Ready For Boards
10th & 12th Exam Prep

CHAPTER 1

Solutions

CBSE Class 12 · Chemistry · Chapter 1

CBSE · Chemistry · Class 12

WHAT THIS CHAPTER DOES

A Express any solution's concentration in 4+ ways (mass %, molarity, molality, mole fraction).

B Apply Raoult's law to predict vapour pressure of an ideal solution.

Boards prep that builds confidence, not anxiety.

TODAY'S MISSION

Today's mission

1. Express any solution's concentration in 4+ ways (mass %, molarity, molality, mole fraction).
2. Apply Raoult's law to predict vapour pressure of an ideal solution.
3. Solve every type of colligative-property numerical (ΔP, ΔT_b, ΔT_f, π).
4. Score 6-7 marks on this chapter's slice of the board paper.

WHY THIS MATTERS

Why this chapter matters

1. 5-7 marks every CBSE board paper — most-tested chapter in Physical Chemistry.
2. Colligative properties are why salt melts ice on roads + why deep-sea fish have antifreeze proteins.
3. Mole-fraction + vapour-pressure ideas reappear in Electrochemistry and Chemical Kinetics.

TOPIC

A

Concentration — 4 ways to express it

TOPIC

Concentration units · choose by use case

MASS %

Mass percentage = (mass of solute ÷ mass of solution) × 100. The most intuitive concentration unit because it

MOLARITY (M)

Molarity = moles of solute ÷ litres of SOLUTION. The most widely used lab unit because volumetric flasks

MOLALITY (M)

Molality = moles of solute ÷ kilograms of SOLVENT (not solution). Because both mass quantities are temperature-

Unit	Formula	Used for
Mass %	(w_solute / w_solution) × 100	*Intuitive, industrial use*
Molarity M	mol of solute / L of solution	*Temperature-dependent · titrations*
Molality m	mol of solute / kg of solvent	*Temperature-INdependent · BP/FP problems*
Mole fraction x	n_A / n_total	*Vapor pressure · Raoult's law*
ppm	(mass solute / total) × 10^6	*Very dilute (pollutants, trace ions)*

TOPIC

B

Solubility & Henry's law

TOPIC

Three solubility laws

SOLID IN LIQUID

Solubility of most solids in water INCREASES with rising temperature because dissolution is typically endothermic (energy goes into breaking the crystal lattice). NaCl, KNO_3, and sugar all dissolve far more in hot water than cold. However, a few salts show the opposite trend — $Ce_2(SO_4)_3$, $Li_2SO_4 \cdot H_2O$, and Na_2SO_4 (above 32 °C), and

GAS IN LIQUID

Solubility of a gas in a liquid DECREASES with rising temperature (warm soda goes flat; tropical-water fish need lower dissolved O_2 tolerance) and INCREASES with pressure of the gas above the solution. Quantitatively: p_gas = K_H · x_gas (Henry's law). Two practical applications: deep-sea divers breathe high-pressure mixtures and

HENRY'S LAW

Henry's law: p_gas = K_H · x_gas, where K_H is the Henry's-law constant for that gas-solvent pair. A HIGHER K_H means the gas is LESS soluble at a given partial pressure (think of K_H as the 'reluctance' constant). K_H typically increases with temperature, which is why warm liquids hold less dissolved gas. The 'soda-fizz' explanation:

LIQUID IN LIQUID

Two liquids may show three distinct mixing behaviours. (1) COMPLETELY MISCIBLE — they dissolve in each other in all proportions: ethanol+water, methanol+water, benzene+toluene. (2) PARTIALLY MISCIBLE — mix only within a limited range; phenol+water at 25 °C forms two layers, but above the upper critical

TOPIC

C

Raoult's law & ideal solutions

THEOREM · LOAD-BEARING RESULT

Raoult's Law

> *For a solution of two volatile liquids, the partial vapour pressure of each component is proportional to its mole fraction in the liquid phase. The proportionality constant is the vapour pressure of that pure component.*

STATEMENT

$P_A = x_A \cdot P_A^\circ$ and $P_B = x_B \cdot P_B^\circ$. Total vapour pressure (by Dalton's law) $P_{total} = P_A + P_B = x_A \cdot P_A^\circ + x_B \cdot P_B^\circ$. In the vapour phase, mole fractions are $y_A = P_A / P_{total}$.

WHY THIS MATTERS

- Raoult's law is what makes the four colligative properties (ΔP, ΔT_b, ΔT_f, π) work
- Each is ultimately a consequence of solute particles lowering the solvent's mole fraction — and hence its vapour pressure.

WATCH OUT FOR

NOTE Adding solute LOWERS vapour pressure (because $x_{solvent}$ drops). This is the famous 'relative lowering' $\Delta P/P^\circ = x_{solute}$. Students often write 'increases' — instant mark loss.

WORKED EXAMPLE

Vapour-pressure diagram of an ideal solution

1. Plot $P_A = x_A \cdot P_A^\circ$ (rises linearly from 0 to P_A° as x_A goes 0→1).
2. Plot $P_B = x_B \cdot P_B^\circ$ (rises linearly opposite way — from P_B° to 0).
3. P_{total} is the dashed sum line, lying above the larger of P_A°, P_B°.
4. Ideal example: n-hexane + n-heptane.

TOPIC

Non-ideal solutions — positive vs negative deviation

POSITIVE DEVIATION

A solution shows POSITIVE deviation from Raoult's law when A–B intermolecular interactions are WEAKER than the A–A and B–B interactions in the pure components — the molecules 'prefer their own company', so escape to the vapour phase is easier than ideal. Vapour pressure of the mixture is therefore HIGHER than Raoult would

NEGATIVE DEVIATION

A solution shows NEGATIVE deviation when A–B intermolecular interactions are STRONGER than A–A and B–B — molecules of the two components ATTRACT each other more strongly than they attract their own kind, so escape to vapour is harder. Vapour pressure is LOWER than Raoult's prediction. These systems form MAXIMUM-boiling

IDEAL SOLUTION

An IDEAL solution obeys Raoult's law ($p_A = x_A \cdot p_A^\circ$) over the entire composition range, with no deviation. This requires two conditions to be met perfectly: $\Delta H_{mix} = 0$ (no enthalpy change on mixing) AND $\Delta V_{mix} = 0$ (volume of mixture = sum of component volumes). Both conditions occur only when A–A, B–B, and A–B

AZEOTROPE

An AZEOTROPE is a liquid mixture whose vapour has EXACTLY the same composition as the liquid at the boiling point — meaning ordinary fractional distillation cannot separate it (the more-volatile component does not preferentially escape). Two types: MINIMUM-boiling azeotropes (positive-deviation systems, b.p.

TOPIC

D

Colligative properties — 4 manifestations of one idea

TOPIC

Four colligative properties

1. LOWERING OF VAPOUR PRESSURE

Adding a non-volatile solute to a solvent LOWERS the solvent's vapour pressure because some surface sites are now occupied by non-volatile solute particles that cannot escape. Quantitatively (Raoult's law for the solvent): $\Delta P/P_A^\circ = x_B$, where x_B is the mole fraction of solute. The relative lowering of vapour

2. ELEVATION OF BOILING POINT

Adding a non-volatile solute RAISES the boiling point of a solvent. Why: vapour pressure is lowered → solution must be heated MORE before its vapour pressure reaches atmospheric. Quantitatively $\Delta T_b = K_b \cdot m$, where K_b is the ebullioscopic (boiling-point-elevation) constant of the solvent (water: 0.512

3. DEPRESSION OF FREEZING POINT

A dissolved solute LOWERS the freezing point of the solvent (water freezes below 0 °C when salt is added). Quantitative: $\Delta T_f = K_f \cdot m$, where K_f is the cryoscopic constant of the solvent (water: 1.86 K·kg/mol) and m is solute molality. Why: lower vapour pressure shifts the solid-liquid equilibrium, requiring

4. OSMOTIC PRESSURE

Osmotic pressure $\pi = MRT$, where M is molarity, R the gas constant, T temperature in K. When pure solvent and a solution are separated by a semipermeable membrane, solvent flows INTO the solution to dilute it; the hydrostatic pressure needed to STOP this flow is π. Among the four colligative properties

WORKED EXAMPLE

Molar mass from FP depression

1. Problem: 2.5 g of a non-volatile solute is dissolved in 100 g of benzene. ΔT_f = 0.45 °C. K_f for benzene = 5.12 °C·kg/mol. Find M_{solute}.
2. Formula: $M = (1000 \cdot K_f \cdot w_{solute}) / (\Delta T_f \cdot W_{solvent\_grams})$
3. Substitute: $M = (1000 \times 5.12 \times 2.5) / (0.45 \times 100) = 12{,}800 / 45 \approx 284.4$ g/mol
4. Final: molar mass ≈ 284 g/mol. (If much larger than expected, the solute may be associating in benzene — likely a dimer.)

WORKED EXAMPLE

van't Hoff factor for electrolytes

1. For non-electrolytes that don't associate/dissociate: $i = 1$.
2. Dissociation: $NaCl \rightarrow Na^+ + Cl^-$ gives $i \approx 2$ (incomplete in concentrated solutions). $MgCl_2 \rightarrow$ 3 ions $\Rightarrow i \approx 3$.
3. Association: 2 benzoic acid → 1 dimer (in benzene) gives $i \approx 0.5$.
4. Modified colligative: $\Delta T_b = i \cdot K_b \cdot m$. So 1 m NaCl shows ~2× the ΔT_b of 1 m sugar.

TOPIC

Raoult's law direction

TRAP → TRUTH

× **MISTAKE** Raoult's law says vapour pressure INCREASES as more solute is added.

✓ **CORRECT** Raoult's law: $P_A = x_A \cdot P_A^\circ$ says the partial vapour pressure of solvent A is PROPORTIONAL to its mole fraction in the liquid. Since adding solute lowers x_A (the solvent fraction), the vapour pressure goes DOWN, not up. This 'lowering' IS the colligative property.

TOPIC

Molarity vs molality

TRAP → TRUTH

× **MISTAKE** Molarity (M) and molality (m) are interchangeable for dilute aqueous solutions.

✓ **CORRECT** Molarity is mol/L of SOLUTION (volume-based, changes with temperature). Molality is mol/kg of SOLVENT (mass-based, temperature-INdependent). For BP elevation and FP depression problems, ALWAYS use molality — never molarity. Confusing the two costs 2 marks every numerical.

TOPIC

Colligative property dependence

TRAP → TRUTH

× **MISTAKE** Colligative properties depend on the chemical nature of the solute (NaCl vs sugar gives different ΔT_b).

✓ **CORRECT** Colligative properties depend ONLY on the NUMBER of solute particles, not their identity. 1 mol of sugar gives the same ΔT_b as 1 mol of $CO(NH_2)_2$. NaCl gives ~2× the effect (dissociates into Na^+ + Cl^- — two particles), reflected in the van't Hoff factor $i \approx 2$.

TOPIC

van't Hoff factor for association

TRAP → TRUTH

× **MISTAKE** For associating solutes (like benzoic acid in benzene), $i > 1$.

✓ **CORRECT** $i < 1$ for ASSOCIATING solutes (2 molecules → 1 dimer reduces particle count). $i > 1$ for DISSOCIATING solutes (1 → multiple ions). $i = 1$ for non-electrolytes that neither associate nor dissociate. This direction matters in modified colligative formulas.

TOPIC

Ideal solution conditions

TRAP → TRUTH

× **MISTAKE** An ideal solution forms when $\Delta H_{mix} = 0$ only.

✓ **CORRECT** Ideal solution requires BOTH: $\Delta H_{mix} = 0$ AND $\Delta V_{mix} = 0$ (and obeys Raoult's law over the entire composition range). Just one condition isn't enough. Solutions like n-hexane + n-heptane satisfy both; ethanol + water satisfies neither.

TOPIC

Henry's law form

TRAP → TRUTH

× **MISTAKE** Henry's law: $p = K_H \cdot x_{gas}$ always means more pressure = more dissolution.

✓ **CORRECT** Henry's law: $p = K_H \cdot x_{gas}$ correctly says solubility (x) is proportional to partial pressure at constant T. But note: K_H INCREASES with temperature for most gases ⇒ same pressure gives LESS dissolved gas at higher T. That's why warm soda goes flat faster.

TOPIC

Osmotic pressure direction

TRAP → TRUTH

× **MISTAKE** Osmotic pressure flows from high-concentration to low-concentration solution.

✓ **CORRECT** Osmosis is the flow of SOLVENT (not solute) from LOWER-concentration solution to HIGHER-concentration solution (so the concentrations equalise). Osmotic pressure π is the EXTRA pressure that must be applied on the higher-concentration side to STOP this solvent flow. Direction of solvent flow vs direction of applied pressure get confused often.

TOPPER TEMPLATE · MARK-BY-MARK

5-mark numerical: 'Calculate molar mass of solute from freezing-point depression data.'

1	**WRITE THE FORMULA** 1 m	$\Delta T_f = K_f \cdot m$, where m is molality. Combined: $M_{solute} = (1000 \cdot K_f \cdot w_{solute}) / (\Delta T_f \cdot W_{solvent\_grams})$. State each symbol's meaning.
2	**LIST GIVEN DATA + CONVERT UNITS** 1 m	Tabulate: w_{solute} = X g, $W_{solvent}$ = Y g, ΔT_f = Z °C, K_f = K °C·kg/mol. Confirm temperature in °C (since ΔT, sign doesn't matter), masses in grams.
3	**SUBSTITUTE CAREFULLY** 1 m	Write: $M_{solute} = (1000 \times K \times X) / (Z \times Y)$. Show the substitution explicitly — examiners give 1 method mark even if arithmetic is wrong.
4	**COMPUTE + UNITS** 1 m	Calculate the numerical value. State final answer with UNIT (g/mol). Round to appropriate significant figures.
5	**COMMENT + VERIFICATION** 1 m	If the answer is much higher than the expected molar mass, the solute is likely associating (dimerises). If much lower, it dissociates. Mention van't Hoff factor i if relevant.

TOPPER TEMPLATE · MARK-BY-MARK

3-mark question: 'Calculate the osmotic pressure of a solution of given molarity at given T.'

Step	Point	Marks	Explanation
1	WRITE Π = MRT	1 m	Osmotic pressure $\pi = M \cdot R \cdot T$, where M = molarity (mol/L), R = 0.0821 L·atm/(mol·K), T = absolute temperature (K). State each symbol.
2	CONVERT T TO KELVIN IF GIVEN IN °C	1 m	$T(K) = T(°C) + 273$. Forgetting this is the most common error.
3	SUBSTITUTE + COMPUTE + UNITS	1 m	$\pi = M \times 0.0821 \times T(K)$. Final answer in atm; convert to Pa or kPa if asked. Watch unit-system if R is given in J/(mol·K) — then π comes in Pa.

TOPPER TEMPLATE · MARK-BY-MARK

3-mark conceptual: 'State Raoult's law. Distinguish between ideal and non-ideal solutions with examples.'

1	**STATE RAOULT'S LAW** 1 m	For a solution of two volatile liquids A and B: partial vapour pressure of each is proportional to its mole fraction in the liquid. $P_A = x_A \cdot P_A°$, $P_B = x_B \cdot P_B°$, $P_{total} = P_A + P_B$.
2	**IDEAL SOLUTION CRITERIA + EXAMPLE** 1 m	Ideal: obeys Raoult's law over the entire composition range; $\Delta H_{mix} = 0$; $\Delta V_{mix} = 0$; A-B interactions = average of A-A and B-B. Example: n-hexane + n-heptane (similar non-polar liquids).
3	**NON-IDEAL + +VE/−VE DEVIATION EXAMPLES** 1 m	Non-ideal: deviates from Raoult's law. +ve deviation (A-B weaker than A-A, B-B) → vapour pressure higher than predicted → minimum-boiling azeotrope. Example: ethanol + water. −ve deviation (A-B stronger than A-A, B-B) → vapour pressure lower → maximum-boiling azeotrope. Example: HNO_3 + water.

PYQ PATTERNS

Top PYQ patterns to drill

#1	A solution containing X g of solute in Y g of solvent has a depression in freezing point of ΔT_f. Calculate the molar mass of the solute. (K_f given) (3-5 marks)	Almost annual since 2017
#2	State Raoult's law. Distinguish between ideal and non-ideal solutions with one example of each. (3 marks)	2018, 2019, 2022, 2023
#3	Calculate the osmotic pressure of a given solution at temperature T. (n, V or molarity given) (3 marks)	2018, 2020, 2022, 2024
#4	State Henry's law. A sealed bottle of soda water at 25°C has CO_2 at pressure P. Find the molality of dissolved CO_2. (K_H given) (3 marks)	2019, 2021, 2023
#5	Define van't Hoff factor. For an electrolyte that dissociates / associates, find the modified colligative property. (3 marks)	2020, 2022, 2024

MARKS DISTRIBUTION

10-year marks distribution

10-YEAR PYQ MARKS DISTRIBUTION

Colligative properties — numerical (ΔT_b, ΔT_f, π)	45%
Raoult's law — ideal vs non-ideal (positive/ negative deviation)	28%
Molarity / molality / mole fraction inter-conversion	22%
Henry's law — gas solubility numerical	18%
van't Hoff factor + abnormal molar mass	16%
Azeotropes — minimum boiling vs maximum boiling (conceptual)	8%
Definitions: colligative property, osmotic pressure, ideal solution	10%

RECAP · MEMORISE THESE

Recap — 4 must-know formulas + 3 must-know concepts

1 Concentration units — M (mol/L solution), m (mol/kg solvent), x (mol fraction), mass %. Use m for ΔT, x for ΔP.

2 Raoult + Henry — $P_A = x_A \cdot P_A^\circ$ (solvent in solution). $p_{gas} = K_H \cdot x_{gas}$ (gas in liquid). Both = vapour ↔ liquid equilibrium statements.

3 Colligative — $\Delta P/P^\circ = x_B$, $\Delta T_b = K_b \cdot m$, $\Delta T_f = K_f \cdot m$, $\pi = MRT$. Multiply by van't Hoff i for electrolytes.

WHAT'S NEXT

What's next

- Chapter 2 — Electrochemistry (builds on solution concentrations + colligative thinking).
- Sit the 15-MCQ Quick Drill under 25-min timer. Target ≥ 12/15.
- Then the full Board-Pattern Paper — 30 marks, 60 min, real CBSE pattern.

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