FREE EDITION · NOTES + 3 SAMPLE MCQS

CUET · CHEMISTRY · CLASS XII · CODE 306

Solutions

CUET unit: Solutions

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📌 Snapshot

- Establishes the concept of a homogeneous mixture (solution), classifies the nine types of binary solutions (gas/liquid/solid solute in gas/liquid/solid solvent).
- Develops seven quantitative ways to express concentration: mass %, volume %, mass-by-volume %, ppm, mole fraction, molarity (M), molality (m) — and contrasts which are temperature-independent.
- Builds the laws governing solubility (Henry's law $p = K_H \cdot x$ for gases) and vapour pressure (Raoult's law for both volatile + non-volatile solutes), and uses them to classify ideal vs. non-ideal solutions (positive/negative deviation, minimum/maximum-boiling azeotropes).
- Presents the four colligative properties — relative lowering of vapour pressure, $\Delta T_b = K_b \cdot m$, $\Delta T_f = K_f \cdot m$, $\pi = CRT$ — and uses each to determine molar mass of solute.
- Introduces van't Hoff factor i to explain abnormal molar masses when solutes associate ($i < 1$) or dissociate ($i > 1$) in solution.

📖 Detailed Notes

2.1 Core concepts

- A solution is a homogeneous mixture of two or more components; the component in the largest quantity is the solvent and determines the physical state of the solution, while the other components are solutes. We restrict ourselves to binary solutions (NCERT §1.1, p. 1–2).
- Nine types of solutions exist based on the physical state of solute and solvent — gaseous solutions (gas/liquid/solid in gas; e.g. O_2+N_2, chloroform in N_2, camphor in N_2), liquid solutions (gas/liquid/solid in liquid; e.g. O_2 in water, ethanol in water, glucose in water), and solid solutions (gas/liquid/solid in solid; e.g. H_2 in Pd, Na-amalgam, Cu in Au) (NCERT §1.1, Table 1.1, p. 2).
- Concentration can be expressed as mass % (w/w = mass of component × 100 / total mass), volume % (V/V), mass-by-volume % (w/V, mass of solute in 100 mL solution — common in medicine/pharmacy), ppm (parts × 10^6 / total parts) for trace solutes, mole fraction $x_i = n_i / \Sigma n_i$ with $\Sigma x_i = 1$, molarity M = moles of solute /

litre of solution, and molality m = moles of solute / kg of solvent (NCERT §1.2, p. 2–4).

- Mass %, ppm, mole fraction and molality are independent of temperature; molarity depends on temperature because volume varies with temperature while mass does not (NCERT §1.2, p. 5).
- Solubility is the maximum amount of a substance that can be dissolved in a specified quantity of solvent at a specified temperature; it depends on the nature of solute and solvent, temperature, and pressure. "Like dissolves like" — polar solutes dissolve in polar solvents and non-polar in non-polar (NCERT §1.3, §1.3.1, p. 5–6).
- For a solid in a liquid, dissolution and crystallisation reach a dynamic equilibrium (Solute + Solvent $\rightleftharpoons$ Solution); the saturated concentration equals the solubility. If dissolution is endothermic ($\Delta_{sol} H > 0$) solubility increases with temperature; if exothermic ($\Delta_{sol} H < 0$) it decreases. Pressure has no significant effect on solid–liquid solubility (NCERT §1.3.1, p. 6).
- For a gas in a liquid, solubility increases with pressure. Henry's law: at constant temperature, the partial pressure of the gas in vapour phase is directly proportional to its mole fraction in solution — $p = K_H \cdot x$. Higher $K_H \Rightarrow$ lower solubility at given pressure; K_H increases with temperature, so gas solubility decreases as temperature rises (aquatic life prefers cold water) (NCERT §1.3.2, p. 7–8, Table 1.2).
- Applications of Henry's law: CO_2 sealed under high pressure in soft drinks; scuba divers' tanks use He-diluted air to prevent "bends" (N_2 bubbles in blood on ascent); anoxia at high altitudes due to low partial pressure of O_2 (NCERT §1.3.2, p. 8–9).
- Raoult's law (two volatile components 1 and 2): partial vapour pressure of each volatile component is proportional to its mole fraction in solution — $p_1 = x_1 \cdot p_1^\circ$, $p_2 = x_2 \cdot p_2^\circ$; total $p_{total} = p_1^\circ + (p_2^\circ - p_1^\circ) \cdot x_2$. In the vapour phase, mole fraction of component i is $y_i = p_i / p_{total}$; the vapour is always richer in the more volatile component (NCERT §1.4.1, p. 9–11).
- Raoult's law is a special case of Henry's law where the proportionality constant $K_H = p_1^\circ$ (i.e. the gas becomes a volatile component) (NCERT §1.4.2, p. 12).
- For a non-volatile solute (solid in liquid), only solvent contributes to vapour pressure. Raoult's law in general form: partial vapour pressure of each volatile component is directly proportional to its mole fraction, $p_1 = x_1 \cdot p_1^\circ$. A plot of $p_{solution}$ vs. $x_{solvent}$ is linear, varying from 0 to p_1° (NCERT §1.4.3, p. 12–13, Fig. 1.5).
- Ideal solutions obey Raoult's law over the entire concentration range, with $\Delta_{mix} H = 0$ and $\Delta_{mix} V = 0$; A-A, B-B and A-B interactions are nearly equal. Examples: n-hexane + n-heptane, bromoethane + chloroethane, benzene + toluene (NCERT §1.5.1, p. 13).
- Non-ideal solutions: positive deviation when A-B interactions are weaker than A-A and B-B (vapour pressure higher than Raoult prediction; e.g. ethanol + acetone, CS_2 + acetone). Negative deviation when A-B interactions are stronger than A-A and B-B

(vapour pressure lower; e.g. phenol + aniline, chloroform + acetone — H-bond between CHCl3 H and acetone O) (NCERT §1.5.2, p. 13–14, Fig. 1.6).

- Azeotropes are binary mixtures with identical composition in liquid and vapour phase that boil at constant temperature and cannot be separated by fractional distillation. Large positive deviation ⇒ minimum-boiling azeotrope (e.g. 95% v/v ethanol-water). Large negative deviation ⇒ maximum-boiling azeotrope (e.g. 68% HNO3 + 32% water, b.p. 393.5 K) (NCERT §1.5.2, p. 14–15).
- Four colligative properties (depend only on the number of solute particles, not their identity): (1) relative lowering of vapour pressure, (2) elevation of boiling point, (3) depression of freezing point, (4) osmotic pressure (NCERT §1.6, p. 15).
- Relative lowering of vapour pressure: (p1° – p1)/p1° = x2 (mole fraction of solute); for dilute solutions this equals n2/n1 = (w2·M1)/(M2·w1), used to find M2 (NCERT §1.6.1, p. 15–16, eq. 1.24–1.28).
- Elevation of boiling point: ΔT_b = T_b – T_b° = K_b·m, where K_b is the molal elevation (ebullioscopic) constant (unit K kg mol^{-1}). For water K_b = 0.52, benzene 2.53, chloroform 3.63, etc. M2 = (1000·K_b·w2)/(ΔT_b·w1) (NCERT §1.6.2, p. 16–17, eq. 1.30, 1.33, Table 1.3).
- Depression of freezing point: ΔT_f = T_f° – T_f = K_f·m, where K_f is the molal depression (cryoscopic) constant (unit K kg mol^{-1}). For water K_f = 1.86, benzene 5.12, camphor-like cyclohexane 20.00, carbon tetrachloride 31.8. M2 = (1000·K_f·w2)/(ΔT_f·w1). The values of K_f and K_b can also be calculated from K_f = R·M1·T_f^2/(1000·Δ_fus H) and K_b = R·M1·T_b^2/(1000·Δ_vap H) (NCERT §1.6.3, p. 18–19, eq. 1.34–1.38, Table 1.3).
- Osmosis: net flow of solvent through a semipermeable membrane from pure solvent (or dilute solution) into the more concentrated solution. The excess pressure that must be applied on the solution side to just stop this flow is osmotic pressure π. For dilute solutions π = CRT = (n2/V)·RT, so M2 = (w2·R·T)/(π·V). Isotonic solutions have equal π (e.g. 0.9% w/V NaCl = normal saline ≈ blood plasma); hypertonic causes cells to shrink, hypotonic causes them to swell. Reverse osmosis (RO, used for desalination) drives solvent out of solution when applied pressure > π; cellulose acetate is the workable porous membrane (NCERT §1.6.4 & §1.6.5, p. 20–23, eq. 1.39–1.42, Fig. 1.9–1.11).
- Abnormal molar mass: solutes that dissociate (e.g. KCl, NaCl, K2SO4) give experimental M lower than true M (more particles); solutes that associate (e.g. acetic acid dimer in benzene) give M higher than true (NCERT §1.7, p. 23–24).
- van't Hoff factor i = (normal molar mass)/(abnormal molar mass) = (observed colligative property)/(calculated colligative property) = (moles of particles after dissociation/association)/(moles before). i > 1 for dissociation, i < 1 for association. Modified equations: ΔT_b = i·K_b·m, ΔT_f = i·K_f·m, π = i·(n2/V)·RT, (p1°–p1)/p1° = i·(n2/n1). For KCl, NaCl, MgSO4 i → 2 in dilute solution; for K2SO4 i → 3 (NCERT §1.7, p. 24–25, Table 1.4).

2.2 Definitions to memorise

Term	Definition	Page
Solution	Homogeneous mixture of two or more components	1
Solvent / Solute	Component present in largest quantity / other components	1
Molarity (M)	Moles of solute per litre of solution; temperature-dependent	4
Molality (m)	Moles of solute per kg of solvent; temperature-independent	5
Mole fraction (x_i)	$n_i / \Sigma n_i$; $\Sigma x_i = 1$	3
ppm	(parts of component / total parts) × 10^6	3
Solubility	Maximum amount of substance that can be dissolved in a specified amount of solvent at specified T and P	5
Henry's law	$p = K_H \cdot x$ (at constant T, partial pressure of gas ∝ its mole fraction in solution)	7
Raoult's law (volatile + volatile)	$p_i = x_i \cdot p_i^\circ$; $p_{total} = x1 \cdot p1^\circ + x2 \cdot p2^\circ$	10
Raoult's law (non-volatile solute)	$p1 = x1 \cdot p1^\circ$; $(p1^\circ - p1)/p1^\circ = x2$	12, 15
Ideal solution	Obeys Raoult's law over all concentrations; $\Delta_{mix} H = 0$, $\Delta_{mix} V = 0$	13
Positive deviation	A-B interactions weaker than A-A, B-B; vapour pressure higher than predicted	13
Negative deviation	A-B interactions stronger than A-A, B-B; vapour pressure lower than predicted	14
Minimum-boiling azeotrope	Formed by large positive deviation (e.g. 95% v/v ethanol-water)	14
Maximum-boiling azeotrope	Formed by large negative deviation (e.g. 68% HNO3 + 32% water)	15
Colligative property	Depends on the number of solute particles, not their identity	15
Relative lowering of vapour pressure	$(p1^\circ - p1)/p1^\circ = x2$	16
Molal elevation constant (K_b)	$\Delta T_b = K_b \cdot m$; unit K kg mol^{-1}	17
Molal depression constant (K_f)	$\Delta T_f = K_f \cdot m$; unit K kg mol^{-1}	18
Osmotic pressure (π)	Excess pressure that just stops solvent flow across a semipermeable membrane; $\pi = CRT$	21
Isotonic / Hypertonic / Hypotonic	Equal π / higher π (cells shrink) / lower π (cells swell), relative to a reference solution	22

Term	Definition	Page
Reverse osmosis	Applied pressure > π drives solvent out of solution; used for desalination	23
van't Hoff factor (i)	(normal M)/(abnormal M) = (observed colligative)/(calculated colligative); >1 for dissociation, <1 for association	24

2.3 Diagrams / processes to remember

- Fig. 1.1 (p. 7): Effect of pressure on the solubility of a gas — gas particles compressed above the solution increase dissolution rate.
- Fig. 1.2 (p. 7): Linear plot of partial pressure vs. mole fraction of HCl in cyclohexane at 293 K; slope = K_H.
- Fig. 1.3 (p. 10): Vapour pressure vs. mole fraction for an ideal binary liquid solution — lines I (p1 vs x1), II (p2 vs x2) and III (p_total vs x2) all linear.
- Fig. 1.4 (p. 12): Lowering of vapour pressure when a non-volatile solute is added — fraction of surface available for solvent escape is reduced.
- Fig. 1.5 (p. 13): Linear plot of solution vapour pressure vs. mole fraction of solvent (Raoult's law plot for non-volatile solute).
- Fig. 1.6 (p. 14): Vapour pressure plots showing (a) positive deviation, (b) negative deviation from Raoult's law.
- Fig. 1.7 (p. 17): Vapour-pressure-vs-temperature curves of pure solvent and solution — ΔT_b is the horizontal gap at 1.013 bar.
- Fig. 1.8 (p. 18): Same diagram showing ΔT_f as the gap between the freezing points of pure solvent and solution.
- Fig. 1.9 / 1.10 (p. 20–21): Thistle funnel and U-tube setups demonstrating osmosis and the definition of osmotic pressure.
- Fig. 1.11 (p. 23): Reverse osmosis schematic — applied pressure > π forces pure water through a cellulose acetate membrane.
- Table 1.2 (p. 8): K_H values; e.g. He = 144.97 kbar at 293 K, CO2 = 1.67 kbar at 298 K, N2 = 76.48 kbar at 293 K.
- Table 1.3 (p. 19): K_b and K_f for water (0.52, 1.86), benzene (2.53, 5.12), chloroform (3.63, 4.79), CCl4 (5.03, 31.8), camphor-like cyclohexane (2.79, 20.00).
- Table 1.4 (p. 25): van't Hoff factor i values for NaCl, KCl, MgSO4, K2SO4 at 0.1 m, 0.01 m, 0.001 m — approach the integer ideal value on dilution.

2.4 Common confusions / NTA trap points

- Confusing molarity (per litre of solution, T-dependent) with molality (per kg of solvent, T-independent). NTA often gives density to convert one to the other.
- Forgetting that K_H increases with temperature, so a higher K_H means lower solubility — students misread the trend.

- Mixing up positive and negative deviation: positive deviation ⇒ weaker A-B forces ⇒ minimum-boiling azeotrope; negative deviation ⇒ stronger A-B forces ⇒ maximum-boiling azeotrope.
- Forgetting to include the van't Hoff factor i for electrolytes (i = 2 for NaCl/KCl, i = 3 for K_2SO_4) when computing colligative properties.
- For association (e.g. benzoic acid dimer in benzene), $i < 1$ and observed molar mass is higher than the true molecular mass — the opposite of dissociation.
- Confusing isotonic / hypertonic / hypotonic — recall that 0.9% w/V NaCl is isotonic with blood; cells in hypertonic solutions shrink (water leaves), in hypotonic solutions swell.

🎯 Practice MCQs

Q1. **Which of the following concentration units is temperature-dependent?**

A. Mass percentage

B. Mole fraction

C. Molality

D. Molarity

Q2. **According to Henry's law, the partial pressure of a gas above a solution is related to its mole fraction in solution by $p = K_H \cdot x$. A higher value of K_H at a given partial pressure implies that**

A. the gas has higher solubility in the liquid

B. the gas has lower solubility in the liquid

C. the solubility is independent of K_H

D. the gas obeys Raoult's law instead of Henry's law

Q3. If N2 gas is bubbled through water at 293 K at a partial pressure of 0.987 bar, and K_H for N2 at 293 K is 76.48 kbar, the mole fraction of N2 in the solution is approximately

A. 1.29×10^{-3}

B. 1.29×10^{-5}

C. 7.16×10^{-4}

D. 0.987

📊 PYQ Alignment

The "Solutions" chapter is one of the highest-yield units in CUET (UG) Chemistry: every recent paper carries direct application of Henry's law (mole-fraction or solubility calculation), at least one Raoult's-law / vapour-pressure numerical, and a colligative-property numerical (ΔT_b, ΔT_f or π) involving the van't Hoff factor for an electrolyte; conceptual questions on positive/negative deviation, azeotropes (minimum vs. maximum boiling), and isotonic/hypertonic/hypotonic solutions also recur each year.

CUET 2025 — Actual PYQs from this chapter

Q.1 (CUET 2025) The value of van’t Hoff factor i for CH_3COOH solution in water will be:

- A) Between 1 and 2 B) Less than 1 C) 2 D) 1

Tests: Solutions **Answer:** Not in extracted key

Q.3 (CUET 2025) Match List-I (Solutions) with List-II (Explanation). List-I List-II (A) Saturated solution (i) Solution having two components (B) Isotonic solutions (ii) A solution whose osmotic pressure is more than another (C) Binary solution (iii) Solution containing maximum amount of solute (D) Hypertonic solution (iv) Solutions having same osmotic pressure Options given.

- A) — B) — C) — D) —

Tests: Solutions **Answer:** Not in extracted key

Q.4 (CUET 2025) Give reason for low concentration of oxygen in blood and tissues of people living at high altitude.

- A) Low temperature and high atmospheric pressure B) Low temperature C) Low atmospheric pressure D) High atmospheric pressure

Tests: Henry's law **Answer:** Not in extracted key

Q.5 (CUET 2025) Calculate the molality of KI if density of 20% (mass/mass) aqueous solution = 1.202 g mL^{-1} (Molar mass KI = 166 g mol^{-1})

- A) 1.5 mol kg^{-1} B) 0.5 mol kg^{-1} C) 0.15 mol kg^{-1} D) 0.2 mol kg^{-1}

Tests: Solutions **Answer:** Not in extracted key

CUET 2024 — Actual PYQs from this chapter

Q.3 (CUET 2024) A molecule X associates in a solvent as: X$\rightleftharpoons$(X)nX \rightleftharpoons (X)_nX$\rightleftharpoons$(X)n For a given concentration, the van't Hoff factor = 0.80 and fraction of associated molecules = 0.3. The value of n is:

- A) 2 B) 3 C) 1 D) 5

Tests: Solutions **Answer:** Not in extracted key

Q.6 (CUET 2024) Copper crystallizes in FCC lattice with unit cell edge length 361 pm. The radius of Cu atom is:

- A) 127 pm B) 181 pm C) 157 pm D) 108 pm

Tests: Solid state (closest – via Solutions/states mapping) **Answer:** Not in extracted key

Q.41 (CUET 2024) Which of the following is not a colligative property?

- A) Relative lowering of vapour pressure B) Osmotic pressure C) Boiling point D) Surface tension

Tests: Solutions **Answer:** Not in extracted key

Q.42 (CUET 2024) The van't Hoff factor i is defined as:

- A) Observed colligative property / calculated value B) Calculated value / observed value C) Ratio of molality to molarity D) Ratio of osmotic pressure to temperature

Tests: Solutions **Answer:** Not in extracted key

CUET 2023 — Actual PYQs from this chapter

Q.4 (CUET 2023) Match List-I with List-II. List-I (K_H values / K bar) List-II (Gas) (A) 145 (I) CO_2 (B) 89 (II) He (C) 76.5 (III) N_2 (293 K) (D) 1.67 (IV) N_2 (303 K) Options:

- A) A-II, B-IV, C-III, D-I B) A-I, B-II, C-III, D-IV C) A-II, B-III, C-IV, D-I D) A-I, B-III, C-II, D-IV

Tests: Solutions **Answer:** Not in extracted key

Q.22 (CUET 2023) The vapour pressure of mixture of ethanol and acetone is higher because:

- A) Weakening of intermolecular interactions B) Strengthening of interactions C) New hydrogen bonds formed D) Molecules cannot escape solution

Tests: Solutions **Answer:** Not in extracted key

Q.24 (CUET 2023) A compound forms hexagonal close packed structure. Number of tetrahedral voids in 0.8 mol is:

- A) (1.5055×10^{23}) B) (2.4088×10^{23}) C) (9.635×10^{23}) D) (3.011×10^{23})

Tests: Solid state (closest – via Solutions/states mapping) **Answer:** Not in extracted key

Q.40 (CUET 2023) Which of the following defects are shown by KCl crystal? (A) Schottky defect (B) Frenkel defect (C) Metal excess defect (D) Metal deficiency defect Options:

- A) (A) and (B) only B) (A) and (C) only C) (B) and (C) only D) (B) and (D) only

Tests: Solid state (closest – via Solutions/states mapping) **Answer:** Not in extracted key