Colligative Properties

Van 't Hoff factor, freezing/boiling shifts, Raoult's law, osmotic pressure, and molar-mass back-calculation.

01 Van 't Hoff factor i — REFERENCE

Solute	i (predicted)
nonelectrolyte (glucose, urea)	1
NaCl, HCl, KBr	2
$CaCl_2$, Na_2SO_4	3
$AlCl_3$, Na_3PO_4	4
$Al_2(SO_4)_3$	5

i = particles per formula unit on full dissociation. Use the predicted (integer) i for forward calculations; measured i runs a bit lower at real concentrations (ion pairing).

02 Strong-electrolyte dissociation — CORE RULE

Each ion's concentration = compound concentration × its coefficient. Total dissolved particles = i × compound concentration. $CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$ gives total = 3 × [$CaCl_2$].

03 Freezing-point depression — CORE RULE

$\Delta T_f = K_f \cdot m \cdot i$ (m = molality). New FP = pure FP − ΔT_f. For water (FP 0 °C) the depressed FP = $-\Delta T_f$. Kf is solvent-specific (supplied).

04 Boiling-point elevation — CORE RULE

$\Delta T_b = K_b \cdot m \cdot i$. New BP = pure BP + ΔT_b. For water (BP 100 °C) the elevated BP = 100 + ΔT_b. Kb is solvent-specific (supplied).

05 Common constants (°C·kg/mol) — REFERENCE

Solvent	Kf	Kb
water	1.86	0.512
benzene	5.12	2.53
chloroform	4.68	3.63
camphor	37.7	n/a

06 Raoult's law (vapor pressure) — CORE RULE

Nonvolatile solute: $\Delta P = X_{solute} \cdot P^\circ_{solvent}$, or $P_{solution} = X_{solvent} \cdot P^\circ_{solvent}$. Use particle-based mole fraction ($i \times n_{solute}$) for electrolytes. Two volatile components: $P_{total} = X_A \cdot P^\circ_A + X_B \cdot P^\circ_B$.

07 Osmotic pressure — CORE RULE

$\pi = i \cdot M \cdot R \cdot T$ with MOLARITY (not molality), R = 0.0821 L·atm/(mol·K), T in K; π in atm. Given in molality/mass? You need density to convert to molarity.

08 Kelvin vs °C — WATCH OUT

Osmotic pressure needs T in Kelvin. But ΔT_f and ΔT_b are the same magnitude in °C or K, so apply K constants directly. Report final FP/BP in °C.

09 Molar mass from ΔT — METHOD

$n_{solute} = \Delta T / (K \cdot kg_{solvent} \cdot i)$, K = Kf or Kb, i = 1 for a nonelectrolyte (the usual MW case). Then MW = $mass_{solute} / n_{solute}$.

10 Molar mass from osmotic pressure — METHOD

$n_{solute} = \pi \cdot V / (R \cdot T \cdot i)$, i = 1 for biomolecules (lysozyme, hemoglobin). Then MW = $mass_{solute} / n_{solute}$. π is often tiny, so convert torr/mmHg to atm first.

11 Molecular formula protocol — METHOD

Back-calc MW from ΔT or π; get the empirical formula from % composition; n = MW / empirical-formula mass (round to an integer); molecular formula = empirical × n. Single-element (S_n): n = MW / atomic mass.