FREE NOTES · NCERT + JEE/NEET LEVEL

Solutions

Types of solutions, concentration terms, solubility and Henry's law, Raoult's law, ideal and non-ideal solutions, the four colligative properties and the van't Hoff factor.

01 Types of solutions
02 Concentration terms
03 Solubility & Henry's law
04 Raoult's law
05 Ideal & non-ideal solutions
06 Colligative properties
07 Osmosis & van't Hoff factor
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01 Types of solutions

A **solution** is a homogeneous mixture of two or more substances. The component present in larger amount is the **solvent**; the others are **solutes**. A binary solution has two components.

Solvent state	Example
Gas	Air (gas in gas), camphor in N_2 (solid in gas)
Liquid	O_2 in water, ethanol in water, sugar in water
Solid	H_2 in palladium, amalgam of Hg with Na, brass/alloys

02 Concentration terms

Term	Formula	Temperature dependent?
Mass %	$(\text{mass of solute} / \text{mass of solution}) \times 100$	No
ppm	$(\text{parts of solute} / \text{total parts}) \times 10^6$	No
Mole fraction (x)	$x_A = n_A/(n_A+n_B);\ \Sigma x = 1$	No
Molarity (M)	$\text{moles of solute} / \text{volume of solution (L)}$	**Yes** (volume changes)
Molality (m)	$\text{moles of solute} / \text{mass of solvent (kg)}$	No

REMEMBER

Anything with **volume** in it (molarity, volume %) changes with temperature. Molality and mole fraction depend only on mass, so they don't. That is why colligative formulas use molality.

03 Solubility & Henry's law

Solid in liquid: "like dissolves like" (polar in polar). If dissolving is endothermic, solubility rises with temperature; if exothermic, it falls. Pressure has almost no effect.

Gas in liquid: solubility **decreases** as temperature rises (dissolving a gas is exothermic) and **increases** with pressure.

$$p = K_H \cdot x$$

Henry's law: the partial pressure of a gas above the solution is proportional to its mole fraction in the solution. **Higher K_H ⇒ lower solubility.** K_H rises with temperature.

REAL-LIFE USES

- Soda bottles are sealed under high CO_2 pressure.
- **Bends** in deep-sea divers: N_2 dissolved at high pressure forms bubbles in blood when they rise fast. Air tanks are diluted with He (11.7% He, 56.2% N_2, 32.1% O_2).
- **Anoxia** at high altitude: low O_2 pressure ⇒ less O_2 in blood.

04 Raoult's law

For a solution of two volatile liquids, the partial vapour pressure of each component is proportional to its mole fraction.

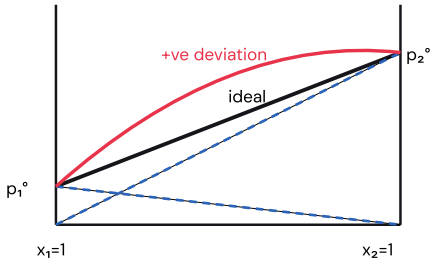
$$p_1 = p_1^\circ x_1, \quad p_2 = p_2^\circ x_2$$

$$p_{total} = p_1^\circ + (p_2^\circ - p_1^\circ)\, x_2$$

Vapour phase: $y_1 = p_1/p_{total}$. The vapour is richer in the more volatile component.

For a **non-volatile solute** only the solvent has vapour pressure, giving **relative lowering of vapour pressure**:

$$(p^\circ - p)/p^\circ = x_{solute}$$



Vapour pressure vs composition: straight line for ideal, bulging curve for positive deviation

05 Ideal & non-ideal solutions

	Ideal	Positive deviation	Negative deviation
A–B attraction	= A–A, B–B	Weaker	Stronger
ΔH_{mix}, ΔV_{mix}	0, 0	+ve, +ve	-ve, -ve
Vapour pressure	Follows Raoult	Higher than expected	Lower than expected
Example	n-hexane + n-heptane, benzene + toluene	ethanol + water, ethanol + acetone, CS_2 + acetone	$CHCl_3$ + acetone (H-bond), HNO_3 + water, phenol + aniline
Azeotrope	None	Minimum-boiling (95% ethanol)	Maximum-boiling (68% HNO_3)

An **azeotrope** boils at constant temperature with the same composition in liquid and vapour, so it cannot be separated by fractional distillation.

06 Colligative properties

Properties that depend only on the **number of solute particles**, not on their nature. There are four.

Property	Formula	Constant
Relative lowering of VP	$\Delta p/p^\circ = x_B \approx n_B/n_A$	None
Elevation of boiling point	$\Delta T_b = K_b \cdot m$	K_b (ebullioscopic), water 0.52 K kg/mol
Depression of freezing point	$\Delta T_f = K_f \cdot m$	K_f (cryoscopic), water 1.86 K kg/mol
Osmotic pressure	$\pi = CRT = (n/V)RT$	R = 0.083 L bar/(mol K)

FINDING MOLAR MASS

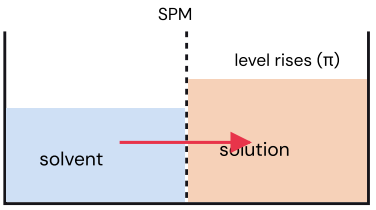
$M_B = (K_b \times w_B \times 1000)/(\Delta T_b \times w_A)$ (same with K_f, ΔT_f)

Osmotic pressure is best for polymers and proteins: the effect is large even at low concentration and it is measured at room temperature.

07 Osmosis & van't Hoff factor

Osmosis: solvent flows through a semipermeable membrane (SPM) from the solvent (or dilute solution) into the concentrated solution. The extra pressure that just stops this flow is the **osmotic pressure π**.

- **Isotonic:** same π (0.9% NaCl = blood, "normal saline").
- **Hypertonic** outside ⇒ cell shrinks (plasmolysis). **Hypotonic** outside ⇒ cell swells.
- **Reverse osmosis:** pressure > π pushes solvent the other way. Used for desalination (cellulose acetate membrane).



Solvent moves through the SPM into the solution

VAN'T HOFF FACTOR I

$$i = \text{observed colligative property / calculated} = \text{normal molar mass / observed molar mass}$$

$$\Delta T_f = i\,K_f\,m, \quad \pi = iCRT$$

Dissociation (NaCl, K_2SO_4) ⇒ i > 1 (NaCl → 2, K_2SO_4 → 3 when complete). Association (acetic acid dimer in benzene) ⇒ i < 1 (≈ ½).
Degree of dissociation α = (i − 1)/(n − 1); degree of association α = (1 − i)/(1 − 1/n).

08 JEE Extra + Tricks

JEE LEVEL

- Colligative properties with van't Hoff factor: $\Delta T_b = iK_b m$, $\Delta T_f = iK_f m$, $\pi = iCRT$, relative lowering = $i \cdot x_{solute}$.
- $i = 1 + \alpha(n - 1)$ for dissociation; $i = 1 - \alpha(1 - 1/n)$ for association (acetic acid dimer in benzene, $i \approx ½$).
- Raoult's law: positive deviation (ethanol + water, acetone + CS_2) ⇒ minimum boiling azeotrope; negative (acetone + chloroform, HNO_3 + water) ⇒ maximum boiling azeotrope.
- Henry's law $p = K_H x$: higher K_H ⇒ lower solubility; solubility of gases decreases with temperature.
- Isotonic solutions have equal osmotic pressure (0.9% NaCl = normal saline). Reverse osmosis used for desalination.

09 Solved numericals

Q1. 18 g glucose (M = 180) is dissolved in 1 kg water. Find the boiling point. (K_b = 0.52)

$m = 0.1/1 = 0.1$ mol/kg ⇒ $\Delta T_b = 0.52 \times 0.1 = 0.052$ K ⇒ $T_b = 373.15 + 0.052 =$ **373.202 K**.

Q2. Find π of 0.1 M NaCl at 300 K (complete dissociation).

$i = 2$ ⇒ $\pi = 2 \times 0.1 \times 0.083 \times 300 =$ **4.98 bar**.

Q3. Vapour pressure of pure benzene is 640 mm Hg. A non-volatile solute lowers it to 600 mm Hg. Find the mole fraction of the solute.

$x_B = (640 - 600)/640 =$ **0.0625**.

Q4. Which has the lowest freezing point: 0.1 m glucose, 0.1 m NaCl, 0.1 m $CaCl_2$?

$i \times m$: 0.1, 0.2, 0.3 ⇒ $CaCl_2$ gives the largest ΔT_f ⇒ **lowest freezing point**.

10 Common mistakes

- Using mass of **solution** instead of mass of **solvent** in molality.
- Thinking higher K_H means more soluble. It's the opposite.
- Forgetting i for electrolytes (NaCl, $CaCl_2$) in colligative questions.
- Using R = 8.314 with concentration in mol/L. For π in bar use 0.083 L bar/(mol K).
- Mixing up minimum- and maximum-boiling azeotropes (positive deviation ⇒ minimum boiling).

11 Formula sheet & practice

Henry's law	$p = K_H\, x$
Raoult's law	$p_{total} = p_1^{\circ} x_1 + p_2^{\circ} x_2$
RLVP	$(p^{\circ} - p)/p^{\circ} = x_B$
Boiling / freezing	$\Delta T = i\, K\, m$
Osmotic pressure	$\pi = iCRT$
Molar mass	$M = 1000\, K\, w_B/(\Delta T\, w_A)$
Dissociation	$\alpha = (i - 1)/(n - 1)$

1. Why is molality preferred over molarity?
2. Give an example of a solution with negative deviation and say why.
3. Why do we sprinkle salt on icy roads?
4. Find i for $K_4[Fe(CN)_6]$ (complete dissociation).
5. Why do raw mangoes shrivel in brine?

ANSWERS

1) It doesn't change with temperature · 2) Chloroform + acetone: H-bond forms between them · 3) Salt lowers the freezing point of water · 4) 5 · 5) Brine is hypertonic, so water leaves the mango by osmosis

12 Quick revision: 5 minutes before the exam

CONCENTRATION

- Molarity changes with T; molality doesn't.
- Henry: $p = K_H x$; high K_H = less soluble.
- Gas solubility falls as T rises.

RAOULT

- $p = p^{\circ} x$ for each volatile part.
- +ve deviation ⇒ min-boiling azeotrope.
- -ve deviation ⇒ max-boiling azeotrope.

COLLIGATIVE

- Depend on number of particles.
- $\Delta T_b = iK_b m$, $\Delta T_f = iK_f m$, $\pi = iCRT$.
- π best for polymers/proteins.

VAN'T HOFF

- $i > 1$ dissociation, $i < 1$ association.
- 0.9% NaCl isotonic with blood.
- RO = desalination.

Have a doubt? Ask the AI Doubt Solver at padhaiadda.netlify.app, or take the mock test on this chapter.