# Solutions

- **Mixture**

1. Mixtures refer to those substances which consist of two or more elements or compounds, mixed together in any ratio and do not give rise to new compound. For example: sea water, air, chocolate milk etc.

2. Mixture is composed of two or more substances mixed together in any ratio i.e. the composition is variable and do not possess properties like fixed melting or boiling point.

3. Mixture shows the properties similar to that of its constituents and they can be separated by using physical and chemical methods.

4. There are two types of mixtures:
   i. **Homogeneous mixtures:** Such mixtures have only one phase. They have the same composition throughout and there is no visible separation of line between the constituents. For example: sugar solution, vinegar etc.
   ii. **Heterogeneous mixture:** Mixtures which has more than one phase is known as heterogeneous mixture. There is a visible boundary of separation between the components and they do not have the same composition throughout.

5. Homogeneous mixtures are of three types: (i) Solid homogeneous mixture (alloys), (ii) Liquid homogeneous mixture (solution of alcohol in water) and (iii) Gaseous homogeneous mixture (air).

6. Heterogeneous mixtures are of three types: (i) Solid heterogeneous mixture (mixture of sand and sugar), (ii) Solid-liquid heterogeneous mixture (solution of chalk in water) and (iii) Gaseous heterogeneous mixture (smoke in air).

- **Substance** – Cannot be separated into its constituent particles by any physical process
- **Solution –** Homogeneous mixture of two or more substances
- **Alloys** – Homogeneous mixture of metals
- **Solution**:
  - The component of the solution that dissolves the other component in it is called solvent (present in larger amount).
  - The component of the solution that is dissolved in the solvent is called solute (present in lesser quantity).
- **Properties of solution:**
  - Homogeneous mixture
  - Particles are extremely small, not visible to the naked eye
  - Light path not visible
  - Solute particles cannot be separated by filtration

**Solubility:**

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

- **Solubility of a solid in a liquid:**

  -Effect of temperature (Le Chatelier's principle) –

    When the dissolution process is endothermic, the solubility will increase with increase in temperature.

When the dissolution process is exothermic, the solubility will decrease with increase in temperature.

-Effect of pressure: Pressure does not affect solubility.

- **Solubility of a gas in a liquid:**

Henry's law → The solubility of a gas in a liquid is directly proportional to the pressure of the gas.

**Or**

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

$$p = K_H x$$

Where, $K_H$ → Henry's law constant

- Some applications of Henry's law –

-The solubility of $CO_2$ in soft drinks and soda water is increased by sealing the bottles under high pressure.

-At high pressure underwater, scuba divers have to cope with high concentrations of dissolved gases while breathing air.

-At high altitudes, climbers become weak and are unable to think clearly, which are symptoms of a condition called anoxia

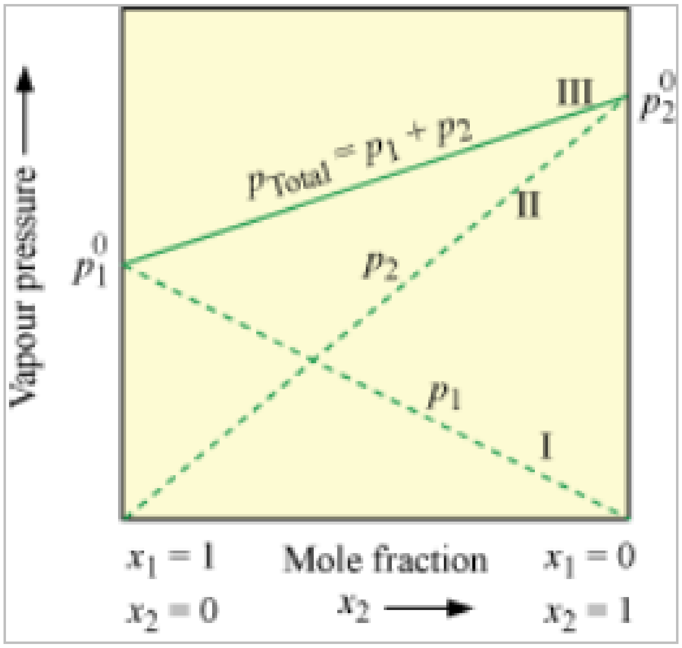
Effect of temperature –

With increase in temperature, the solubility of gases in liquids decreases.

**Vapour pressure of liquid solutions:**

- 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.

$$p_1 = p_1^o x$$
$$p_{total} = p_1^o + (p_2^o - p_1^o)\, x_2$$



(For an ideal solution at constant temperature)

- Vapour pressure of solutions of solids in liquids:

$$p_1 = x_1\, p_1^o$$

**Ideal and non-ideal solutions:**

- Ideal solutions –

  Solutions which obey Raoult's law over the entire range of concentrations

  $$\Delta_{mix}H = 0$$
  $$\Delta_{mix}V = 0$$

  -In an ideal solution, the solute–solute and solvent–solvent interactions are nearly equal to the solute–solvent interactions.

- Non-ideal solutions – Solutions which do not obey Raoult's law over the entire range of concentrations

-Positive deviation from Raoult's law –

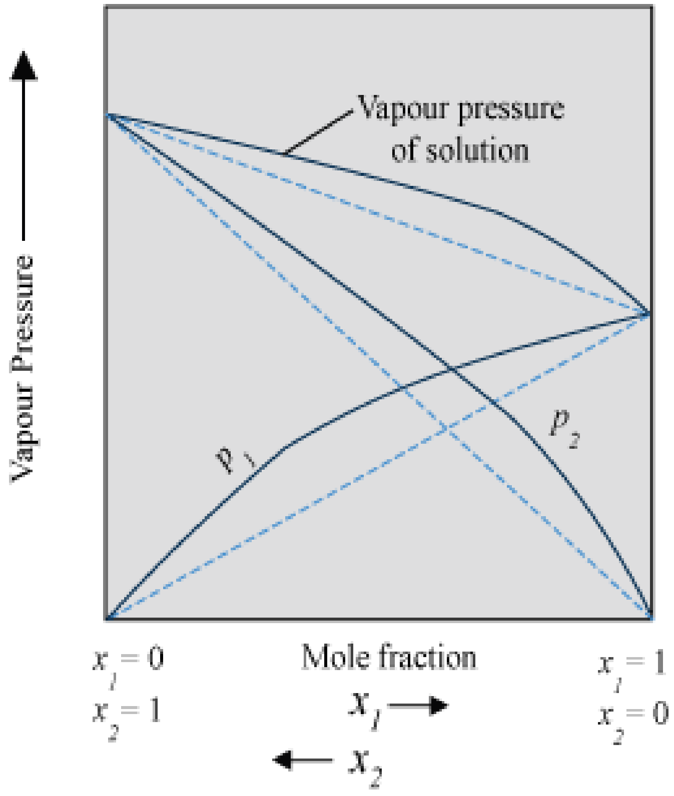
- -Vapour pressure of the solution is higher than that predicted by Raoult's law.

- -Solute–solvent interactions are weaker than solute–solute and solvent–solvent interactions.

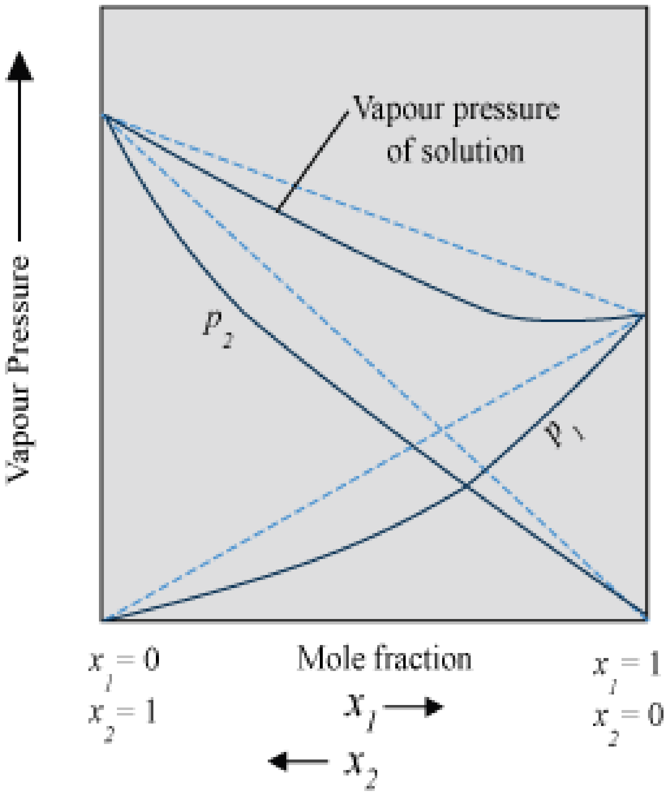
-Negative deviation from Raoult's law –

- -Vapour pressure of the solution is lower than that predicted by Raoult's law.

- -Solute–solute and solvent–solvent interactions are weaker than solute–solvent interactions.



(For a two-component solution showing positive deviation from Raoult's law)



(For a two-component solution showing negative deviation from Raoult's law)

**Colligative properties and determination of molar mass:**

- **Relative lowering of vapour pressure:**
- Relative lowering of vapour pressure is equal to the mole fraction of the solute.

i.e., $\frac{p_1^0 - p_1}{p_1^0} = x_2$

However, $x_2 = \frac{n_2}{n_1 + n_2}$

Where, $n_2$ = Number of moles of solute

$n_1$ = Number of moles of solvent

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

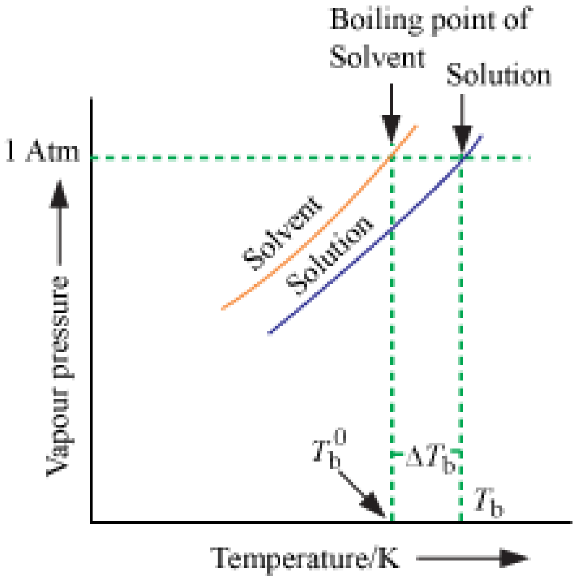
For dilute solution, $n_1 >> n_2$

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

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

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

- **Elevation of boiling point:**



- Here, $\Delta T_b = T_b - T_b^0$ = Elevation of boiling point

Where,

$T_b$ = Boiling of solution

$T_b^0$ = Boiling point of solvent

- $\Delta T_b \propto m$ (for dilute solution)

$\Rightarrow \Delta T_b = K_b m$

Where,

$m$ = Molality

$K_b$ = Proportionality constant known as Boiling Point Elevation Constant or Molal Elevation Constant or Ebullioscopic constant (Unit = K kg mol$^{-1}$)

However, $m = \dfrac{\frac{w_2}{M_2}}{\frac{w_1}{1000}} = \dfrac{1000 \times w_2}{M_2 \times w_1}$

Where,

$w_2$ = Mass of solute

$M_2$ = Molar mass of solute

$w_1$ = Mass of solvent

Now, $\Delta T_b = \dfrac{K_b \times 1000 \times w_2}{M_2 \times w_1}$

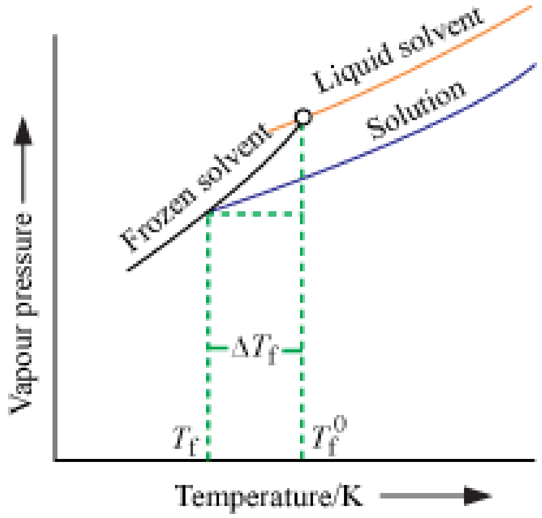
Or, $M_2 = \dfrac{1000 \times w_2 \times K_b}{\Delta T_b \times w_1}$

Where, $K_b$= Boiling-point elevation constant

Or, Molal elevation constant

Or, Ebullioscopic constant

- **Depression of freezing point:**



- Here, $\Delta T_f = T_f^0 - T_f$ = Depression of freezing point

Where,

$T_f^0$ = Freezing point of solvent

$T_f$ = Freezing point of solution

- For dilute solution (ideal solution),
  $\Delta T_f \propto m$

$\Rightarrow \Delta T_f = K_f m$

Where,

$m$ = Molality

$K_f$ = Proportionality constant known as Freezing Point Constant or Molal Depression Constant or Cryoscopic constant (Unit = K kg mol$^{-1}$)

However, $m = \dfrac{\dfrac{w_2}{M_2}}{\dfrac{w_1}{1000}} = \dfrac{1000 \times w_2}{M_2 \times w_1}$

Where,

$w_2$ = Mass of solute

$M_2$ = Molar mass of solute

$w_1$ = Mass of solvent

Now, $\Delta T_f = \dfrac{K_f \times w_2 \times 1000}{M_2 \times w_1}$

Or, $M_2 = \dfrac{1000 \times w_2 \times K_f}{\Delta T_f \times w_1}$

- The value of $K_b$ and $K_f$ can be determined by the following relations:

$$K_b = \frac{R \times M_1 \times T_b^2}{1000 \times \Delta_{vap} H}$$

$$K_f = \frac{R \times M_1 \times T_f^2}{1000 \times \Delta_{fus} H}$$

Where,

$M_1$ = Molar mass of the solvent

R = Gas constant

$\Delta_{vap}H$ = Enthalpy of vaporisation

$\Delta_{fus}H$ = Enthalpy of fusion

- **Osmosis and osmotic pressure:**

$$\pi = CRT$$

$$\text{Or,}\ \pi = \left(\frac{n_2}{V}\right)RT$$

$$\text{Or,}\ M_2 = \frac{w_2 RT}{\pi V} \qquad \left[n_2 = \frac{w_2}{M_2}\right]$$

  - If two solutions have the same osmotic pressure at a given temperature, then the solutions are called isotonic solutions.

- **Abnormal molar masses:** Molar mass lower or higher than expected or normal value

- **Van’t Hoff factor, *i*:** Expresses the quantitative extent to which a solute is dissociated or associated

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

$$\Delta T_b = iK_b m$$

$$\Delta T_f = iK_f m$$

$$\pi = i\left(\frac{n_2}{V}\right)RT$$

- **Modification of the equations for colligative properties:**

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

$$\Delta T_b = iK_b m$$

$$\Delta T_f = iK_f m$$

$$\pi = i\left(\frac{n_2}{V}\right)RT$$