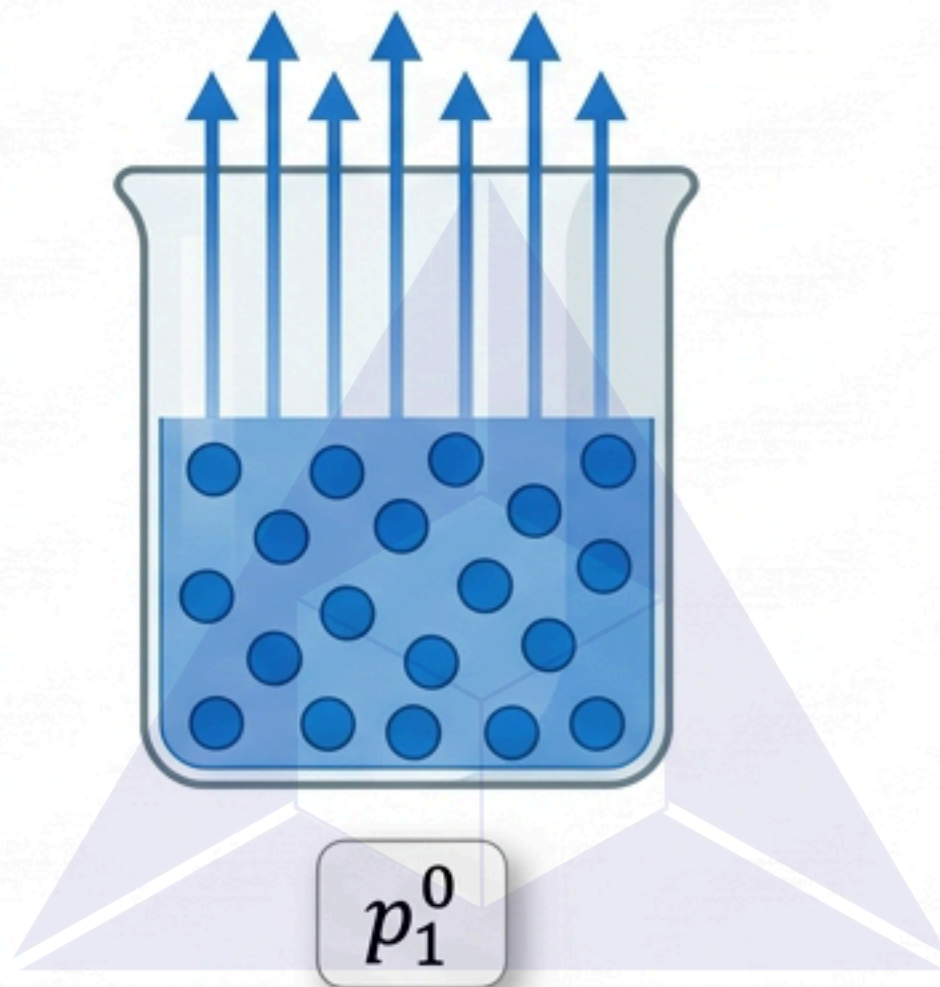


1.6.1 Relative Lowering of Vapour Pressure

A step-by-step mathematical derivation mapping macroscopic pressure changes to microscopic particle fractions.

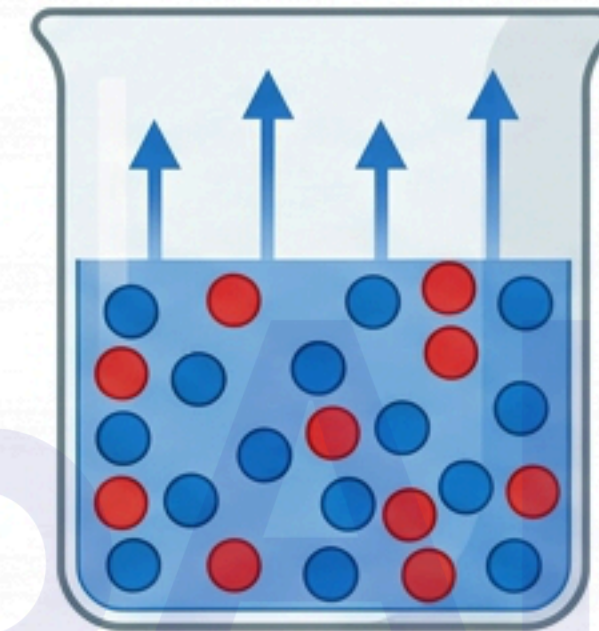
$$\frac{(p_1^0 - p_1)}{p_1^0} = \frac{w_2 M_1}{M_2 w_1}$$

The Physical Phenomenon: Vapour Pressure Drop



Vapour pressure of pure solvent

100% surface area available for evaporation. High escaping tendency.



Vapour pressure of solution

Surface area blocked by non-volatile solute. Reduced escaping tendency.

The addition of a non-volatile solute always lowers the vapour pressure: $p_1 < p_1^0$

Defining the Relative Lowering



Absolute Lowering

The raw decrease in vapour pressure.

$$\Delta p_1 = p_1^0 - p_1$$

Relative Lowering

The absolute decrease expressed as a fraction of the pure solvent's original pressure.

$$\frac{\Delta p_1}{p_1^0}$$

$$\frac{p_1^0 - p_1}{p_1^0}$$

Variable Legend

p_1^0

Vapour pressure of pure solvent

p_1

Vapour pressure of solution

Δp_1

Change in vapour pressure



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The Derivation Bridge

Step 1: Raoult's Law

$$p_1 = x_1 p_1^0$$

Vapour pressure is proportional to solvent mole fraction.

Step 2: Substitution

$$\Delta p_1 = p_1^0 - x_1 p_1^0$$

Substitute p_1 into the lowering equation.

Step 3: Factoring

$$\Delta p_1 = p_1^0 (1 - x_1)$$

Factor out the pure solvent pressure.

Step 4: The Identity

$$x_2 = 1 - x_1$$

Mole fractions must sum to 1. x_2 is the solute.

Step 5: The Final Ratio

$$\frac{\Delta p_1}{p_1^0} = x_2$$

The relative lowering of vapour pressure is exactly equal to the **mole fraction** of the solute.

The Dilute Solution Approximation

The Scale Metaphor



$$n_2 \ll n_1$$

For highly dilute solutions, the solute quantity is so small it can be ignored in the denominator.

The Transformation Strip

$$x_2 = \frac{n_2}{n_1 + n_2}$$

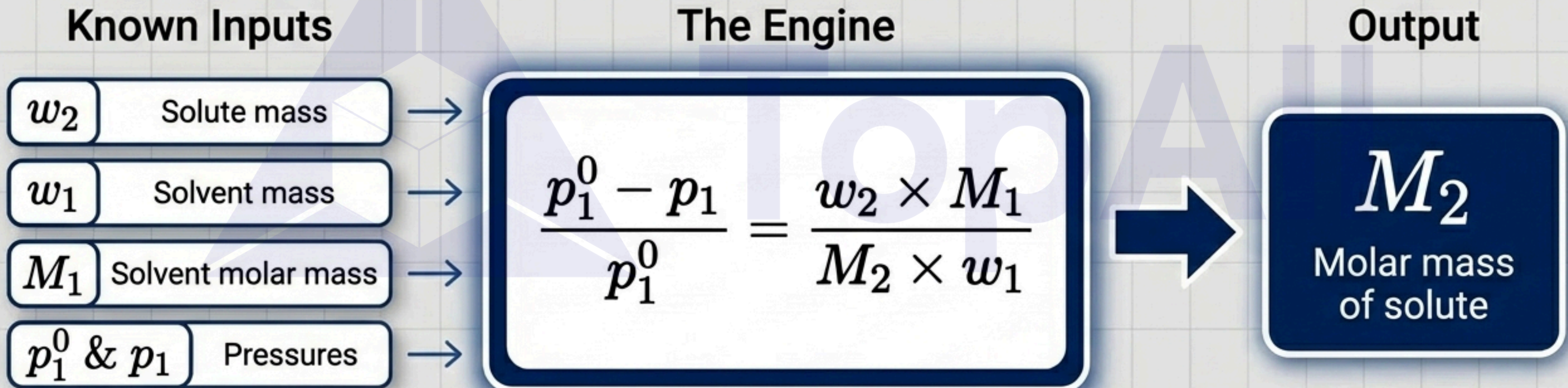
$$x_2 = \frac{n_2}{\cancel{n_1} + \cancel{n_2}}$$

$$x_2 \approx \frac{n_2}{n_1}$$

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{n_2}{n_1}$$

Application: Molar Mass Determination

$$\text{Moles} = \frac{\text{Mass}}{\text{Molar Mass}} \quad n = \frac{w}{M} \rightarrow \frac{n_2}{n_1} = \frac{w_2/M_2}{w_1/M_1}$$



By measuring the pressure drop of a known mass, we can pinpoint the exact **molar mass** of an unknown solute.

Final Recap: Macroscopic meets Microscopic

The Macroscopic

$$\frac{p_1^0 - p_1}{p_1^0}$$

The relative change in vapour pressure.

=

The Microscopic

$$x_2 \left(\frac{n_2}{n_1} \right)$$

The fraction of solute particles in the mixture.

Colligative properties depend strictly on the ratio of particles, not their chemical identity.
A 10% relative drop in pressure guarantees the solute makes up 10% of the particles.



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