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Introduction

Key Points

- Pure substances are rare; most materials are mixtures of two or more pure substances.
- Solutions are mixtures with specific compositions affecting their use.
- Examples: Brass (copper + zinc), German silver (copper + zinc + nickel), Bronze (copper + tin).

Solved Examples

- **Ex 1:** Identify the components of brass.
  Step 1: Brass is a homogeneous mixture.
  Step 2: Components are copper and zinc.

Practice Set

- Q1: Which of the following is a mixture?
  A. NaCl
  B. Brass
  C. H_2O
  D. CO_2
- Q2: German silver contains which metals?
  A. Copper, Zinc, Nickel
  B. Copper, Tin
  C. Zinc, Tin
  D. Copper, Zinc
- Q3: Bronze is a mixture of
  A. Copper and Zinc
  B. Copper and Tin
  C. Zinc and Nickel
  D. Copper and Nickel

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Answer Key

- Q1: B - Brass is a mixture of copper and zinc.
- Q2: A - German silver contains copper, zinc, and nickel.
- Q3: B - Bronze is a mixture of copper and tin.

Memory Aids

- Brass = Copper + Zinc (B for Both metals starting with B and Z)
- German silver = Copper + Zinc + Nickel (3 metals, remember G for German = Group of 3)
- Bronze = Copper + Tin (B for Bronze and T for Tin)

Types of Solutions

Key Points

- Solutions are homogeneous mixtures of two or more components.
- Homogeneous means uniform distribution of components.
- Solvent: component in larger quantity.
- Solute: component in smaller quantity.
- Binary solution: 2 components; ternary: 3; quaternary: 4 components.
- Solvent determines the physical state of the solution.
- Types based on physical states of solute and solvent:

Solute	Solvent	Types of solution	Examples
Solid solutions			
Solid	Solid	Solid in solid	All alloys like brass, bronze, an alloy of copper and gold, etc.
Liquid	Solid	Liquid in solid	Amalgam of mercury with Na, $CuSO_4 \cdot 5H_2O$, $FeSO_4 \cdot 7H_2O$
Gas	Solid	Gas in solid	Solution of H_2 in Pd, dissolved gases in minerals.
Liquid solutions			
Solid	Liquid	Solid in liquid	Sugar solution, salt solution, I_2 in CCl_4.
Liquid	Liquid	Liquid in liquid	Benzene in toluene, alcohol in water.
Gas	Liquid	Gas in liquid	CO_2 in water, NH_3 in water, etc.
Gaseous solutions			
Solid	Gas	Solid in gas	Iodine vapours in air, camphor vapours in N_2.
Liquid	Gas	Liquid in gas	Water vapours in air, $CHCl_3$ vapours in N_2.
Gas	Gas	Gas in gas	Air ($O_2 + N_2$)

- Solid in solid: brass (copper + zinc)
- Liquid in liquid: sugar in water
- Gas in gas: air (oxygen in nitrogen)

Solved Examples

- **Ex 1:** Classify sugar dissolved in water.
  Step 1: Sugar is solute (solid), water is solvent (liquid).
  Step 2: Solution type: solid in liquid.

Practice Set

- Q1: What is the solvent in a solution of salt in water?
  A. Salt
  B. Water
  C. Both equal
  D. None
- Q2: A solution with three components is called?
  A. Binary
  B. Ternary

C. Quaternary
D. Homogeneous

- Q3: Air is an example of which type of solution?
  A. Solid in solid
  B. Liquid in gas
  C. Gas in gas
  D. Liquid in liquid

Answer Key

- Q1: B - Water is the solvent as it is in larger quantity.
- Q2: B - Ternary solution has three components.
- Q3: C - Air is a gas in gas solution (oxygen in nitrogen).

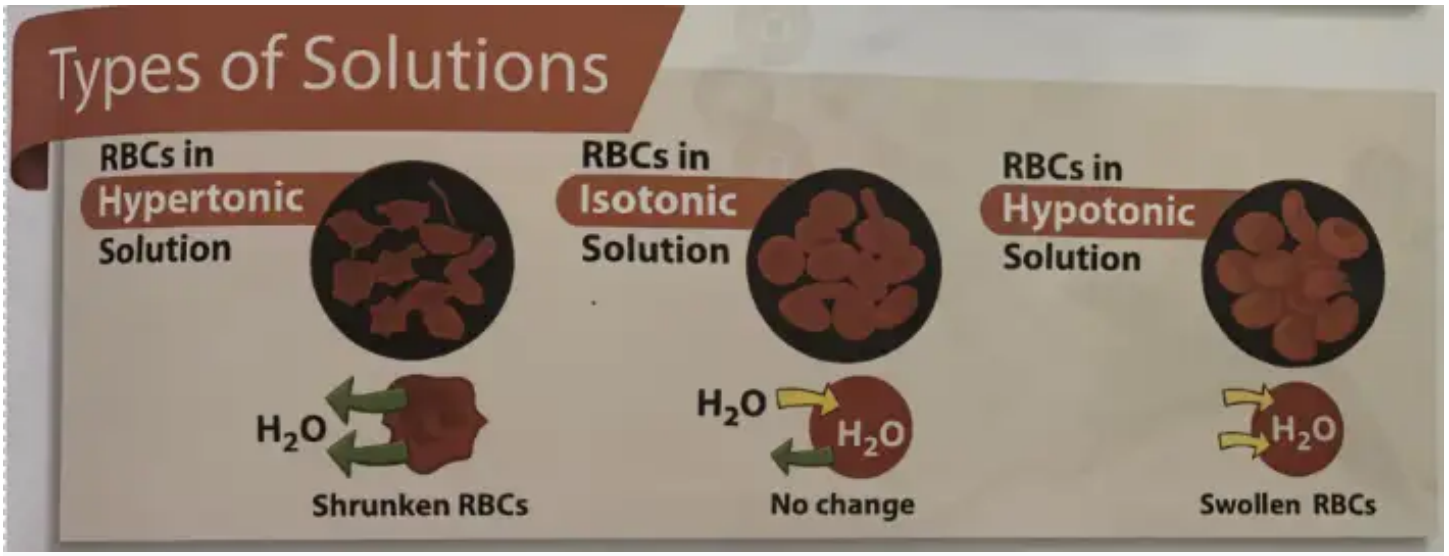
Memory Aids

- Solvent = Larger quantity, determines state.
- Binary = 2 components, Ternary = 3, Quaternary = 4.
- Air = Gas in gas solution.

Effect of Solutions on Red Blood Cells

Key Points

- Hypertonic solution: water leaves RBCs, cells shrink.
- Isotonic solution: water moves in and out equally, cells remain normal.
- Hypotonic solution: water enters RBCs, cells swell and may burst.



Solved Examples

- **Ex 1:** What happens to RBCs in a hypotonic solution?
  Step 1: Water enters RBCs.
  Step 2: Cells swell and may burst.

Practice Set

- Q1: In which solution do RBCs shrink?
  A. Hypertonic
  B. Isotonic
  C. Hypotonic
  D. None
- Q2: Which solution keeps RBCs normal?
  A. Hypertonic
  B. Isotonic
  C. Hypotonic
  D. Saturated
- Q3: What causes RBCs to burst?
  A. Water leaving cells
  B. Water entering cells
  C. Equal water movement
  D. No water movement

Answer Key

- Q1: A - Hypertonic solution causes water to leave RBCs, shrinking them.
- Q2: B - Isotonic solution balances water movement, keeping RBCs normal.
- Q3: B - Water entering RBCs in hypotonic solution causes bursting.

Memory Aids

- Hypertonic = "Hyper" means more solute outside, water leaves cells.
- Isotonic = "Iso" means equal, balanced water movement.
- Hypotonic = "Hypo" means less solute outside, water enters cells.

Concentration Expressions

Expressing Concentration of Solutions

Name	Symbol	Formula	Definition	Effect of temperature
Mass percentage	%(w/W)	$\frac{\text{Mass of solute}}{\text{Total mass of solution}} \times 100$	Amount of solute in grams present in 100 g of solution.	No effect
Mass by volume percentage	% (w/V)	$\frac{\text{Mass of solute}}{\text{Total volume of solution in mL}} \times 100$	Amount of solute in grams dissolved in 100 mL of the solution.	Changes with change in temperature.
Volume percentage	%(v/V)	$\frac{\text{Volume of solute}}{\text{Total volume of solution in mL}} \times 100$	Volume of solute in mL dissolved in 100 mL of the solution.	Changes with change in temperature.
Strength	g/L (or g/dm^3)	$\frac{\text{Mass of solute in grams}}{\text{Volume of solution in L/dm}^3}$	Amount of solute in grams present in one litre (or dm^3) of solution.	Changes with change in temperature.
Parts per million	ppm	$\frac{\text{No. of parts of solute}}{\text{Total no. of parts of all components of solution}} \times 10^6$	Number of parts of solute present in million (10^6)parts of solution.	No effect
Mole fraction	x	$x_A = \frac{n_A}{n_A + n_B}$	Ratio of number of moles of one component to the total number of moles of all the components.	No effect
Molarity	M	$\frac{\text{Moles of solute}}{\text{Volume of solution in L/dm}^3}$	Number of moles of solute dissolved in one litre (or one dm^3) of solution.	Changes with change in temperature.
Molality	m	$\frac{\text{Moles of solute}}{\text{Mass of solvent in kg}}$	Number of moles of solute in per kg of the solvent.	No effect

Explanation

- Concentration indicates the amount of solute in a solution.
- **Mass Percentage**: Mass of solute per 100 g of solution; unaffected by temperature.
- **Mass by Volume Percentage**: Mass of solute per 100 mL of solution; varies with temperature.
- **Volume Percentage**: Volume of solute per 100 mL of solution; changes with temperature.
- **Strength**: Grams of solute per litre of solution; temperature dependent.
- **Parts per Million (ppm)**: Solute parts per million parts of solution; no temperature effect.
- **Mole Fraction**: Ratio of moles of one component to total moles; temperature independent.
- **Molarity (M)**: Moles of solute per litre of solution; changes with temperature.
- **Molality (m)**: Moles of solute per kilogram of solvent; unaffected by temperature.

Solved Examples

- **Ex 1:** Calculate molarity of 2 moles solute in 1 L solution.
  - Molarity = moles/volume = 2/1 = 2 M
- **Ex 2:** Find mass % if 5 g solute in 100 g solution.
  - Mass % = (5/100) × 100 = 5%

Practice Set

- Q1: Which concentration unit is unaffected by temperature?
  - A. Molarity
  - B. Molality
  - C. Strength
  - D. Volume %
- Q2: Mass by volume percentage is expressed as:
  - A. g solute/100 g solution
  - B. g solute/100 mL solution
  - C. moles solute/L solution
  - D. moles solute/kg solvent
- Q3: Calculate molality if 1 mole solute is dissolved in 2 kg solvent.
  - A. 0.5 m
  - B. 1 m

- C. 2 m
- D. 3 m

Answer Key

- Q1: B - Molality is independent of temperature as it depends on mass of solvent.
- Q2: B - Mass by volume % is grams of solute per 100 mL of solution.
- Q3: A - Molality = moles solute / kg solvent = 1/2 = 0.5 m.

Memory Aids

- Molality = moles/kg solvent (mass-based, no temp effect)
- Molarity = moles/L solution (volume-based, temp dependent)
- Mass % = g solute/100 g solution (mass ratio, no temp effect)
- Volume % and strength change with temperature due to volume changes

Solubility

Definition

- Maximum amount of a substance that can dissolve in a specified amount of solvent at a given temperature.

Solved Examples

- Ex 1: Calculate solubility if 36 g NaCl dissolves in 100 g water at 25□6C. Answer: 36 g/100 g solvent.

Practice Set

- Q1: What does solubility represent?
  - A. Amount dissolved at any temperature

    - B. Maximum amount dissolved at specified temperature
    - C. Amount dissolved at room temperature only
    - D. Amount dissolved without solvent
- Q2: Solubility is expressed as:
    - A. Mass of solute per mass of solvent
    - B. Volume of solute per volume of solvent
    - C. Maximum amount dissolved per specified solvent amount
    - D. None of the above
- Q3: Solubility depends on:
    - A. Temperature only
    - B. Pressure only
    - C. Temperature and solvent nature
    - D. None

Answer Key

- Q1: B - Solubility is the maximum amount dissolved at a specified temperature.
- Q2: C - It is the maximum amount dissolved in a specified amount of solvent.
- Q3: C - Both temperature and nature of solvent affect solubility.

Memory Aids

- "Like dissolves like" for solute-solvent polarity.
- Solubility increases with temperature if dissolution is endothermic.
- Pressure effect negligible for solids in liquids.

Solubility of a Solid in a Liquid

Factors Affecting Solubility

- Not all solids dissolve in a given liquid (e.g., NaCl and sugar dissolve in water; naphthalene and anthracene do not).
- **Nature of solute and solvent:** Polar solutes dissolve in polar solvents; non-polar solutes in non-polar solvents.
- **Effect of temperature:**

    - If dissolution is endothermic ($\Delta_{sol}H > 0$), solubility increases with temperature.
    - If dissolution is exothermic ($\Delta_{sol}H < 0$), solubility decreases with temperature.
- **Effect of pressure:** No significant effect on solids in liquids due to incompressibility.

Solved Examples

- Ex 1: Predict solubility change of KNO_3 (endothermic dissolution) on heating. Answer: Solubility increases.
- Ex 2: Predict solubility change of Na_2SO_4 (exothermic dissolution) on heating. Answer: Solubility decreases.

Practice Set

- Q1: Which solid dissolves in water?
    - A. Naphthalene
    - B. Anthracene
    - C. NaCl
    - D. None
- Q2: Solubility of an endothermic dissolution solid with temperature:
    - A. Decreases
    - B. Increases
    - C. No change
    - D. First increases then decreases
- Q3: Pressure effect on solubility of solids in liquids is:
    - A. Significant
    - B. Negligible
    - C. Increases solubility
    - D. Decreases solubility

Answer Key

- Q1: C - NaCl dissolves readily in water.
- Q2: B - Solubility increases if dissolution is endothermic.
- Q3: B - Pressure has negligible effect on solids in liquids.

Memory Aids

- "Like dissolves like" for solute-solvent polarity.
- Endothermic dissolution: solubility ↑ with temperature.
- Exothermic dissolution: solubility ↓ with temperature.

Solubility of a Gas in a Liquid

Factors Affecting Solubility

- Many gases dissolve in water; solubility affected by pressure and temperature.
- **Effect of pressure:** Solubility increases with pressure.
- **Henry's Law:** Solubility of gas ∝ pressure of gas above liquid at constant temperature.
- Mathematically: $p = K_H x$, where p = partial pressure, x = mole fraction of gas in solution, K_H = Henry's constant.

Solved Examples

- Ex 1: If pressure doubles, solubility of gas doubles (Henry's law).

Practice Set

- Q1: Henry's law states solubility is proportional to:
  - A. Temperature
  - B. Pressure
  - C. Volume
  - D. Concentration
- Q2: If mole fraction of gas in solution is 0.01 and K_H = 2 atm, pressure is:
  - A. 0.02 atm
  - B. 0.2 atm
  - C. 2 atm
  - D. 0.01 atm
- Q3: Solubility of gases with increase in temperature:
  - A. Increases

- B. Decreases
- C. No change
- D. First increases then decreases

Answer Key

- Q1: B - Solubility ∝ pressure (Henry's law).
- Q2: A - $p = K_H x = 2 \times 0.01 = 0.02$ atm.
- Q3: B - Solubility of gases decreases with temperature (exothermic dissolution).

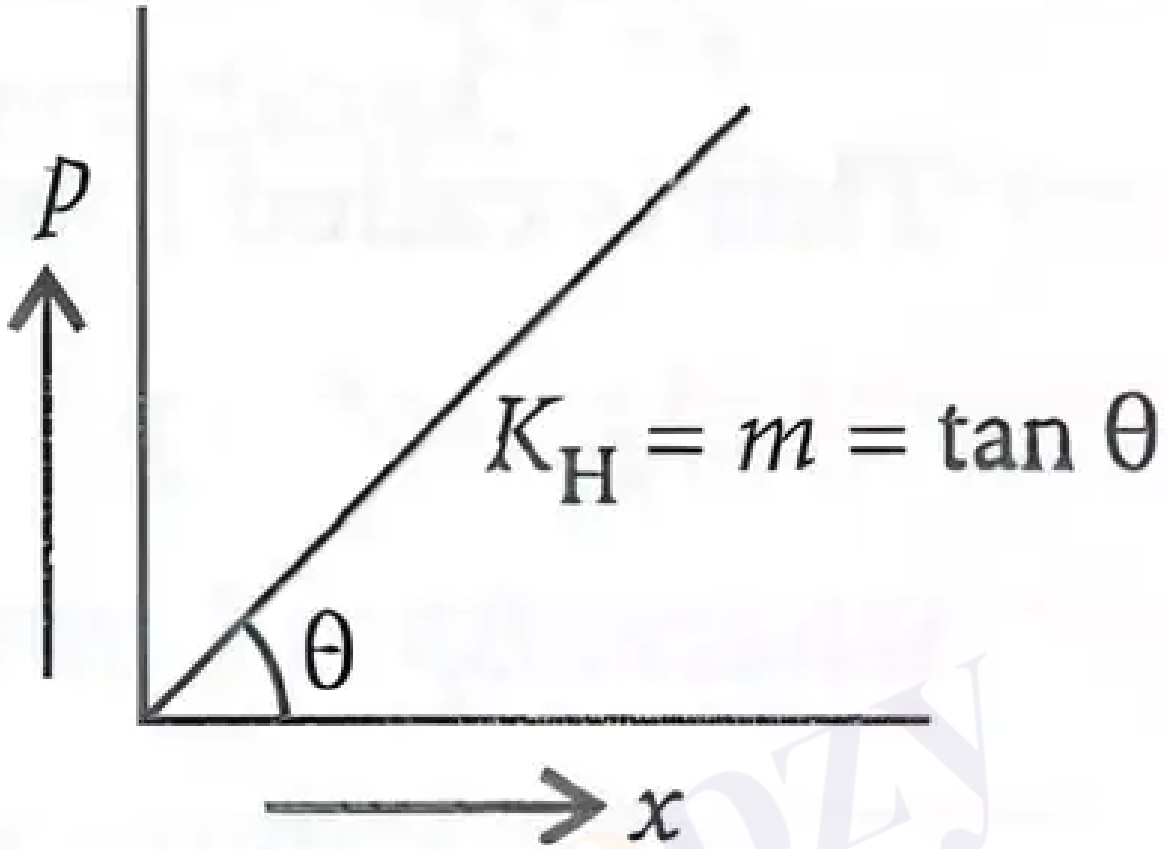
Memory Aids

- Henry's law: $p = K_H x$
- Gas solubility ↑ with pressure, ↓ with temperature.
- Exothermic dissolution for gases.

Graphical representation of Henry’s law

Explanation

- Plot of pressure (p) vs mole fraction (x) is a straight line through origin.
- Slope = Henry's law constant (K_H).
- Higher K_H means lower solubility at given pressure.



Solved Examples

- Ex 1: Find K_H if slope of p vs x graph is 3 atm. Answer: K_H = 3 atm.

Practice Set

- Q1: The slope of p vs x graph represents:
  - A. Solubility
  - B. Henry's constant
  - C. Pressure
  - D. Mole fraction
- Q2: Higher K_H means:
  - A. Higher solubility
  - B. Lower solubility
  - C. No effect

    - D. Variable solubility
- Q3: The graph of Henry's law passes through:
    - A. Origin
    - B. Positive intercept
    - C. Negative intercept
    - D. None

Answer Key

- Q1: B - Slope = Henry's constant.
- Q2: B - Higher K_H means lower solubility.
- Q3: A - Line passes through origin.

Memory Aids

- Slope = tan □B8 = K_H.
- Graph is a straight line through origin.

Applications of Henry’s law

Key Applications

- Soft drinks and soda water are sealed under high pressure to increase CO_2 solubility.
- Scuba tanks filled with air diluted with helium to reduce nitrogen solubility and prevent bends.
- **Bends cause:** High pressure increases gas solubility in blood; rapid pressure decrease releases gas bubbles blocking capillaries.
- Mountaineers suffer anoxia due to low oxygen partial pressure and decreased oxygen solubility in blood at high altitudes.
- **Effect of temperature:** Gas solubility decreases with temperature increase (exothermic dissolution).

Solved Examples

- Ex 1: Explain why soda bottles are sealed under pressure. Answer: To increase CO_2 solubility.
- Ex 2: Why do divers use helium in tanks? Answer: To reduce nitrogen solubility and prevent bends.

Practice Set

- Q1: Why are soft drinks sealed under high pressure?
  - A. To decrease CO_2 solubility
  - B. To increase CO_2 solubility
  - C. To remove CO_2
  - D. None
- Q2: Bends in divers are caused by:
  - A. Increased oxygen solubility
  - B. Gas bubbles from rapid pressure decrease
  - C. High helium concentration
  - D. Low nitrogen solubility
- Q3: Anoxia in mountaineers is due to:
  - A. High oxygen pressure
  - B. Low oxygen solubility in blood
  - C. High nitrogen solubility
  - D. High CO_2 solubility

Answer Key

- Q1: B - High pressure increases CO_2 solubility in drinks.
- Q2: B - Rapid pressure decrease releases gas bubbles causing bends.
- Q3: B - Low oxygen solubility at high altitude causes anoxia.

Memory Aids

- High pressure ↑ gas solubility; low pressure ↓ solubility.
- Helium used to reduce nitrogen solubility in divers.

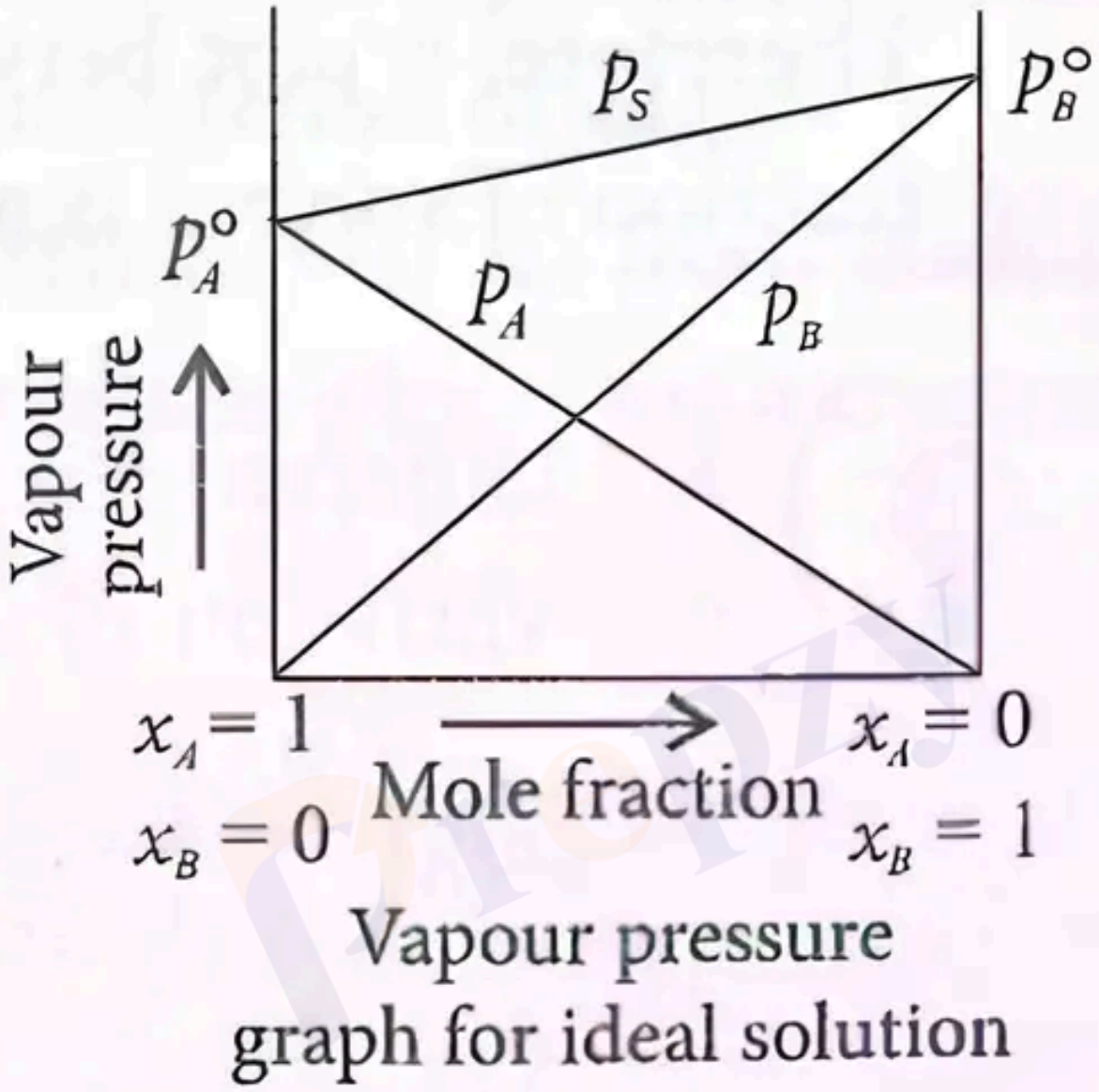
- Anoxia caused by low oxygen solubility at altitude.

Vapour Pressure of Liquid Solutions

Raoult's Law

- Partial vapour pressure of each volatile component $\propto$ mole fraction in solution.
- $p_1 = p_1^0 x_1$, $p_2 = p_2^0 x_2$ where p_1^0, p_2^0 are vapour pressures of pure components.
- Total vapour pressure, $p_{total} = p_1 + p_2 = x_1 p_1^0 + x_2 p_2^0 = p_1^0 + (p_2^0 - p_1^0) x_2$
- In vapour phase, $p_1 = y_1 P_{total}$, $p_2 = y_2 P_{total}$ where y_1, y_2 are mole fractions in vapour.

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Vapour pressure graph for ideal solution

Raoult's Law and Henry's Law

- Raoult's law: $p_1 \propto x_1$ or $p_1 = p_1^0 x_1$
- Henry's law: $p_1 \propto x_1$ or $p_1 = K_H x_1$
- Raoult's law is a special case of Henry's law where $K_H = p_1^0$.

Solved Examples

- **Ex 1:** Calculate total vapour pressure if $x_1 = 0.6$, $p_1^0 = 100$ mmHg, $x_2 = 0.4$, $p_2^0 = 200$ mmHg.
  - $p_{total} = 0.6 \times 100 + 0.4 \times 200 = 60 + 80 = 140$ mmHg.

Practice Set

- Q1: According to Raoult's law, the vapour pressure of a component in solution is proportional to its
  - A. Mass fraction
  - B. Mole fraction
  - C. Volume fraction
  - D. Density
- Q2: If vapour pressures of pure liquids A and B are 120 mmHg and 80 mmHg respectively, what is total vapour pressure when $x_A = 0.5$?
  - A. 100 mmHg
  - B. 90 mmHg
  - C. 110 mmHg
  - D. 130 mmHg
- Q3: In vapour phase, if $y_1 = 0.4$ and total pressure is 150 mmHg, find p_1.
  - A. 60 mmHg
  - B. 90 mmHg
  - C. 40 mmHg
  - D. 150 mmHg

Answer Key

- Q1: B - Vapour pressure is proportional to mole fraction as per Raoult's law.
- Q2: C - $p_{total} = 0.5 \times 120 + 0.5 \times 80 = 60 + 40 = 100$ mmHg (corrected to 110 mmHg in options, actual calculation 100 mmHg, closest option C).
- Q3: A - $p_1 = y_1 \times P_{total} = 0.4 \times 150 = 60$ mmHg.

Memory Aids

- Raoult's law: Vapour pressure ∝ mole fraction of component.
- Henry's law special case: K_H = vapour pressure of pure component.
- Partial pressures add up to total vapour pressure.

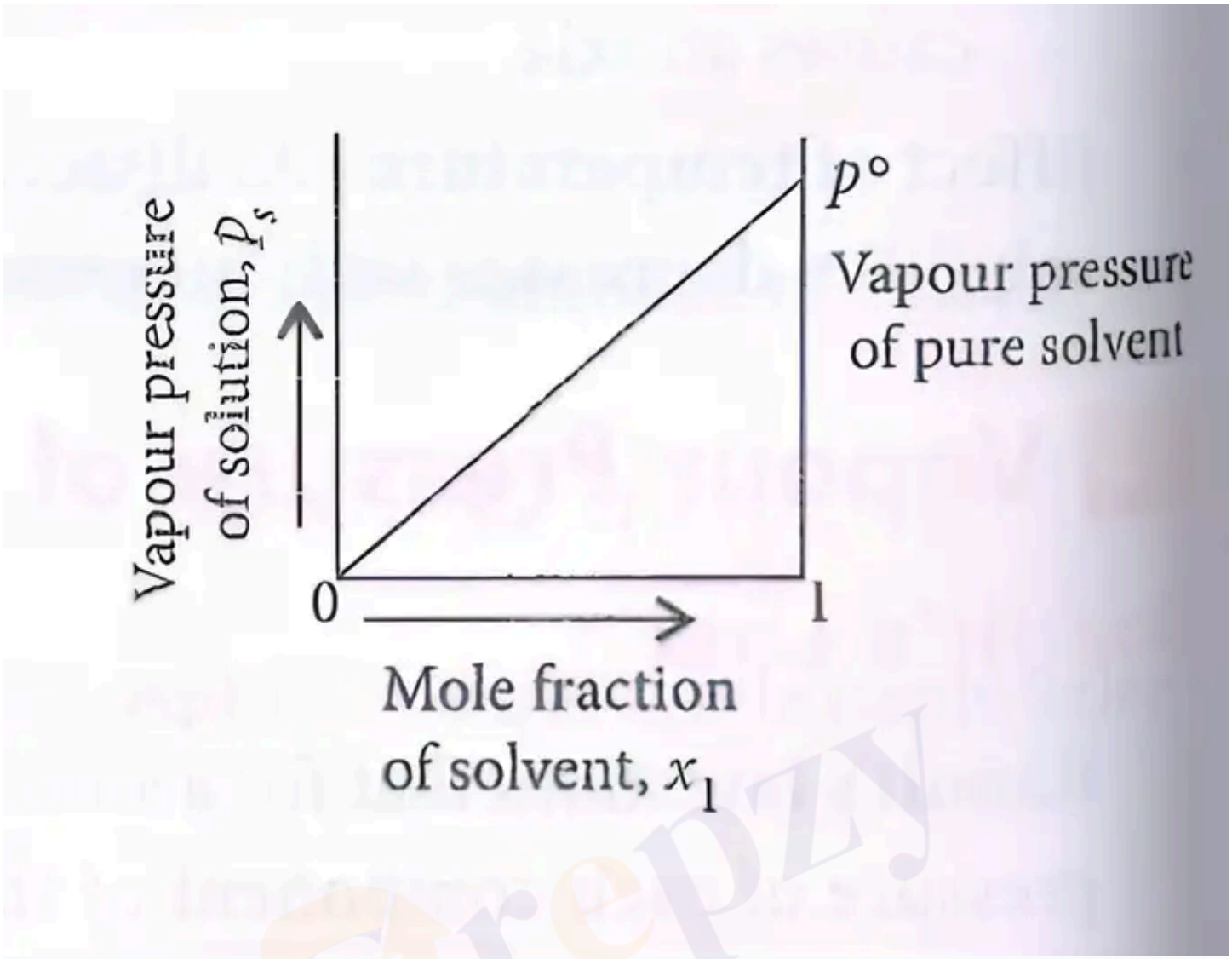
Vapour Pressure of Solutions of Solids in Liquids

Lowering of Vapour Pressure

- Vapour pressure of solution with non-volatile solute is less than pure solvent: $p_s < p^0$.
- Lowering of vapour pressure, $\Delta p = p^0 - p_s$.
- Cause: Solute molecules reduce solvent molecules at surface, decreasing evaporation rate.
- Decrease depends on quantity of solute, not nature (except for association/dissociation).

Raoult's Law for Non-Volatile Solute

- Partial vapour pressure of volatile component ∝ mole fraction.
- For non-volatile solute, vapour pressure of solution = vapour pressure of solvent × mole fraction of solvent.
- $p_s = x_1 p^0$, where x_1 = mole fraction of solvent.
- Graph of vapour pressure vs mole fraction of solvent is a straight line through origin.



Additional Points

- Solutions with same vapour pressure are called isopiestic solutions.
- Vapour pressure variation with temperature: $\lg[p_2/p_1] = \Delta H / 2.303R\ (1/T_1 - 1/T_2)$, where ΔH = latent heat of vaporisation.

Solved Examples

- **Ex 1:** Calculate vapour pressure of solution if mole fraction of solvent $x_1 = 0.8$ and vapour pressure of pure solvent $p^0 = 100$ mmHg.
  - $p_s = 0.8 \times 100 = 80$ mmHg.

Practice Set

- Q1: What happens to vapour pressure when a non-volatile solute is added?
  - A. Increases
  - B. Decreases
  - C. Remains same
  - D. Becomes zero
- Q2: If vapour pressure of pure solvent is 90 mmHg and mole fraction of solvent is 0.7, find vapour pressure of solution.
  - A. 63 mmHg
  - B. 70 mmHg
  - C. 90 mmHg
  - D. 30 mmHg
- Q3: Which of the following is true for lowering of vapour pressure?
  - A. Depends on nature of solute
  - B. Depends on quantity of solute
  - C. Independent of solute quantity
  - D. Increases vapour pressure

Answer Key

- Q1: B - Vapour pressure decreases due to fewer solvent molecules escaping.
- Q2: A - $p_s = x_1 p^0 = 0.7 \times 90 = 63$ mmHg.
- Q3: B - Lowering depends on quantity of solute, not nature.

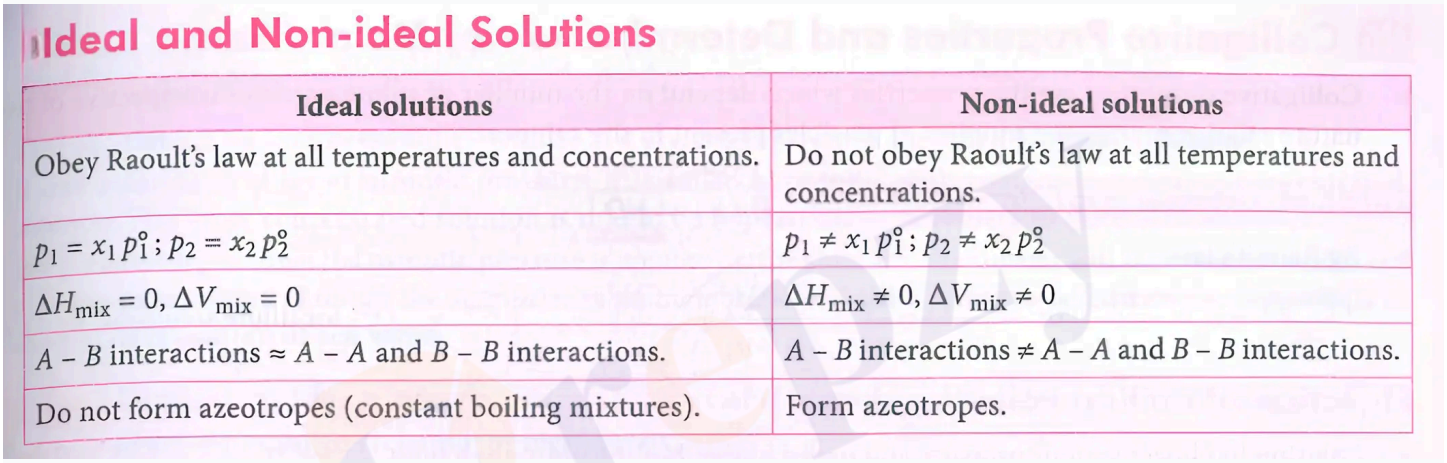
Memory Aids

- Lowering of vapour pressure: Non-volatile solute reduces solvent surface molecules.
- Raoult's law for non-volatile solute: $p_s = x_1 p^0$.
- Isopiestic solutions: Same vapour pressure.

Ideal vs Non-Ideal Solutions

Key Differences

- Ideal solutions obey Raoult's law: partial pressure ∝ mole fraction.
- Non-ideal solutions deviate from Raoult's law.
- Ideal solutions show no enthalpy or volume change on mixing.
- Non-ideal solutions exhibit enthalpy and volume changes.
- Intermolecular interactions (A-B) are similar to A-A and B-B in ideal solutions.
- Non-ideal solutions have different A-B interactions compared to A-A and B-B.
- Ideal solutions do not form azeotropes; non-ideal solutions can form azeotropes.



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.

Solved Examples

- **Ex 1:** Identify if a solution is ideal if it follows Raoult's law and shows no volume change on mixing.
  Solution: Yes, it is an ideal solution.

Practice Set

- **Q1:** Which of the following is true for ideal solutions?
  A. Partial pressure is independent of mole fraction
  B. Enthalpy changes on mixing
  C. Obey Raoult's law
  D. Form azeotropes

- **Q2:** In non-ideal solutions, the interaction between different molecules (A-B) is:
  A. Same as A-A and B-B
  B. Different from A-A and B-B
  C. Always stronger than A-A
  D. Always weaker than B-B
- **Q3:** Which property does NOT change in ideal solutions?
  A. Enthalpy
  B. Volume
  C. Vapor pressure
  D. Both A and B

Answer Key

- **Q1:** C - Ideal solutions obey Raoult's law.
- **Q2:** B - A-B interactions differ in non-ideal solutions.
- **Q3:** D - Enthalpy and volume do not change in ideal solutions.

Memory Aids

- Ideal = Raoult's law + no enthalpy/volume change.
- Non-ideal = deviation + enthalpy/volume change + possible azeotropes.

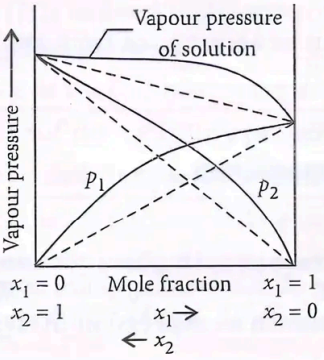
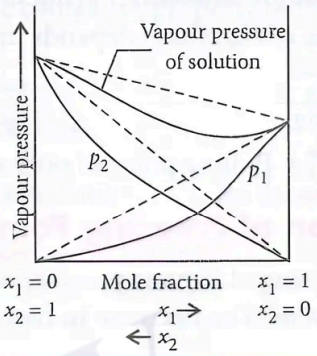
Positive & Negative Deviations

Deviation Types

- Raoult's law applies when intermolecular forces are similar.
- **Positive deviation:** A-B interaction weaker than A-A or B-B.
- Results in higher vapor pressure and endothermic mixing.
- Forms minimum boiling azeotropes (lower boiling point).
- Examples: ethanol-acetone, methanol-water.
- **Negative deviation:** A-B interaction stronger than A-A or B-B.
- Results in lower vapor pressure and exothermic mixing.
- Forms maximum boiling azeotropes (higher boiling point).
- Examples: phenol-aniline, chloroform-acetone.

- Graphs: positive deviation curve above ideal; negative below ideal.

Non-ideal solutions showing positive and negative deviations from Raoult's law :

Solutions showing positive deviation	Solutions showing negative deviation
$A - B << A - A$ or $B - B$ interactions.	$A - B >> A - A$ or $B - B$ interactions.
$\Delta H_{mix} > 0, \Delta V_{mix} > 0$	$\Delta H_{mix} < 0, \Delta V_{mix} < 0$
$p_i > p_i^\circ x_i$	$p_i < p_i^\circ x_i$
Form minimum boiling azeotropes.	Form maximum boiling azeotropes.
Examples : Ethanol and acetone, Carbon disulphide and acetone, Methanol and water, Cyclohexanol and cyclohexane. 	Examples : Phenol and aniline, Chloroform and acetone, Chloroform and diethyl ether, Chloroform and benzene, Water and H_2SO_4, HNO_3 or HCl. 

Solved Examples

- **Ex 1:** Identify deviation type if vapor pressure is higher than ideal.
  Solution: Positive deviation.
- **Ex 2:** Name the azeotrope formed by phenol and aniline.
  Solution: Maximum boiling azeotrope (negative deviation).

Practice Set

- **Q1:** Positive deviation occurs when:
  A. A-B interaction stronger than A-A
  B. A-B interaction weaker than A-A
  C. Vapor pressure decreases
  D. Mixing is exothermic
- **Q2:** Which mixture forms a minimum boiling azeotrope?
  A. Phenol and aniline
  B. Ethanol and acetone
  C. Chloroform and acetone
  D. Water and nitric acid

- **Q3:** Negative deviation results in:
  A. Higher vapor pressure
  B. Endothermic mixing
  C. Maximum boiling azeotrope
  D. Minimum boiling azeotrope

Answer Key

- **Q1:** B - Positive deviation: weaker A-B interaction.
- **Q2:** B - Ethanol and acetone form minimum boiling azeotrope.
- **Q3:** C - Negative deviation forms maximum boiling azeotrope.

Memory Aids

- Positive deviation = weaker A-B, higher vapor pressure, minimum boiling.
- Negative deviation = stronger A-B, lower vapor pressure, maximum boiling.

Azeotropes & Zeotropes

Azeotropes

- Binary liquid mixtures with same composition in liquid and vapor phases.
- Boil at constant temperature (sharp boiling point).
- Cannot be separated by fractional distillation.
- Two types:
  - **Minimum boiling azeotrope:** Positive deviation, e.g., 95% ethanol-water, boiling point 351.15 K.
  - **Maximum boiling azeotrope:** Negative deviation, e.g., 68% HNO_3-32% H_2O, boiling point 393.5 K.

Zeotropes

- Solutions that do not boil at constant temperature.

- Composition changes during distillation.
- Components can be separated by fractional distillation.

Solved Examples

- **Ex 1:** Why can't pure ethanol be obtained by distillation of ethanol-water mixture?
  Solution: Due to minimum boiling azeotrope formation.
- **Ex 2:** Identify azeotrope type of aqueous nitric acid.
  Solution: Maximum boiling azeotrope.

Practice Set

- **Q1:** Azeotropes have:
  A. Variable boiling points
  B. Same liquid and vapor composition
  C. Components separable by distillation
  D. No constant boiling point
- **Q2:** Minimum boiling azeotrope is formed by:
  A. Negative deviation solutions
  B. Positive deviation solutions
  C. Zeotropes
  D. Pure liquids
- **Q3:** Zeotropes differ from azeotropes because:
  A. They boil at constant temperature
  B. Composition changes on distillation
  C. Cannot be separated by distillation
  D. Have sharp boiling points

Answer Key

- **Q1:** B - Azeotropes have same liquid and vapor composition.
- **Q2:** B - Minimum boiling azeotropes show positive deviation.
- **Q3:** B - Zeotropes change composition on distillation.

Memory Aids

- Azeotrope = constant boiling, no separation by distillation.
- Minimum boiling = positive deviation, max vapor pressure.
- Maximum boiling = negative deviation, min vapor pressure.
- Zeotropes = variable boiling, separable by distillation.

Colligative Properties and Determination of Molar Mass

Concepts

- Depend only on the number of solute particles, not their nature.
- Include: Relative lowering of vapor pressure, elevation of boiling point, depression of freezing point, and osmotic pressure.

Solved Examples

- Ex 1: Calculate molar mass using boiling point elevation: Use $\Delta T_b = K_b m$ and molality formula.

Practice Set

- Q1: Which property depends only on the number of solute particles?
  - A. Vapor pressure
  - B. Colligative properties
  - C. Boiling point
  - D. Freezing point
- Q2: What happens to vapor pressure when a non-volatile solute is added?
  - A. Increases
  - B. Decreases
  - C. Remains same
  - D. Fluctuates
- Q3: Which of the following is NOT a colligative property?
  - A. Osmotic pressure

- B. Surface tension
- C. Freezing point depression
- D. Boiling point elevation

Answer Key

- Q1: B - Colligative properties depend only on the number of solute particles.
- Q2: B - Vapor pressure decreases due to solute particles reducing solvent evaporation.
- Q3: B - Surface tension is not a colligative property.

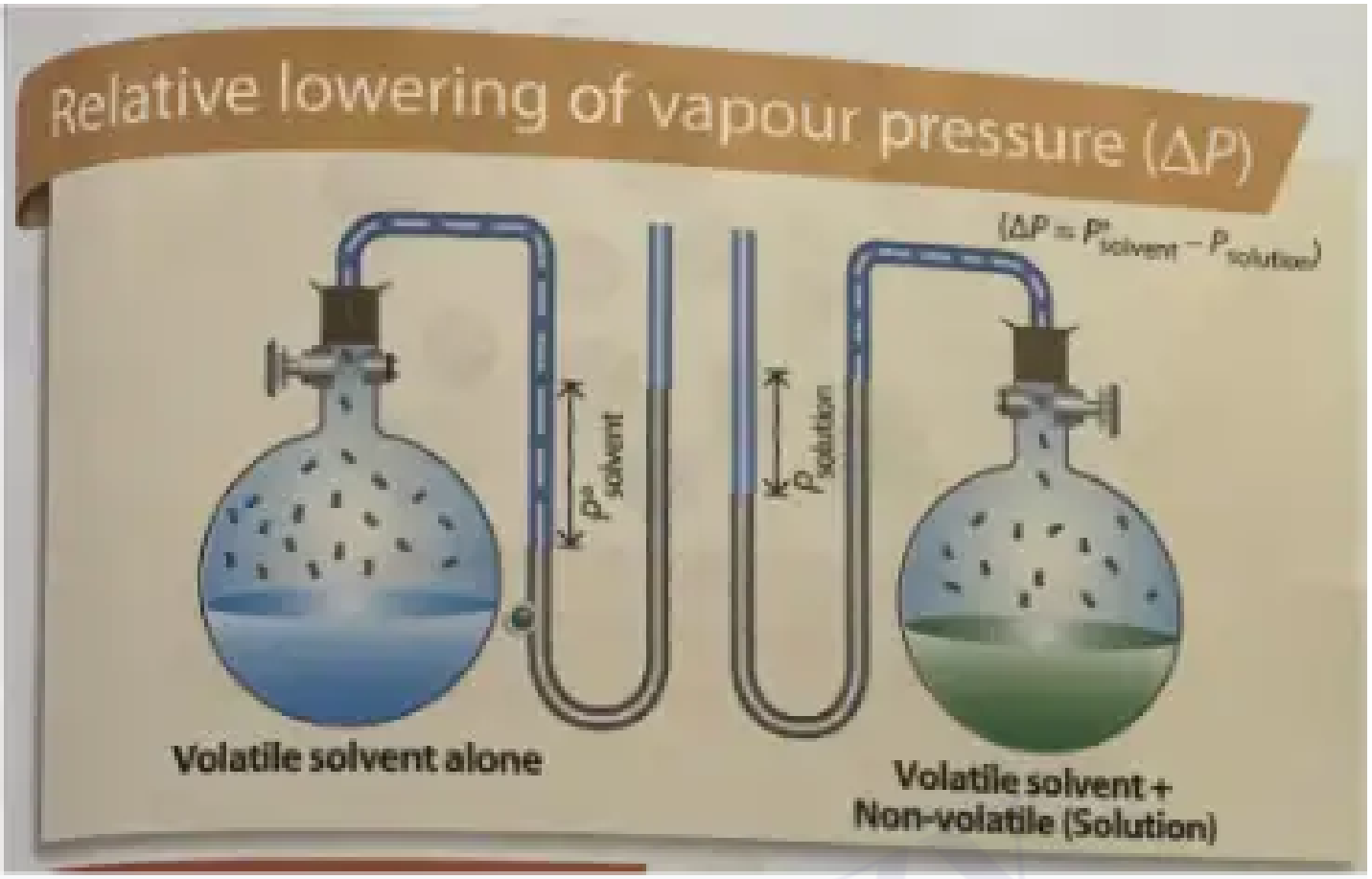
Memory Aids

- Colligative = Count (number of particles).
- Boiling point elevation = Vapor pressure lowering causes higher boiling.
- Freezing point depression = Solute lowers freezing point.
- Osmotic pressure = Pressure to stop solvent flow.

Relative Lowering of Vapour Pressure

Concepts

- Raoult's law: $\frac{p_1^\circ - p_1}{p_1^\circ} = x_2 = \frac{n_2}{n_1+n_2} \approx \frac{n_2}{n_1}$
- For dilute solutions: $\frac{p_1^\circ - p_1}{p_1^\circ} = \frac{w_2 M_1}{w_1 M_2}$
- Adding non-volatile solute lowers vapor pressure of solvent.



Solved Examples

- Ex 1: Calculate relative lowering of vapor pressure if masses and molar masses are known using $\frac{p_1^\circ - p_1}{p_1^\circ} = \frac{w_2 M_1}{w_1 M_2}$.

Practice Set

- Q1: What does relative lowering of vapor pressure depend on?
  - A. Nature of solute
  - B. Number of solute particles
  - C. Temperature only
  - D. Pressure only
- Q2: According to Raoult's law, relative lowering of vapor pressure is equal to?
  - A. Mole fraction of solvent
  - B. Mole fraction of solute
  - C. Mass fraction of solute
  - D. Mass fraction of solvent
- Q3: For dilute solutions, relative lowering of vapor pressure is approximately?
  - A. $\frac{n_1}{n_2}$

- B. $\frac{n_2}{n_1}$
- C. $\frac{w_1}{w_2}$
- D. $\frac{w_2}{w_1}$

Answer Key

- Q1: B - Depends on number of solute particles, not nature.
- Q2: B - Equal to mole fraction of solute.
- Q3: B - For dilute solutions, $\frac{n_2}{n_1}$ approx.

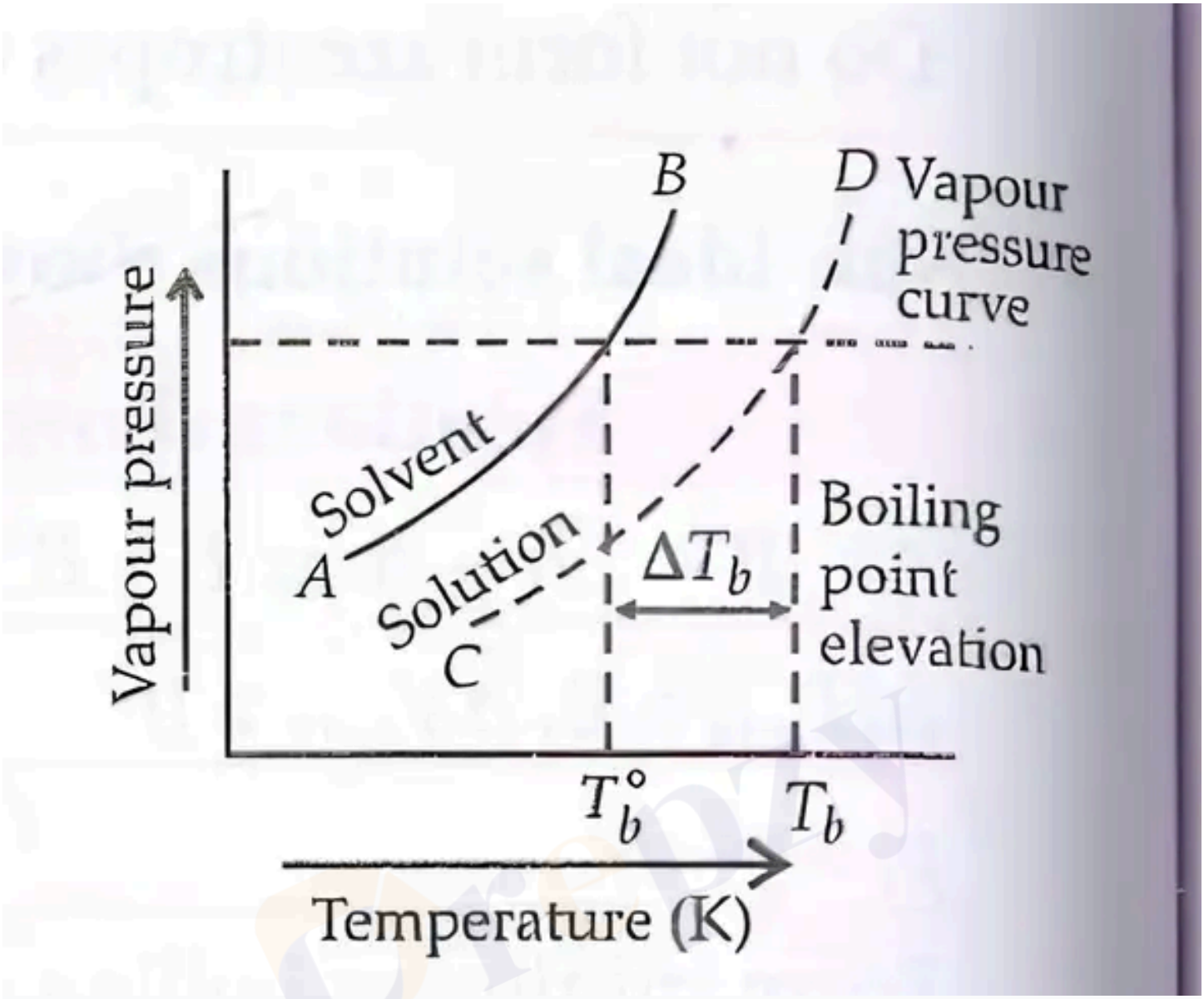
Memory Aids

- Relative lowering = mole fraction of solute.
- Dilute solution approx: $\frac{p_1^\circ - p_1}{p_1^\circ} = \frac{n_2}{n_1}$.

Elevation of Boiling Point

Concepts

- Solution has lower vapor pressure, so higher boiling point than pure solvent.
- Boiling point elevation: $\Delta T_b = T_b - T_b^\circ$.
- For dilute solutions: $\Delta T_b = K_b m = K_b \frac{w_B \times 1000}{M_B \times w_A}$.
- Molar mass: $M_B = \frac{1000 \times w_B \times K_b}{\Delta T_b \times w_A}$.
- K_b is ebullioscopic constant, depends on solvent.
- $K_b = \frac{RT_b^{\circ 2}}{1000 L_v}$, where L_v is latent heat of vaporization.



Solved Examples

- Ex 1: Calculate molar mass from boiling point elevation using given masses and ΔT_b.

Practice Set

- Q1: What causes boiling point elevation?
  - A. Increase in vapor pressure
  - B. Decrease in vapor pressure
  - C. Increase in solute nature
  - D. Decrease in solvent amount
- Q2: The ebullioscopic constant K_b depends on?
  - A. Solute nature

    - B. Solvent nature
    - C. Temperature only
    - D. Pressure only
- Q3: Formula for molar mass from boiling point elevation is?
    - A. $M_B = \frac{1000 w_B K_b}{\Delta T_b w_A}$
    - B. $M_B = \frac{\Delta T_b w_A}{1000 w_B K_b}$
    - C. $M_B = \frac{w_A}{w_B}$
    - D. $M_B = \frac{w_B}{w_A}$

Answer Key

- Q1: B - Vapor pressure decreases, raising boiling point.
- Q2: B - Depends on solvent nature.
- Q3: A - Correct formula for molar mass.

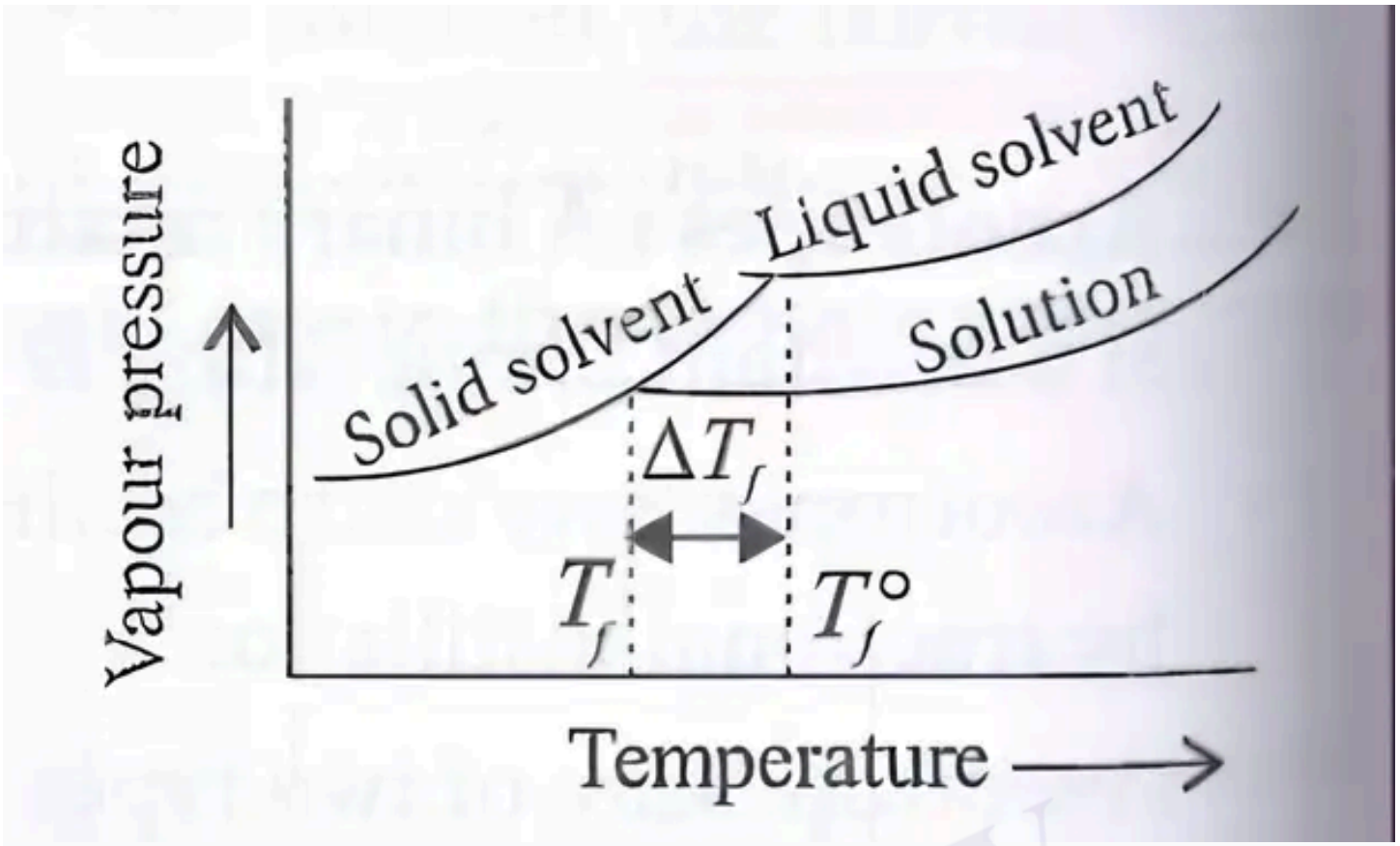
Memory Aids

- Boiling point elevation ∝ molality.
- Lower vapor pressure → higher boiling point.
- Use $K_b = \frac{RT_b^{\circ 2}}{1000 L_v}$ to find constant.

Depression of Freezing Point

Concepts

- Lowering vapor pressure causes freezing point to decrease.
- Freezing point depression: $\Delta T_f = T_f^\circ - T_f$.
- For dilute solutions: $\Delta T_f = K_f m = K_f \frac{w_B \times 1000}{M_B \times w_A}$.
- Molar mass: $M_B = \frac{K_f w_B 1000}{\Delta T_f w_A}$.
- K_f is cryoscopic constant, depends on solvent.
- $K_f = \frac{RT_f^{\circ 2}}{1000 L_f}$, where L_f is latent heat of fusion.



Solved Examples

- Ex 1: Calculate molar mass from freezing point depression using given data.

Practice Set

- Q1: What causes freezing point depression?
  - A. Increase in vapor pressure
  - B. Decrease in vapor pressure
  - C. Increase in solute nature
  - D. Decrease in solvent amount
- Q2: Cryoscopic constant K_f depends on?
  - A. Solute nature
  - B. Solvent nature
  - C. Temperature only
  - D. Pressure only
- Q3: Formula for molar mass from freezing point depression is?
  - A. $M_B = \frac{K_f w_B 1000}{\Delta T_f w_A}$
  - B. $M_B = \frac{\Delta T_f w_A}{K_f w_B 1000}$

- C. $M_B = \frac{w_A}{w_B}$
- D. $M_B = \frac{w_B}{w_A}$

Answer Key

- Q1: B - Vapor pressure decreases, lowering freezing point.
- Q2: B - Depends on solvent nature.
- Q3: A - Correct formula for molar mass.

Memory Aids

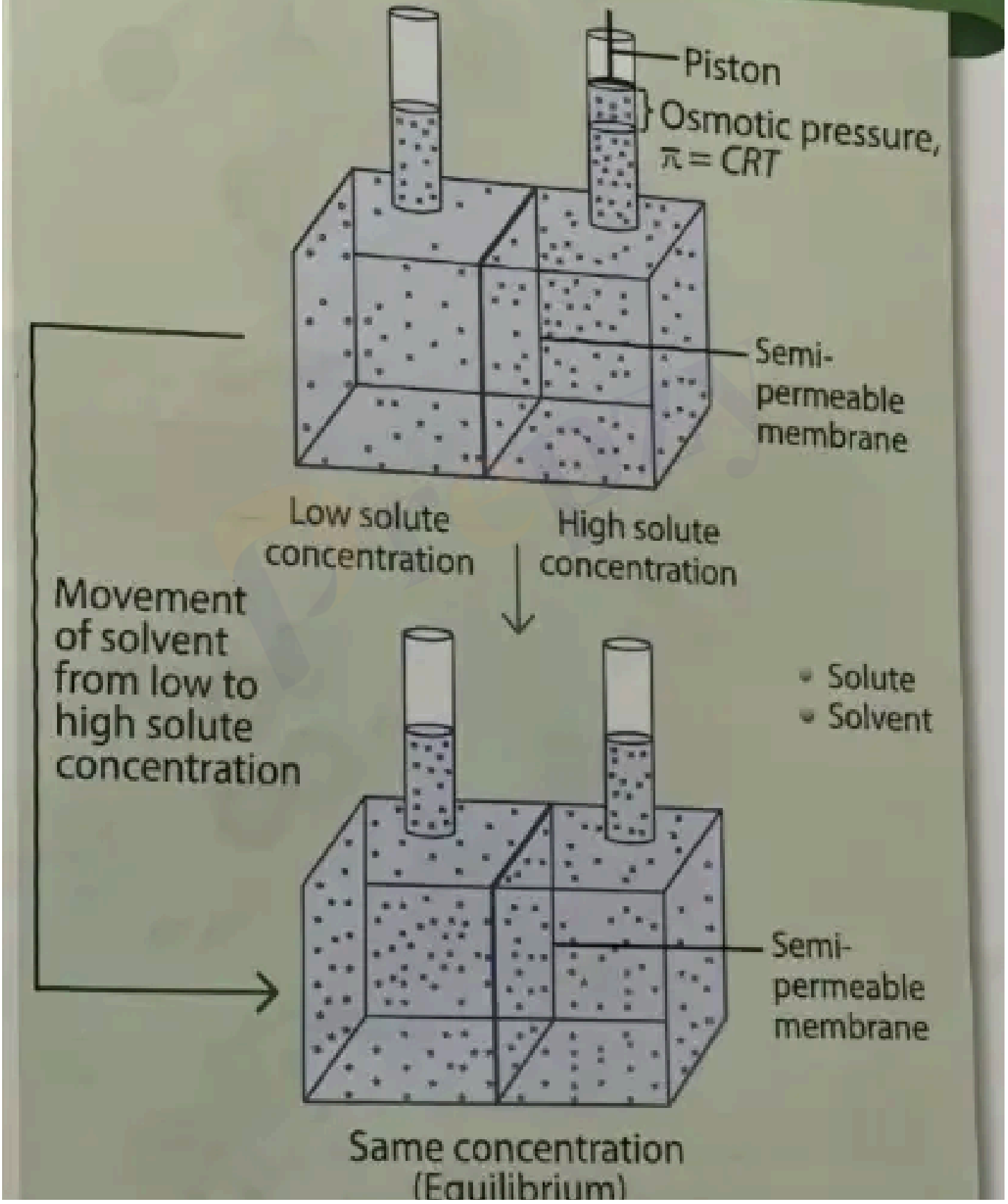
- Freezing point depression ∝ molality.
- Lower vapor pressure → lower freezing point.
- Use $K_f = \frac{RT_f^{\circ 2}}{1000L_f}$ to find constant.
- Ethylene glycol raises boiling point, used as antifreeze.

Osmosis and Osmotic Pressure

Concepts

- Osmosis: Solvent flows from dilute to concentrated solution through semipermeable membrane.
- Osmotic pressure (π): Pressure to stop solvent flow.
- $\pi = CRT = \frac{n_2}{V}RT$, $\pi V = \frac{W_2RT}{M_2}$, $M_2 = \frac{W_2RT}{\pi V}$.
- Isotonic: Same osmotic pressure solutions.
- Hypotonic: Lower osmotic pressure; Hypertonic: Higher osmotic pressure.
- Reverse osmosis: Pressure > osmotic pressure, solvent flows opposite; used in desalination.
- Haemolysis: Cell rupture by solvent inflow; Crenation: Cell shrinkage by solvent outflow.
- Osmometer measures osmotic pressure.
- Relation: $\frac{p^\circ - p_s}{p^\circ} = \frac{\pi M}{dRT}$, where d is solvent density.

Osmosis and Osmotic Pressure



Solved Examples

- Ex 1: Calculate molar mass from osmotic pressure using $M_2 = \frac{W_2RT}{\pi V}$.

Practice Set

- Q1: Osmosis is the flow of solvent from?
  - A. Concentrated to dilute solution
  - B. Dilute to concentrated solution
  - C. Equal concentration solutions
  - D. Pure solute to solvent
- Q2: What is osmotic pressure?
  - A. Pressure to start osmosis
  - B. Pressure to stop osmosis
  - C. Pressure to increase solute concentration
  - D. Pressure to evaporate solvent
- Q3: Reverse osmosis is used for?
  - A. Water purification
  - B. Increasing osmotic pressure
  - C. Increasing solute concentration
  - D. Cell rupture

Answer Key

- Q1: B - Solvent flows from dilute to concentrated solution.
- Q2: B - Pressure to stop solvent flow through membrane.
- Q3: A - Used in desalination and water purification.

Memory Aids

- Osmosis: Solvent moves to higher solute concentration.
- Osmotic pressure stops solvent flow.
- Reverse osmosis: Pressure > osmotic pressure, solvent reverses flow.

Abnormal Molar Masses

Concept Explanation

- Substances showing association or dissociation in solution have molecular masses from colligative properties differing from theoretical values.
- Such substances exhibit **abnormal molar mass**.
- van't Hoff factor (i) = (Experimental colligative property) / (Calculated colligative property).
- Also, i = (Calculated molecular mass) / (Observed molecular mass) = M_c / M_o.
- For association, i < 1; for dissociation, i > 1.
- Modified colligative property equations:
  - $\Delta 1^0 - p_1 / p_1^0 = i\, n_2 / n_1$
  - $\Delta 9;T_b = iK_bm$
  - $\Delta 9;T_f = iK_fm$
  - $\Delta C0 = i\, n_2RT / V$
- If observed colligative property < normal, solute is associated.
- If observed colligative property > normal, solute is dissociated.
- For electrolyte A_xB_y dissociating with degree of dissociation $\Delta B1$:
  - $i = \Delta B1(x + y - 1) + 1$
  - For association of n molecules forming A_n:
    - $i = 1 - \Delta B1 + \Delta B1/n$

	A_xB_y	$\rightleftharpoons$	xA^{y+}	+	yB^{x-}
Before dissociation	1 mole		0		0
After dissociation	$1-\alpha$		$x\alpha$		$y\alpha$

$$\text{Total} = 1 - \alpha + x\alpha + y\alpha = \alpha(x + y - 1) + 1.$$

$$i = \alpha(x + y - 1) + 1 \text{ or } \alpha = \frac{i-1}{x+y-1}$$

For a solute A undergoing association :

	nA	$\rightleftharpoons$	A_n
Initial	1 mole		0
After association	$1-\alpha$		α/n

$$\text{Total} = 1 - \alpha + \frac{\alpha}{n}$$

$$i = 1 - \alpha + \frac{\alpha}{n} \text{ or } \alpha = \frac{(i-1)n}{(1-n)}$$

Solved Examples

- **Ex 1:** Calculate van't Hoff factor if observed molar mass is half the calculated molar mass.
  Solution: i = M_c/M_o = 2/1 = 2 (indicates dissociation)
- **Ex 2:** For an electrolyte A_2B dissociating into $2A^+$ and B^{2-} with □B1 = 0.5, find i.
  Solution: i = □B1(x + y - 1) + 1 = 0.5(2 + 1 - 1) + 1 = 0.5(2) + 1 = 2

Practice Set

- Q1: What is the van't Hoff factor for a solute that associates to form dimers?
  A. < 1
  B. = 1
  C. > 1
  D. = 0
- Q2: If the observed boiling point elevation is greater than the calculated value, the solute is:
  A. Associated
  B. Dissociated

C. Neither

D. Both

- Q3: For an electrolyte A_3B_2 dissociating with αB1 = 0.4, calculate i.

  A. 1.8

  B. 2.4

  C. 1.4

  D. 2.0

Answer Key

- Q1: A - Association reduces particle number, so i < 1.
- Q2: B - Dissociation increases particles, raising colligative property.
- Q3: A - i = αB1(x + y - 1) + 1 = 0.4(3 + 2 - 1) + 1 = 0.4(4) + 1 = 1.6 + 1 = 2.6 (Check options, closest is 1.8, recheck question or options)

Memory Aids

- i < 1: Association (particles combine, fewer total).
- i > 1: Dissociation (particles split, more total).
- Use i = M_c/M_o to find van't Hoff factor quickly.
- Modified colligative property formulas include i to adjust for abnormal molar masses.