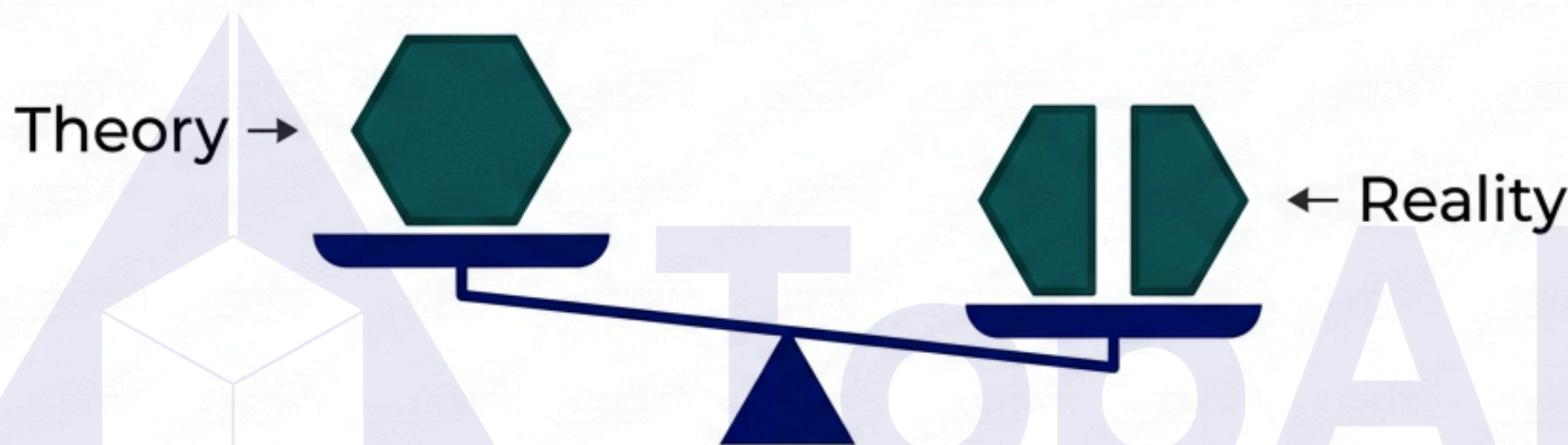


Abnormal Molar Masses



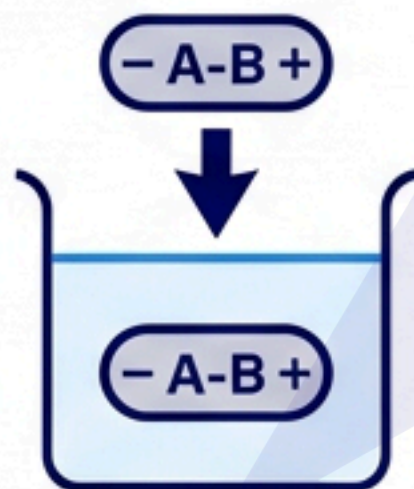
The Colligative Anomaly

Why the experimentally determined molar mass of a solute sometimes defies the chemical formula—and how to correct it.

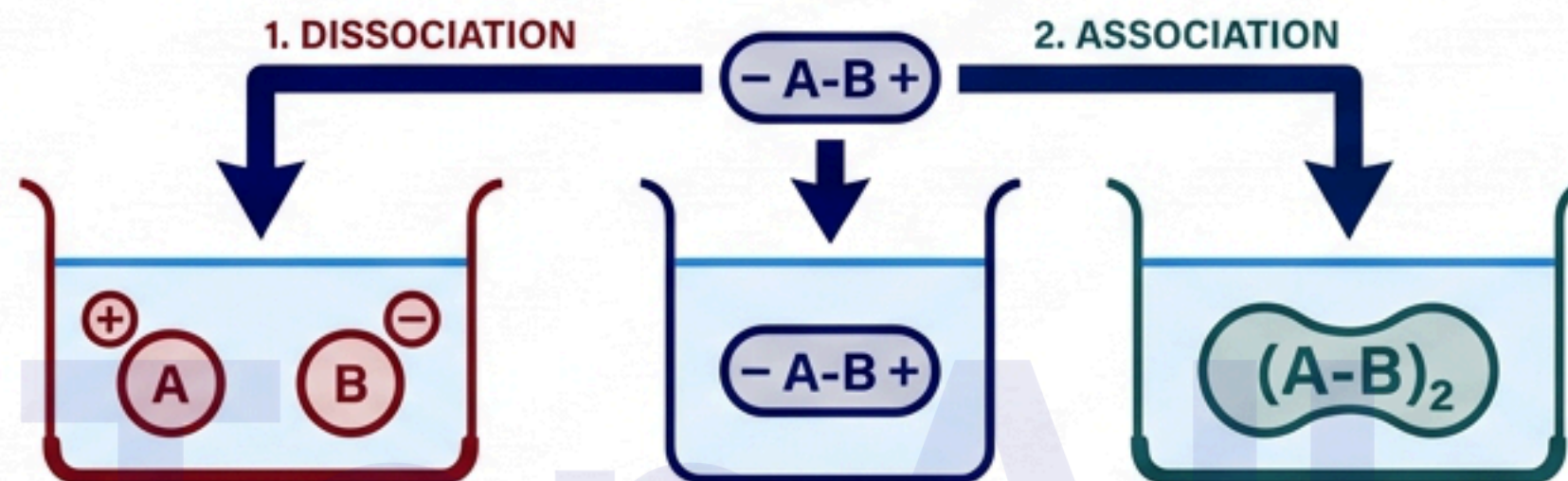
A conceptual guide to dissociation, association, and the van't Hoff factor.

Why Observed Molar Mass Can Be Wrong

The Assumption



The Reality



Colligative Properties $\propto$ Number of Particles $\propto 1 / \text{Molar Mass}$

The Rule

Colligative properties count the total number of discrete particles, completely ignoring their chemical identity.

The Anomaly

If solute particles split or merge in solution, the actual number of particles diverges from the expected moles. Because colligative properties are inversely proportional to molar mass, this causes the calculated molar mass to appear abnormal.

If particle count changes, the apparent molar mass shifts.



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$$E=mc^2$$



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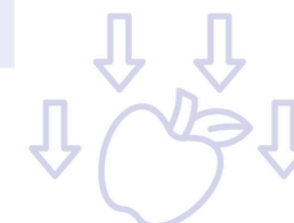
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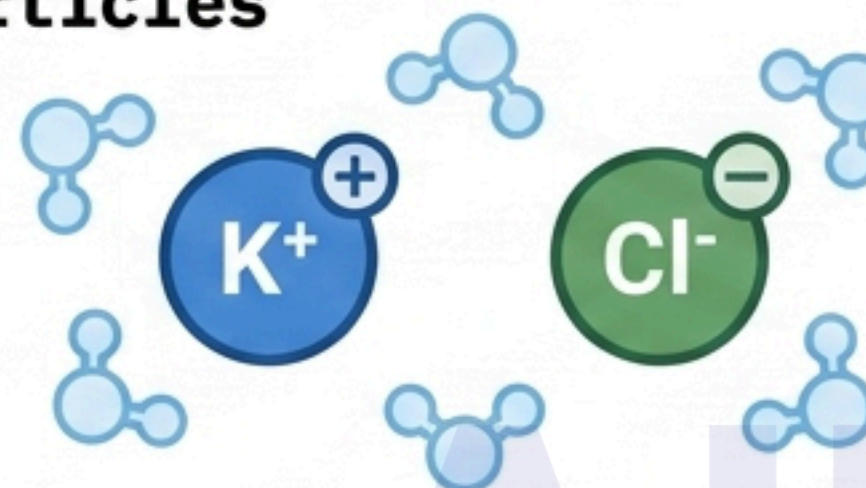
Dissociation and Increased Particle Count



1 Formula Unit $\rightarrow$ 2 Particles



1 mole



The Mechanism

Ionic compounds (like KCl or NaCl) separate into their constituent cations and anions in aqueous solutions.

The Result

The total number of particles increases. Therefore, the colligative effect (e.g., boiling point elevation) is multiplied.

Example: KCl in H₂O

Expected Boiling Point Elevation: 0.52 K

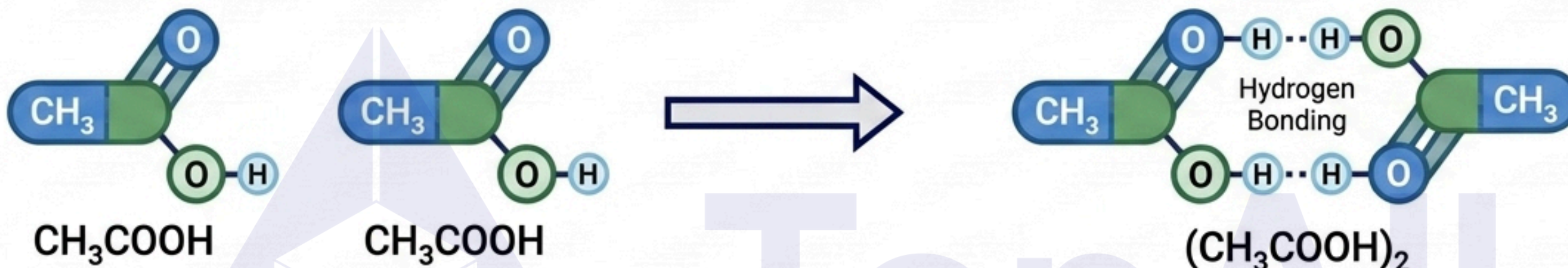
Observed Boiling Point Elevation: 1.04 K (Double)

True Molar Mass: 74.5 g/mol $\rightarrow$ Calculated Molar Mass: 37.25 g/mol

Rule of Dissociation: Particles Multiply $\rightarrow$ Calculated Molar Mass is LOWER than true value.

Association and Reduced Particle Count

2 Molecules $\rightarrow$ 1 Dimer Particle



The Mechanism

In solvents with low dielectric constants (like benzene), molecules may associate together via hydrogen bonding.

The Result

The total number of particles decreases. Therefore, the magnitude of the colligative effect is drastically reduced.

Example: Ethanoic Acid in Benzene

Reaction: $2 \text{CH}_3\text{COOH} \rightleftharpoons (\text{CH}_3\text{COOH})_2$

Calculated Molar Mass = TWICE the expected value

Rule of Association: Particles Merge $\rightarrow$ Calculated Molar Mass is HIGHER than true value.

The van't Hoff Factor (i)

i

$$i = \frac{\text{Normal Molar Mass}}{\text{Abnormal Molar Mass}}$$

$$i = \frac{\text{Observed Colligative Property}}{\text{Calculated Colligative Property}}$$

$$i = \frac{\text{Total Moles of Particles After}}{\text{Moles of Particles Before}}$$

Dissociation ($i > 1$)

Example: KCl ($i \approx 2$), K_2SO_4 ($i \approx 3$).

Association ($i < 1$)

Example: Ethanoic acid in benzene ($i \approx 0.5$).

Normal ($i = 1$)

No association or dissociation (e.g., glucose in water).

Modified Colligative Equations

$$\Delta T_b = i K_b m$$

$$\Delta T_f = i K_f m$$

$$\Pi = i \left(\frac{n_2}{V} \right) R T$$

$$\frac{p_1^0 - p_1}{p_1^0} = i x_2$$

The factor i mathematically corrects the formulas to match the physical particle count.

Final Recap: Colligative Properties Count Particles, Not Formula Units

	Normal Solution	Dissociation	Association
Behavior	Stays intact	Splits into ions	Merges (e.g., dimers)
Particle Count	Same as moles	Increases	Decreases
van't Hoff i	$i = 1$	$i > 1$	$i < 1$
Calculated Mass	Normal	Lower than normal	Higher than normal

All colligative properties—vapor pressure lowering, boiling point elevation, freezing point depression, and osmotic pressure—share one universal truth: they are blind to chemistry, and only see particle quantity.

Exam Rule: Always check for dissociation or association before calculating molar mass.



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