ideal solutions
Obey Raoult's law at all temperatures and concentrations.	Do not obey Raoult's law at all temperatures and concentrations.
$p_1 = x_1 p_1^\circ; p_2 = x_2 p_2^\circ$	$p_1 \neq x_1 p_1^\circ; p_2 \neq x_2 p_2^\circ$
$\Delta H_{mix} = 0, \Delta V_{mix} = 0$	$\Delta H_{mix} \neq 0, \Delta V_{mix} \neq 0$
$A - B$ interactions $\approx A - A$ and $B - B$ interactions	$A - B$ interactions $\neq A - A$ and $B - B$ interactions.
Do not form azeotropes (constant boiling mixtures).	Form azeotropes.

Reverse Osmosis

- Direction of osmosis can be reversed by applying higher pressure than the osmotic pressure to the solution side. Then solvent starts flowing in reverse direction.
- In reverse osmosis, solvent moves from solution to pure solvent.
- Used in water purification and desalination of sea water.

Abnormal Molecular Mass

- When the molecular mass of a substance determined by any of the colligative properties comes out to be different than the expected value, the substance is said to show abnormal molecular mass.
- Abnormal molecular masses are observed when the solution is non-ideal (not dilute) or the solute undergoes association or dissociation in the solution.

van't Hoff Factor

- It is defined as the ratio of the experimental value of the colligative property to the calculated value of the colligative property.

$$i = \frac{\text{Observed value of the colligative property}}{\text{Calculated value of the colligative property}}$$

$$i = \frac{\text{Calculated molecular mass}}{\text{Observed molecular mass}}$$

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

- If $i > 1$, solute undergoes dissociation in the solution and if $i < 1$, solute undergoes association in the solution.

$$\alpha_{\text{dissociation}} = \frac{i-1}{n-1}; \alpha_{\text{association}} = \frac{1-i}{1-\frac{1}{n}}$$

α = Degree of association or dissociation.

SPEED PRACTICE

1. Clausthalite is a mineral composed of lead selenide, PbSe, which adopts a NaCl-type structure. The density of PbSe at 25 °C is 8.27 g/cm^3. Length of an edge of the PbSe unit cell (molecular weight = 286.2 g) would be
   (a) 6.44 Å (b) 6.13Å (c) 7.11 Å (d) 3.065 Å
2. Which one of the following statements is false?
   (a) Two sucrose solutions of same molality prepared in different solvents will have the same freezing point depression.
   (b) The osmotic pressure (π) of a solution is given by the equation, $\pi = MRT$, where M is the molarity of the solution.
   (c) Raoult's law states that the vapour pressure of a component over a solution is proportional to its mole fraction.
   (d) The correct order of osmotic pressure for 0.01 M aqueous solution of each compound is $BaCl_2 > KCl > CH_3COOH >$ Sucrose
3. A compound made of particles A, B and C forms *ccp* lattice. In the lattice, ions A occupy the lattice points and ions B and C occupy the alternate tetrahedral voids. If all the ions along one of the body diagonals are removed, then formula of the compound is
   (a) $A_{3.75}B_3C_3$ (b) $A_{3.75}B_3C_4$
   (c) $A_3B_{3.75}C_3$ (d) $A_3B_3C_{3.75}$
4. For a dilute solution containing 2.5 g of a non-volatile, non-electrolyte solute in 100 g of water, the elevation in boiling point at 1 atm pressure is 2 °C. Assuming concentration of solute is much lower than the concentration of solvent, the vapour pressure (mm of Hg) of the solution is ($K_b = 0.76$ K kg mol^{-1})
   (a) 726 (b) 740 (c) 736 (d) 718
5. The site labelled as 'a' in *fcc* arrangement is
   (a) face with 1/4 contribution
   (b) edge with 1/4 contribution
   (c) corner with 1/4 contribution
   (d) tetrahedral void with 1/8 contribution.