SOLUTION & COLLIGATIVE PROPERTIES

IDEAL AND NON-IDEAL SOLUTION

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IDEAL SOLUTION:

A solution is defined as a homogeneous mixture of two or more components. The component present in the highest quantity within a solution is termed the solvent, influencing the solution's physical state, while the other components are referred to as solutes. A solution composed of two components is specifically called a binary solution. Various properties of a solution, such as vapor pressure, boiling point, freezing point, and other colligative properties, are used to characterize it. Binary liquid in liquid solutions can be categorized into two types: ideal and non-ideal solutions.

Ideal Solution

An ideal solution is characterized by intermolecular interactions between solute-solute (A-A) and solvent-solvent (B-B) that closely resemble the interactions between solute-solvent (A-B). The following criteria define an ideal solution:

- It adheres to Raoul's law across all concentration and temperature ranges, indicating that the partial vapor pressure of each component is directly proportional to its mole fraction in the solution at a given temperature.
- It exhibits zero enthalpy of mixing ($\Delta H_{mix} = 0$), indicating neither heat absorption nor release during the mixing process.
- It has zero volume of mixing ($\Delta V_{mix} = 0$), meaning the solution's volume equals the sum of the volumes of its components.

Ideal solutions are achievable when the components are of similar size and polarity, and there is no association, dissociation, or reaction between them. While a perfectly ideal solution is rare, some solutions closely approach ideality.

Examples include benzene and toluene, hexane and heptane, bromoethane and chloroethane, chlorobenzene and bromobenzene, among others.

Non-ideal Solution

If a solution fails to adhere to Raoult's law across all concentration and temperature ranges, it is termed a non-ideal solution. Such a solution may exhibit either positive or negative deviations from Raoult's law, with ΔH_{mix} and ΔV_{mix} values differing from zero for non-ideal solutions.

a) Non-ideal solution showing positive deviation

In this case, the overall vapor pressure exceeds the value predicted by Raoult's equation. The interaction between solute and solvent (A-B) is less robust compared to the interactions within pure components (A-A or B-B). Positive values for ΔH_{mix} and ΔV_{mix} are observed.

Examples include ethanol and acetone, carbon disulphide and acetone, acetone and benzene, among others.

b) Non-ideal solution showing negative deviation

In this scenario, the overall vapor pressure is less than what Raoult's equation predicts. The interaction between the solute and solvent (A-B) is more potent than the interactions within the pure components (A-A or B-B). Negative values for both ΔH_{mix} and ΔV_{mix} are observed.

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

Difference between Ideal and Non-ideal Solution

The table below shows the main differences between Ideal and Non-ideal Solutions:

IDEAL SOLUTION	NON-IDEAL SOLUTION
RAOULT'S LAW	
They obey Raoult's law	They do not obey Raoult's law
MOLECULAR INTERACTIONS	
Intermolecular interaction between solute and solvent is the same as that of pure components	Intermolecular interaction between solute and solvent is weaker or stronger than that of between pure components
TOTAL VAPOUR PRESSURE	
The total vapour pressure is the same as predicted by Raoult's law	The total vapour pressure increases or decreases from the predicted value according to Raoult's law
ENTHALPY OF MIXING	
No heat is released or absorbed, so the enthalpy of mixing is zero, $\Delta H_{mix} = 0$	Heat is either absorbed or released, so the enthalpy of mixing is either positive or negative, $\Delta H_{mix} \neq 0$
VOLUME OF MIXING	
The total volume is equal to the sum of the volume of components (solute and solvent), so the volume of mixing is zero, $\Delta V_{mix} = 0$	The volume of mixing is not zero, $\Delta V_{mix} \neq 0$. There is either expansion or contraction.
SEPARATION OF COMPONENTS	
Components can be separated by fractional distillation	Components can't be separated in the pure form by fractional distillation
AZEOTROPE FORMATION	
Does not form an azeotrope	Forms azeotrope mixture
EXAMPLES	
Benzene and toluene, hexane and heptane, etc. All the dilute solutions nearly behave as an ideal solution	Ethanol and acetone, carbon disulphide and acetone, phenol and aniline, chloroform and acetone, etc.

SOLUTION WITH POSITIVE DEVIATION:

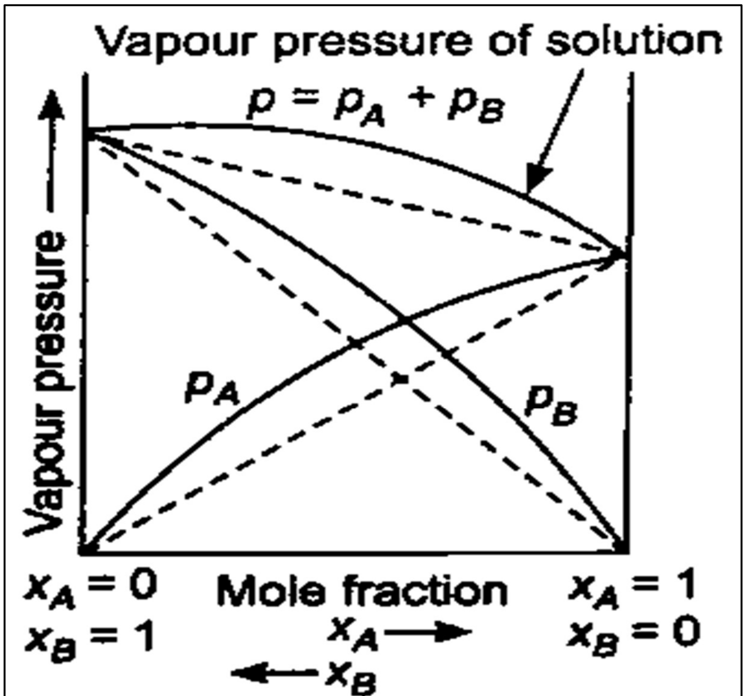
Positive deviation:

When the interactions between A and B in a solution are less robust than the interactions within the pure A-A and B-B liquids constituting the solution, molecules of both A and B exhibit a greater inclination to escape from the solution compared to their escape from pure liquids. Consequently, as per Raoult's law, each component of the solution demonstrates a partial vapor pressure surpassing the anticipated values. The overall vapor pressure in such a scenario exceeds the vapor pressure expected in an ideal solution with an equivalent composition. This deviation from Raoult's law is indicative of a solution displaying positive departures.

$H_{mixing} > 0$ for positive deviation.

The following are some examples of solutions with positive deviations:

- Ethyl alcohol and cyclohexane
- Acetone and carbon disulphide



Vapour pressure diagram showing positive deviation