

NEET Revision Notes

Chemistry

Solution

Definition

A solution is a homogeneous mixture of two or more components.
For example: the presence of ordinary salt in water.

Classification

- Binary solutions are those that have two components. Components are the substances used to create a solution.
- The component with the highest concentration is solvent. The solvent determines the physical state of a solution.
- A solute is a component of a solution that is present in smaller amounts.
- Each element can be solid, liquid, or gaseous.

Types of Solution	Solute	Solvent	Common Examples
Gaseous Solutions	Gas	Gas	Oxygen and nitrogen gas mixture
	Liquid	Gas	a mixture of chloroform and nitrogen gas
	Solid	Gas	nitrogen gas with camphor
Liquid Solutions	Gas	Liquid	Water with oxygen dissolved in it
	Liquid	Liquid	Ethanol is a liquid that can be dissolved in water.
	Solid	Liquid	Glucose that has been dissolved in water
Solid Solutions	Gas	Solid	Hydrogen solution in palladium
	Liquid	Solid	Mercury and sodium amalgam
	Solid	Solid	dissolving copper in gold

Strength of Solutions:

The amount of solute dissolved per unit of solution or solvent is referred to as solution strength. There are several methods for determining a solution's strength.

1. Mass Percentage (%w/w):

"It denotes the mass of a component in 100 g of solution."

$$\text{Mass \% of a component} = \frac{\text{Mass of component in the sol.}}{\text{Total Mass of sol.}} \times 100$$

2. Volume percentage (%v/v):

"It represents the volume of a component in a solution of 100mL. "

$$\text{Volume \% of a component} = \frac{\text{Volume of component}}{\text{Total Volume of sol.}} \times 100$$

3. Mass by volume percentage (% w / v):

"It denotes the mass of the solute in grams in 100mL of solution. "

$$\text{Mass by vol. percent} = \frac{\text{Mass of solute in g}}{\text{Vol. of sol. in mL}} \times 100$$

4. Parts per Million (ppm):

$$\text{Parts per million} = \frac{\text{No. of parts of the component}}{\text{Total no. of all the components of sol.}} \times 10^6$$

Mass to mass, volume to volume, and mass to volume are all ways to express concentration in parts per million.

5. Mole Fraction (x):

"It denotes the number of moles of a solute in one mole of solution."

$$\text{Mole fraction} = \frac{\text{No. of moles of the component}}{\text{Total no. of moles all the components}}$$

If the amount of moles of A and B in a binary mixture is $n_{\{A\}}$ and $n_{\{B\}}$, respectively, the mole fraction of A will be

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

6. Molarity, M:

"It represents the number of moles of solute in 1 litre of solution."

$$\text{Molarity, } M = \frac{\text{Moles of solute}}{\text{Vol. of sol in L}}$$

Molarity is measured in milligrams per litre and is denoted by the letters 'M' or 'Molar.' "The density of a solution is its mass per unit volume."

$$\text{Density, } d = \frac{\text{Mass of sol.}}{\text{Vol. of sol.}} = m / V$$

7. Molality, m :

“It denotes the number of moles of solute present per kilogram of solvent.”

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

Molality is measured in mol/kg, which can also be written as 'm' or 'molal.'

8. Normality, N :

It denotes the number of solute equivalents in 1 litre of solution.

$$\text{Normality, } N = \frac{\text{No. of Equivalents of solute}}{\text{Vol. of sol. in L}}$$

$$\text{No. of equivalents, } eq = \frac{\text{Weight}(W)}{\text{Equivalent weight}(E)}$$

$$E = \frac{M}{z} \text{ (Z is the valency factor).}$$

Some important relationships

Dilution Law:

When we dilute a solution with solvent, the solute concentration remains constant, and we can write:

$$M_1V_1 = M_2V_2 \text{ and } N_1V_1 = N_2V_2$$

Relation between Molarity and Normality

$$\text{Normality} = z \times \text{Molarity}$$

IMPORTANT:

Temperature has no effect on mass percent, ppm, mole fraction, or molality, but it does affect molarity and normality. This is because temperature has no effect on volume but has no effect on mass.

Vapour pressure

Definition

The vapour pressure of a liquid/solution at a given temperature is the pressure exerted by vapours in equilibrium with the liquid/solution.

Vapour pressure \propto escaping tendency

Vapour pressure of liquid solutions and Raoult's Law: (Raoult's law for volatile solutes)

According to Raoult's law, the partial vapour pressure of each component in a volatile liquid solution is directly proportional to its mole fraction.

$$p_1 \propto x_1 \text{ and } p_1 = p_1^0 x_1$$

Component 2 is the same way as follows,

$$p_2 = p_2^0 x_2$$

According to Dalton's partial pressure law, the total pressure over the solution phase in the container is equal to the sum of the partial pressures of the solution's components and is given as:

$$P_{(\text{total})} = p_1 + p_2$$

On substituting the values of p_1 and p_2 as follows,

$$\begin{aligned} P_{(\text{total})} &= x_1 p_1^0 + x_2 p_2^0 \\ &= (1 - x_2) p_1^0 + x_2 p_2^0 \\ &= p_1^0 + (p_2^0 - p_1^0) x_2 \end{aligned}$$

At constant temperature, the plot of vapour pressure and mole fraction of an ideal solution.

Mole fraction in the vapour phase

Using Dalton's law of partial pressures, if y_1 and y_2 are the mole fractions of components 1 and 2 in the vapour phase, then:

$$p_1 = y_1 P_{\text{total}}$$

$$p_2 = y_2 P_{\text{total}}$$

Generally, the formula can be represented as,

$$p_i = y_i P_{\text{total}}$$

Vapour pressures of solutions of solids in liquids and Raoult's Law (Raoult's law for non-volatile solutes)

When a nonvolatile solute is added to a solvent to form a solution, the number of solvent molecules leaving the surface decreases, lowering the vapour pressure. The drop in solvent vapour pressure is determined by the amount of non-volatile solute present in the solution, regardless of its composition.

Raoult's law states, in its most general form, that the partial vapour pressure of each volatile component in a solution is directly proportional to its mole fraction for every solution.

$$p_1 \propto x_1$$

$$p_1 = x_1 p_1^0 = p_{total}$$

If Raoult's law holds true for all concentrations, the vapour pressure of a solution will vary linearly from zero to the vapour pressure of the pure solvent.

Ideal and Non-ideal solutions

Ideal solutions:

An ideal solution is one in which each component follows Raoult's rule at all temperatures and concentrations.

Properties of Ideal solutions:

- $\Delta H_{\text{MIXING}} = 0$
- $\Delta V_{\text{MIXING}} = 0$
- The attractive forces between A-A and B-B molecules are roughly equivalent to those between A-B molecules.
- For example: Benzene and toluene or *n*-hexane and *n*-heptane solutions.

Non – ideal solutions:

- A non-ideal solution is one that deviates from Raoult's law over a wide concentration range.

Solutions showing positive deviation from Raoult's Law:

- The forces of solute-solute (B-B) and solvent-solvent (A-A) are weaker than the forces of Solvent-Solute(A-B).
- The vapour pressure is higher than predicted by the law.
- $\Delta H_{\text{MIXING}} > 0$
- $\Delta V_{\text{MIXING}} > 0$
- For example:
Ethanol with acetone or carbon disulphide and acetone.

Negative deviations from Raoult's law are shown in the following solutions:

The Solvent-Solute (A-B) force is stronger than the other two, and the vapour pressure is lower than predicted by the law.

$$\Delta H_{\text{MIXING}} < 0$$

$$\Delta V_{\text{MIXING}} < 0$$

Examples are phenol and aniline, chloroform and acetone, and so on.

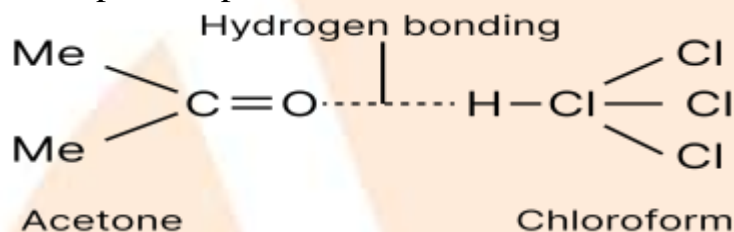


Image: Chloroform and acetone deviation

Azeotropes

Azeotropes are binary mixtures that have the same composition in the liquid and vapour phases and boil at the same temperature.

Minimum boiling azeotrope

Solutions with a significant positive deviation from Raoult's law form the minimum boiling azeotrope at a given composition.

An azeotrope with a boiling point of 351.15 K, for example, is formed by a mixture of ethanol and water containing approximately 95% ethanol.

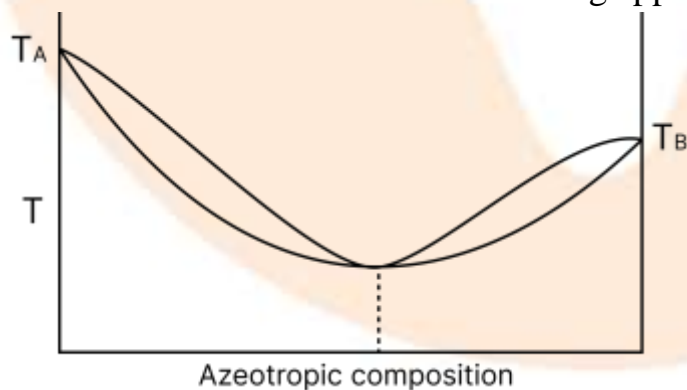


Image: Minimum boiling azeotropic composition

The temperature at which water boils - composition Large positive deviations are depicted in this diagram for solutions (Minimum boiling azeotrope).

Maximum boiling azeotrope:

Solutions with a significant negative divergence from Raoult's law form the maximum boiling azeotrope at a given composition. An azeotrope with a boiling point of 393.5 K is produced by a mixture of 68% nitric acid and water.

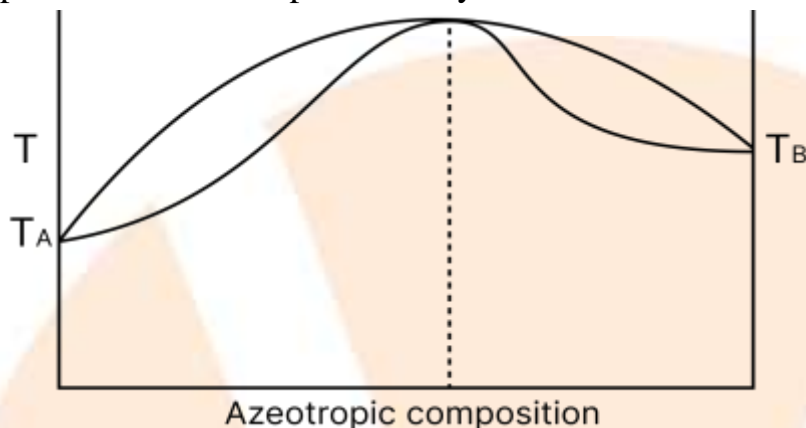


Image: Maximum boiling azeotropic composition

Water boiling temperature – composition, this diagram depicts large negative variances for solutions. (highest boiling point azeotrope)

Solubility

Solubility of a solid in liquid

The solubility of a substance refers to how much of it can be dissolved in each amount of solvent.

Factors impacting a solid's solubility in a liquid include:

1. Nature of solute and solvent:

Like dissolves into like. For example, sodium chloride and sugar dissolve quickly in water, but naphthalene and anthracene do not. Naphthalene and anthracene dissolve rapidly in benzene, but sodium chloride and sugar do not.

2. Temperature:

If ($\Delta_{sol}H > 0$) the solubility of a nearly saturated solution increases with the increase in temperature, and if ($\Delta_{sol}H < 0$) the solubility decreases with the increase in temperature.

3. Pressure's Effect:

Because solids and liquids are highly incompressible, this has little impact.

Henry's law

According to Henry's law, the solubility of a gas in a liquid is directly proportional to the pressure of the gas at a constant temperature.

According to the most common version of Henry's law, "the partial pressure of the gas in the vapour phase (p) is directly related to the mole fraction of the gas (x) in the solution."

The constant K_H stands for Henry's law.

Characteristics of K_H :

- The nature of the gas determines K_H .
- The lower the solubility of the gas in the liquid, the higher the value of K_H at a given pressure.
- K_H values increase as temperature decreases, indicating that gas solubility increases as temperature decreases.

Applications:

- In the manufacture of carbonated drinks.
- During a deep-water dive.
- Climbers and those who live at high altitudes will benefit from this.

Henry's Law as a specific example of Raoult's Law

Raoult's law states that

$$p_i = x_i p_i^0$$

One of the gases in a liquid solution is so volatile that it exists as a gas. It is soluble in water, according to Henry's law.

$$p_i = K_H x$$

As a result, Raoult's law becomes a specific case of Henry's law, in which K_H equals p_i^0 .

Colligative properties

Colligative properties are those that are determined by the number of solute particles present in a solution, regardless of their type, in relation to the total number of particles present.

Collaborative qualities include the following:

1. A Relative Decrease in Vapor Pressure
2. Boiling Point Elevation
3. Freezing point depression
4. Osmotic pressure is the factor to consider.

Relative Lowering of vapour Pressure

The vapour pressure of a solvent decreases when a non-volatile solute is added. The reduction in vapour pressure with respect to the pure solvent's vapour pressure is referred to as "relative lowering in vapour pressure."

Raoult's Law states that:

$$p_1 = x_1 p_1^0$$

The reduction in the vapour pressure of solvent (Δp_1) is given as:

$$\begin{aligned}\Delta p_1 &= p_1^0 - p_1 \\ &= p_1^0 - p_1^0 x_1 \\ &= p_1^0 (1 - x_1)\end{aligned}$$

It is known that $x_2 = 1 - x_1$ equation then reduces to

$$\Delta p = x_2 p_1^0$$

This equation can be written as

$$\frac{\Delta p}{p_1^0} = \frac{p_1^0 - p_1}{p_1^0} = x_2$$

The expression on the left-hand side of the equation, as previously stated, is known as relative lowering of vapour pressure and equals the mole fraction of the solute. The above equation can be written as:

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{n_2}{n_1 + n_2} \left(\text{since } x_2 = \frac{n_2}{n_1 + n_2} \right)$$

The number of moles of solvent and solute present in the solution are represented by n_1 and n_2 , respectively. Since $n_2 \ll n_1$ for dilute solutions, n_2 in the denominator can be ignored.

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

Or

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

Here, w_1 and w_2 are the masses of the solvent and solute, respectively, while M_1 and M_2 are the molar masses of the solvent and solute.

Elevation in Boiling Point

- The boiling point of a liquid is the temperature at which its vapour pressure equals atmospheric pressure.
- When a non-volatile solute is added, the solvent's vapour pressure decreases, requiring a higher temperature to boil the solution. As a result, the solution's boiling point will rise.
- Elevation of boiling point is defined as an increase in boiling point $\Delta T_b = T_b - T_b^0$, where T_b^0 is the boiling point of pure solvent and T_b is the boiling point of solution.

Expression:

$$\Delta T_b = K_b m$$

Boiling Point Elevation Constant, or K_b , is also known as the Molal Elevation Constant (Ebullioscopic Constant).

Depression in freezing point

- The freezing point of a substance is the temperature at which its vapour pressure in its liquid phase equals its vapour pressure in its solid phase.
- When a non-volatile solid is introduced into a solvent, the vapour pressure decreases until it equals the vapour pressure of a solid solvent at a lower temperature. As a result, the freezing point of the solvent decreases.
- Depression in freezing point is defined $\Delta T_f = T_f^0 - T_f$, where T_f^0 is the freezing point of pure solvent and T_f is the freezing point when a non-volatile solute is dissolved.

Expression

$$\Delta T_f = K_f m$$

Freezing Point Depression Constant, Molal Depression Constant, or Cryoscopic Constant are all names for K_f .

Osmosis

When a semipermeable membrane separates a pure solvent from a solution, the solvent particles move from the solvent side to the solution side. This phenomenon is known as "osmosis."

Only small molecules can pass through the semi-permeable membrane, while larger solute molecules are blocked.

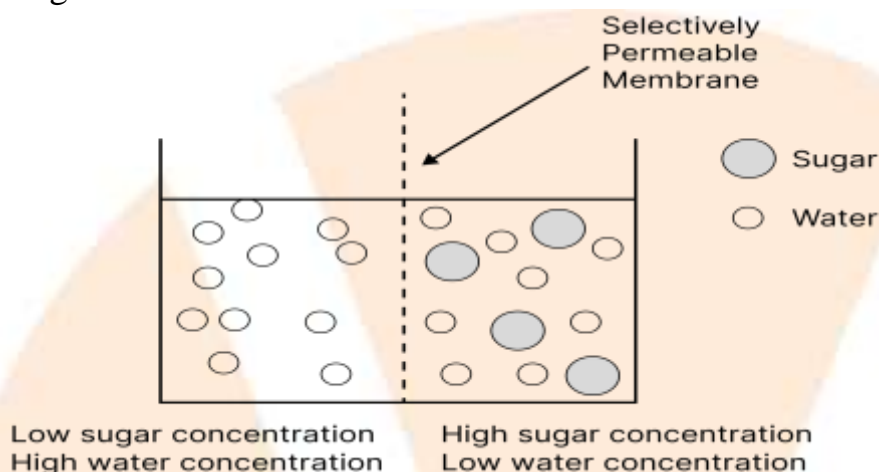


Image: Process of osmosis

Osmotic pressure:

- The osmotic pressure of a solution is the excess pressure that must be applied to a solution to prevent osmosis, or the flow of solvent molecules through a semipermeable barrier into the solution.
- The osmotic pressure must be equal to or greater than the excess pressure. A coating should be applied to the solution to prevent osmosis.

Expression: At a given temperature T , osmotic pressure is directly related to the molarity, C , of a dilute solution.

Thus:

$$\pi = CRT$$

Here, osmotic pressure is π , while the gas constant is R .

Isotonic solutions:

Isotonic solutions are defined as two liquids with the same osmotic pressure at the same temperature.

A solution with a lower concentration or lower osmotic pressure than a more concentrated solution is referred to as "Hypotonic."

A solution with a higher concentration or higher osmotic pressure than a dilute solution is referred to as "hypertonic."

Reverse osmosis:

If a pressure greater than the osmotic pressure is applied to the solution side, the solvent will flow from the solution into the pure solvent through the semipermeable membrane. Reverse osmosis is the name given to this process.

Application:

Desalination of sea water: When a pressure greater than osmotic pressure is applied to the membrane, pure water is squeezed out of the sea water.

Abnormal Molar Masses

When the molecular mass of a substance is determined by investigating any of the colligative qualities and differs from the theoretically expected value, it is said to have aberrant molar mass.

Abnormal Molar Masses are observed:

1. When a solute in a solution forms a bond.
2. When the solute in the solution dissociates.

Van't Hoff Factor:

Van't Hoff proposed a factor (i) known as the van't Hoff Factor in order to determine the level of association or dissociation.

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

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

$$= \frac{\text{Total no. of moles of particles after association (dissociation)}}{\text{No. of moles of particles before association (dissociation)}}$$

Modified Expressions:

Relatively lowering of solvent's vapour pressure as shown below.

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

Depression of Freezing point:

$$\Delta T_f = iK_f m$$

Osmotic pressure of solution:

$$\pi = in_2RT / V$$

Vapour pressure

When the temperature of a liquid rises, so does the desire of the molecules to escape, and the vapour pressure rises. The distribution of kinetic energy among molecules in a liquid.

Clausius-Clapeyron Equation

The equation can be represented as:

$$p_2 / p_1 = (\Delta H_{\text{VAP}} / R)(1 / T_1 - 1 / T_2)$$

Here, ΔH_{VAP} represents the liquid's vaporisation enthalpy.

Examples:

1. 4 litres of 0.02 M aqueous solution of NaCl was diluted by adding one litre of water. The molality of the resultant solution is _____.

(A) 0.004 (B) 0.008 (C) 0.012 (D) 0.016

Correct Answer: Option (D)

Explanation:

Volume $V_1 = 4\text{L}$

Molarity $M_1 = 0.02\text{M}$

Volume $V_2 = 4 + 1 = 5\text{L}$

The formula used will be:

$$M_1V_1 = M_2V_2$$

By substituting the values in the formula $M_1V_1 = M_2V_2$ we get

$$M_1V_1 = M_2V_2$$

$$0.02 \times 4 = M_2 \times 5$$

$$\Rightarrow M_2 = \frac{0.02 \times 4}{5}$$

$$\Rightarrow M_2 = 0.016\text{M}$$

Thus, the molarity of the resultant solution is 0.016M.

2. Relative lowering of vapour pressure is a colligative property because _____.

(A) It depends on the concentration of a non electrolyte solute in solution and does not depend on the nature of the solute molecules.

(B) It depends on number of particles of electrolyte solute in solution and does not depend on the nature of the solute particles.

(C) It depends on the concentration of a non electrolyte solute in solution as well as on the nature of the solute molecules.

(D) It depends on the concentration of an electrolyte or nonelectrolyte solute in solution as well as on the nature of solute molecules.

Correct Answer: Option (i) and option (ii)

Explanation:

The relative lowering of vapour pressure depends on the concentration of a nonelectrolyte solute in a solution and the number of particles of electrolyte solute in a solution. The relative lowering of vapour pressure does not depend on the nature of the solute molecules and the nature of the solute particles. That is why it is a colligative property.

3. Which of the following binary mixtures will have the same composition in liquid and vapour phase?

(A) Benzene – Toluene

(B) Water - Nitric acid

(C) Water – Ethanol

(D) *n*-Hexane - *n*-Heptane

Correct Answer: Option (ii) and option (iii)

Explanation:

The mixture having the same composition in liquid as well as the vapour phase is known as azeotropes. The property of azeotropic mixture is that it boils at the same temperature.

The solutions, water-nitric acid and water-ethanol are non-ideal solutions which have the same composition in liquid and vapour phase, hence they are azeotropes. While benzene-toluene and *n*-hexane-*n*-heptane are ideal solutions so they will not behave as azeotropes.