

1. Introduction to Solutions and Types

A **solution** is a homogeneous mixture of two or more chemically non-reacting substances.

- **Solvent:** The component present in the largest quantity, determining the physical state of the solution.
- **Solute:** The component(s) present in lesser quantity.

Types of Solutions (based on the physical state of the solvent):

1. **Gaseous Solutions:** Gas in gas (air), liquid in gas (chloroform mixed with nitrogen gas), solid in gas (camphor in nitrogen gas).
2. **Liquid Solutions:** Gas in liquid (oxygen in water), liquid in liquid (ethanol dissolved in water), solid in liquid (salt in water).
3. **Solid Solutions:** Gas in solid (solution of hydrogen in palladium), liquid in solid (amalgam of mercury with sodium), solid in solid (copper dissolved in gold).

2. Expressing Concentration of Solutions

Concentration indicates the amount of solute present in a given quantity of solvent or solution.

- **Mass Percentage (w/w):**

$$\text{Mass}\% = \frac{\text{Mass of component}}{\text{Total mass of solution}} \times 100$$

- **Volume Percentage (v/v):**

$$\text{Volume}\% = \frac{\text{Volume of component}}{\text{Total volume of solution}} \times 100$$

- **Mass by Volume Percentage (w/v):** Mass of solute (in grams) dissolved in 100 mL of the solution (commonly used in medicine/pharmacy).

- **Parts Per Million (ppm):** Used for trace quantities.

$$\text{ppm} = \frac{\text{Number of parts of component}}{\text{Total number of parts of all components}}$$

- **Mole Fraction (x):** Ratio of number of moles of one component to the total number of moles in the solution. For component A:

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

(Note: The sum of mole fractions of all components is always 1, i.e., $x_A + x_B = 1$)

- **Molarity (M):** Number of moles of solute dissolved per litre of solution. (**Temperature dependent**)

$$M = \frac{\text{Moles of solute}}{\text{Volume of solution in L}}$$

- **Molality (m):** Number of moles of solute per kilogram of the solvent. (**Temperature independent**)

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

3. Solubility

Solubility is the maximum amount of a substance that can be dissolved in a specified amount of solvent at a specified temperature.

Solubility of a Solid in a Liquid

- **Nature of Solute/Solvent:** "Like dissolves like" (polar solutes dissolve in polar solvents, non-polar in non-polar).
- **Effect of Temperature:** Follows Le Chatelier's Principle. If the dissolution process is endothermic ($\Delta_{sol}H > 0$), solubility increases with a rise in temperature. If exothermic ($\Delta_{sol}H < 0$), solubility decreases.
- **Effect of Pressure:** Negligible effect because solids and liquids are highly incompressible.

Solubility of a Gas in a Liquid & Henry's Law

- **Effect of Temperature:** Solubility of gases always *decreases* with an increase in temperature (dissolution is exothermic).
- **Henry's Law:** The partial pressure of the gas in the vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.

$$p = K_H x$$

Where K_H is the Henry's law constant. Higher K_H means lower solubility at a given pressure.



4. Vapour Pressure of Liquid-Liquid Solutions

Raoult's Law

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

For components 1 and 2:

$$p_1 = p_1^0 x_1$$

$$p_2 = p_2^0 x_2$$

Where p_1^0 and p_2^0 are the vapour pressures of pure components.

Total vapour pressure (p_{total}) over the solution phase:

$$p_{total} = p_1 + p_2 = p_1^0 x_1 + p_2^0 x_2$$

5. Ideal and Non-Ideal Solutions

Ideal Solutions

Solutions that obey Raoult's law over the entire range of concentration.

- **Conditions:** $\Delta_{mix}H = 0$ and $\Delta_{mix}V = 0$.
- **Molecular level:** The intermolecular attractive forces between the solute-solvent ($A - B$) are nearly equal to those between pure components ($A - A$ and $B - B$).
- **Example:** n-hexane and n-heptane.

Non-Ideal Solutions

Solutions that deviate from Raoult's law.

- **Positive Deviation:** $A - B$ interactions are weaker than $A - A$ or $B - B$. Vapour pressure is higher than expected. $\Delta_{mix}H > 0$ and $\Delta_{mix}V > 0$. (Example: Ethanol + Acetone).
- **Negative Deviation:** $A - B$ interactions are stronger than $A - A$ or $B - B$. Vapour pressure is lower than expected. $\Delta_{mix}H < 0$ and $\Delta_{mix}V < 0$. (Example: Phenol + Aniline).

Azeotropes

Binary mixtures having the same composition in liquid and vapour phase and boiling at a constant temperature. They cannot be separated by fractional distillation.

- **Minimum Boiling Azeotrope:** Formed by solutions showing a large *positive* deviation from Raoult's law (e.g., 95% ethanol in water).
- **Maximum Boiling Azeotrope:** Formed by solutions showing a large *negative* deviation from Raoult's law (e.g., 68% nitric acid in water).

6. Colligative Properties and Determination of Molar Mass

Properties of solutions that depend solely on the **number of solute particles** irrespective of their nature relative to the total number of particles present.

A. Relative Lowering of Vapour Pressure

When a non-volatile solute is added to a solvent, the vapour pressure lowers. The relative lowering is equal to the mole fraction of the solute (x_2).

$$\frac{p_1^0 - p_1}{p_1^0} = x_2 = \frac{n_2}{n_1 + n_2}$$

For dilute solutions ($n_2 \ll n_1$), we can approximate:

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{w_2 \times M_1}{M_2 \times w_1}$$

B. Elevation of Boiling Point

The boiling point of a solution containing a non-volatile solute is higher than that of the pure solvent.

$$\Delta T_b = T_b - T_b^0$$

$$\Delta T_b = K_b m$$

Where K_b is the Boiling Point Elevation Constant (Ebullioscopic constant) and m is molality.

C. Depression of Freezing Point

The freezing point of a solution containing a non-volatile solute is lower than that of the pure solvent.

$$\Delta T_f = T_f^0 - T_f$$

$$\Delta T_f = K_f m$$

Where K_f is the Freezing Point Depression Constant (Cryoscopic constant).

D. Osmosis and Osmotic Pressure

- **Osmosis:** The spontaneous flow of solvent molecules through a semipermeable

membrane from a pure solvent to a solution (or dilute to concentrated solution).

- **Osmotic Pressure (π):** The excess pressure that must be applied to a solution to prevent osmosis.

$$\pi = CRT = \frac{n_2}{V} RT$$

Where C is molarity, R is the gas constant, and T is temperature.

7. Reverse Osmosis & Water Purification

If a pressure larger than the osmotic pressure is applied to the solution side, the direction of osmosis is reversed. Pure solvent flows out of the solution through the semi-permeable membrane.

- **Application:** Desalination of seawater. Cellulose acetate is commonly used as a semi-permeable membrane because it allows water molecules to pass but is impermeable to impurities and ions.




One Platform for **UniDrill**
Complete CUET Prep

Mock Tests • PYQs • Domain Notes

www.unidrill.in

The banner features a student sitting at a desk with a laptop and smartphone, surrounded by books and a potted plant. The background is a vibrant blue and orange gradient with icons representing various study resources.

8. Abnormal Molar Masses and Van't Hoff Factor

When solutes undergo dissociation (e.g., $NaCl \rightarrow Na^+ + Cl^-$) or association (e.g., acetic acid in benzene) in a solution, the number of particles changes, leading to an **abnormal molar mass** calculation based on colligative properties.

Van't Hoff Factor (i): Introduced to account for the extent of dissociation or association.

$$i = \frac{\text{Normal molar mass}}{\text{Abnormal molar mass}}$$

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

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

Modified Colligative Property Equations:

1. Relative lowering of vapour pressure:

$$\frac{p_1^0 - p_1}{p_1^0} = i \frac{n_2}{n_1}$$

2. Elevation of Boiling Point: $\Delta T_b = i K_b m$

3. Depression of Freezing Point:

$$\Delta T_f = i K_f m$$

4. Osmotic Pressure: $\pi = i CRT$

