Solutions and Solubility: Why Things Dissolve

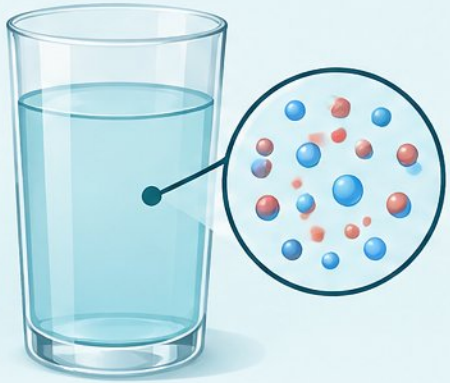
- Goal: explain dissolution with clear particle-level reasoning
- Connect macroscopic observations, submicroscopic models, and symbolic equations
- Guiding questions: What is a solution? What controls solubility?
- Why do some substances dissolve while others do not?
- Roadmap: forces, energy and entropy, rules, temperature and pressure
- Applications for students, adult learners, and teachers



What Counts as a Solution?

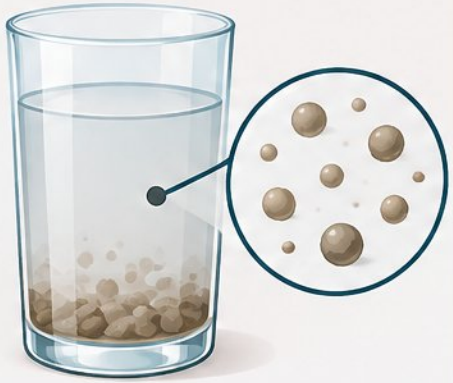
- A solution is a homogeneous mixture; solute particles are dispersed in a solvent.
- Solutions stay mixed, colloids scatter light, and suspensions settle on standing.
- Key terms: solvent, solute, concentration, dilute, concentrated, saturated, unsaturated, supersaturated.
- Examples across phases: salt water, carbonated drinks, brass alloy, and air.
- Saturation marks the solubility limit: the maximum concentration achievable under given conditions.

Solution



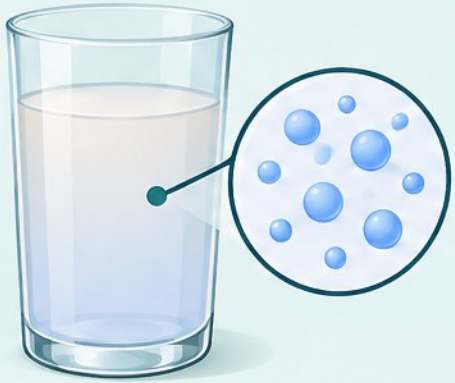
Homogeneous mixture with evenly dispersed particles

Suspension



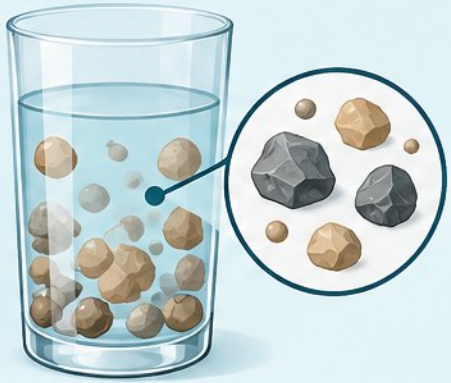
Particles settle on standing

Colloid



Particles scatter light

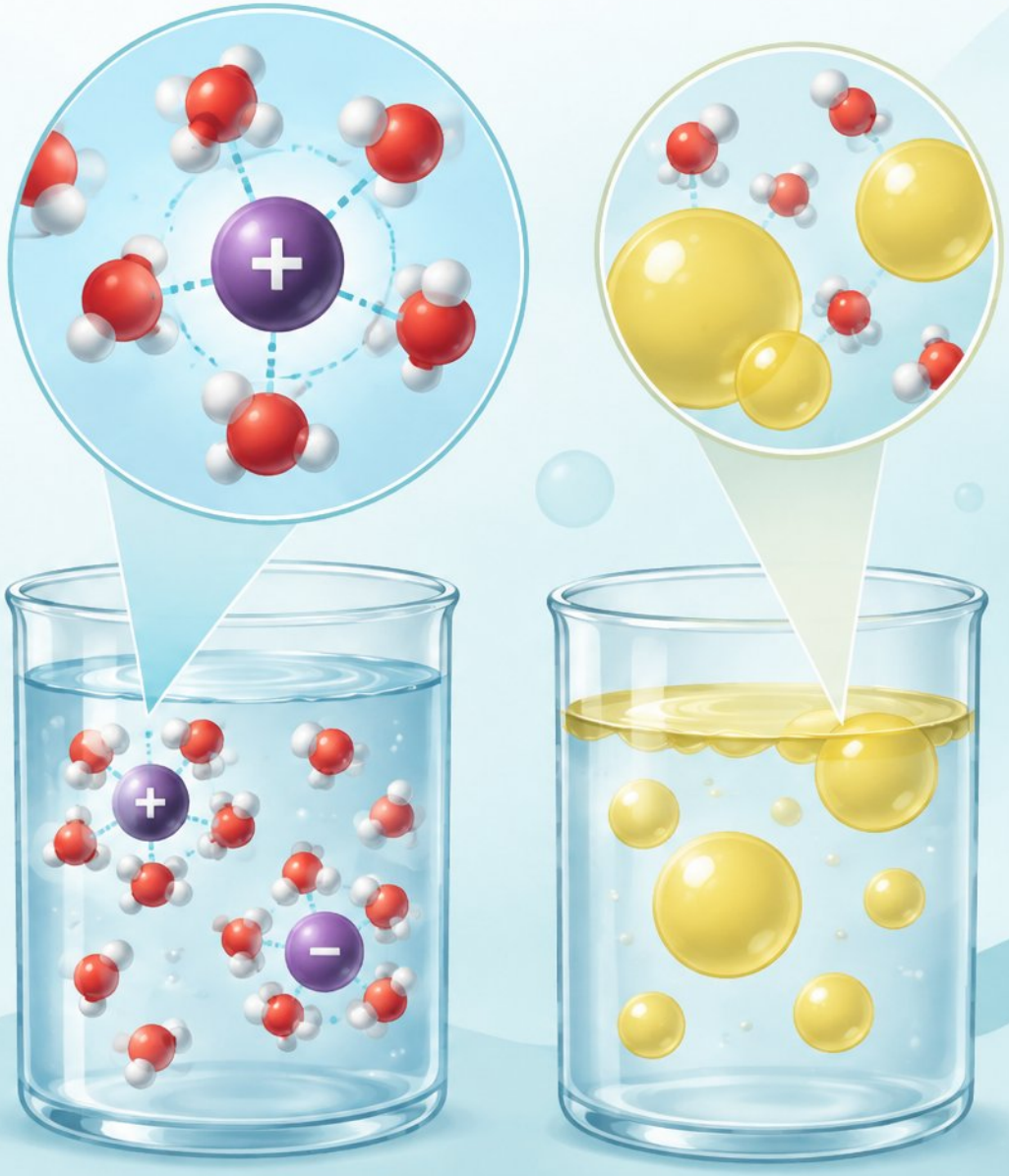
Mechanical Mixture



Non-uniform mixture with visibly different components

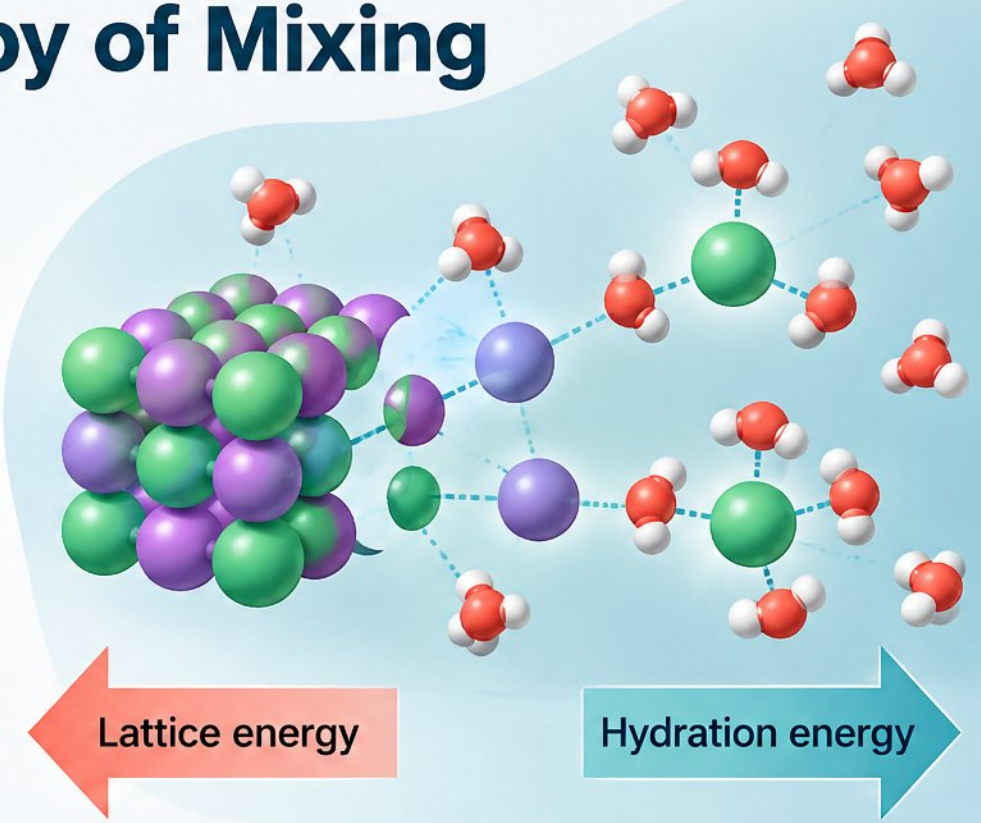
Like Dissolves Like: Intermolecular Forces at Work

- Polar solutes favor polar solvents; hydrogen bonding drives miscibility
- Ion–dipole interactions stabilize ions; water's high dielectric constant weakens attractions
- Nonpolar substances dissolve in nonpolar solvents via dispersion forces
- Heuristic limits: ethanol–water miscibility and detergent amphiphiles bridging water and grease
- 'Like dissolves like' is a starting point, not a law



The Energy and Entropy of Mixing

- Dissolution balance three interactions: solute-solute, solvent-solvent, and solute-solvent
- Ionic solids: lattice energy versus hydration energy; net enthalpy can be positive, negative, or near zero
- $\Delta G = \Delta H - T\Delta S$; positive entropy from dispersing particles can drive endothermic dissolution
- Ammonium nitrate cold packs: endothermic, entropy-driven
- Sodium hydroxide dissolving: exothermic



Ammonium nitrate cold packs: endothermic, entropy-driven



Sodium hydroxide dissolving: exothermic

Why Solubility Rules Work—and Where They Fail

Identify the ions

Group 1 cation or ammonium?

Yes → Soluble

No → Nitrate, acetate or chlorate?

Yes → Soluble

No → Special exceptions for halides or sulfates?

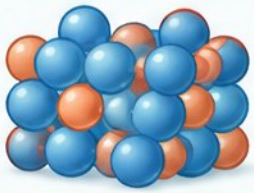
Ag^+, Pb^{2+}, Hg_2^{2+} (Ba^{2+}, Sr^{2+}, Ca^{2+}) → Precipitate

No → Hydroxide or carbonate?

Soluble with group 1 or ammonium → Otherwise insoluble

- Soluble: group 1 cations, ammonium, nitrates, acetates, chlorates
- Most halides soluble; exceptions with Ag^+, Pb^{2+}, Hg_2^{2+}
- Sulfates soluble except Ba^{2+}, Sr^{2+}, Ca^{2+}, Pb^{2+}, Ag^+
- Hydroxides and carbonates insoluble except with group 1 or ammonium
- Rules are heuristics from lattice and hydration energies; check net ionic equations

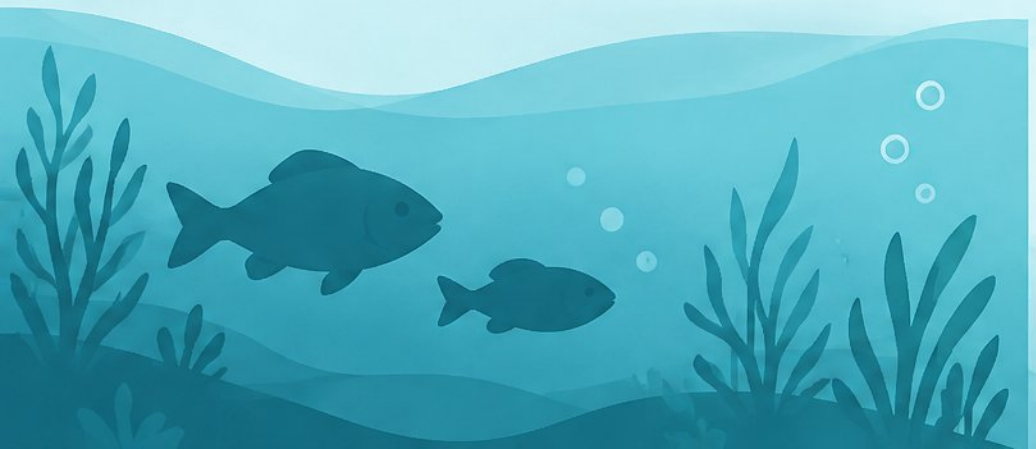


Macroscopic	Submicroscopic	Symbolic
		$M_aX_b\ (aq) \rightleftarrows M_aX_b\ (s)$

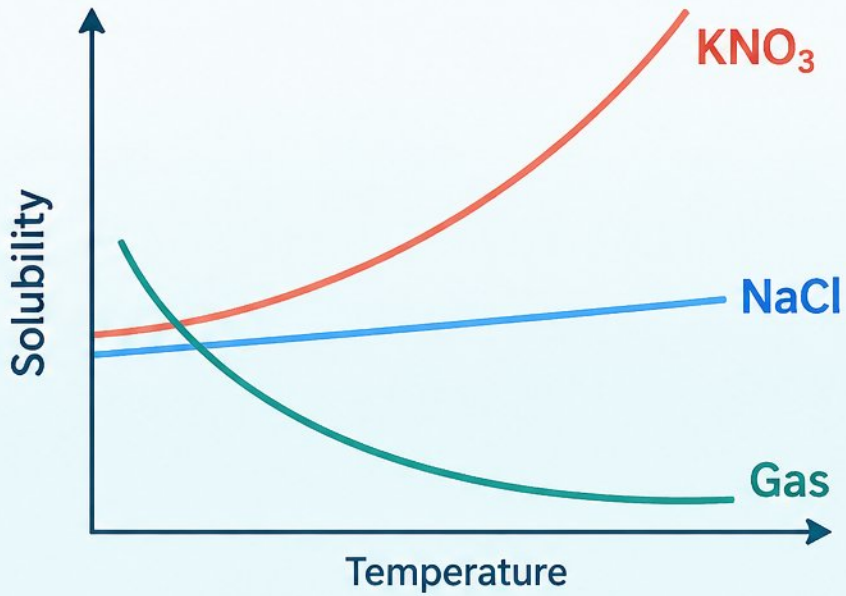
Three views. A deeper understanding.

Temperature and Pressure Effects on Solubility

- Most solids dissolve more as temperature rises; gases dissolve less.
- Exception: calcium hydroxide becomes less soluble when heated.
- Henry's law: C = kP — gas solubility is proportional to partial pressure.
- Opening a carbonated drink lowers CO_2 pressure, so it goes flat.
- Warm water holds less dissolved oxygen, harming fish (thermal pollution).



Solubility vs. Temperature



Henry's Law

$C = kP$



Carbonated Drink



Rate of Dissolution vs. Amount That Dissolves

Rate: how fast solute enters solution; **solubility:** equilibrium amount that stays dissolved

Surface area: crushing or powdering speeds dissolution by increasing solvent contact

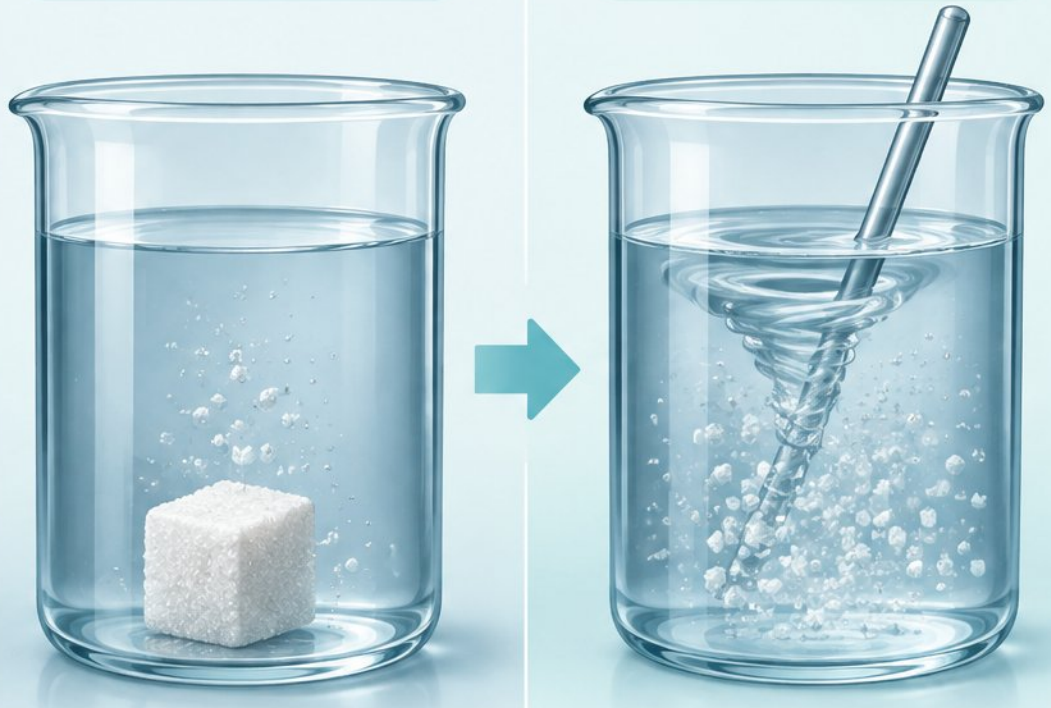
Stirring reduces diffusion-layer thickness and speeds dissolution, but final solubility unchanged

Higher temperature increases molecular motion and typically speeds dissolution

Concentration gradient and proximity to saturation limit the rate

Whole cube (dissolves slowly)

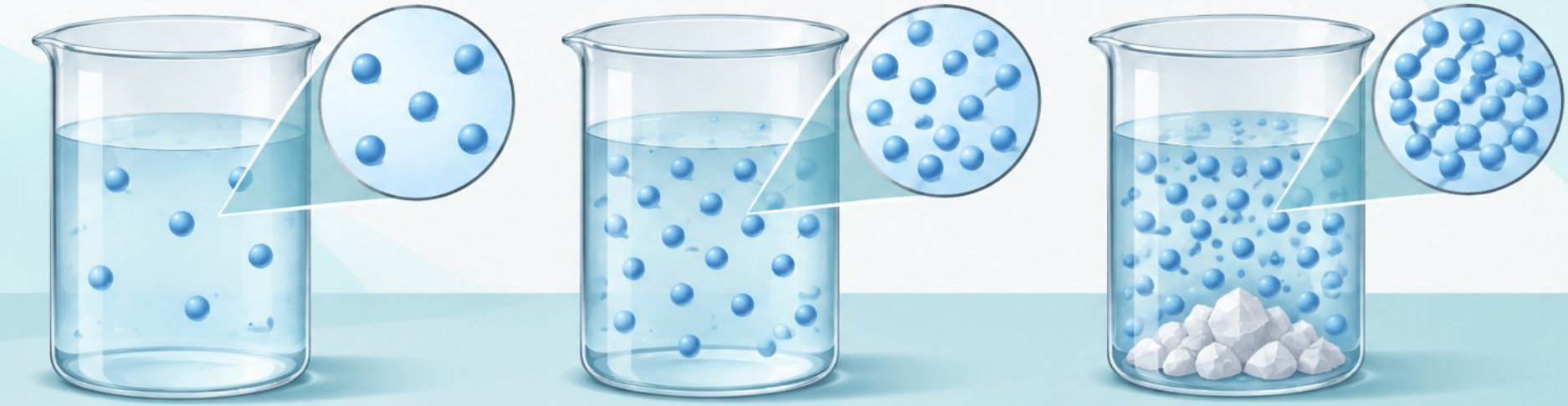
Crushed and stirred (dissolves quickly)



Same final concentration (after settling)

Concentration, Saturation, and Supersaturation

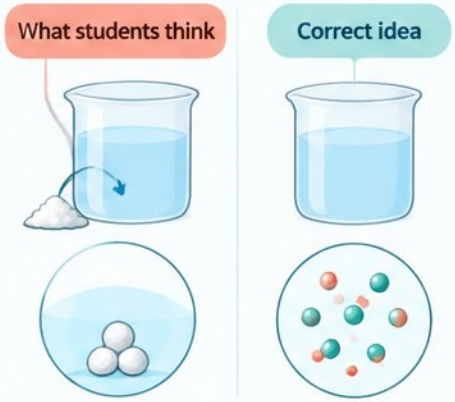
- Molarity, mass percent, and ppm express concentration
- Unsaturated, saturated, and supersaturated differ by solute relative to the solubility limit
- Saturation is dynamic equilibrium: dissolution and crystallization occur equally
- Misconception: supersaturated means excess solid is still present
- Use solubility data to predict whether added solute dissolves



Common Misconceptions and Classroom Checks

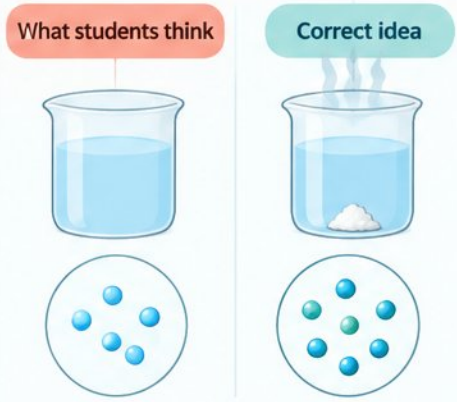
Clearer ideas. Stronger reasoning. Deeper understanding.

Dissolved solute does not disappear; track mass and draw particle diagrams



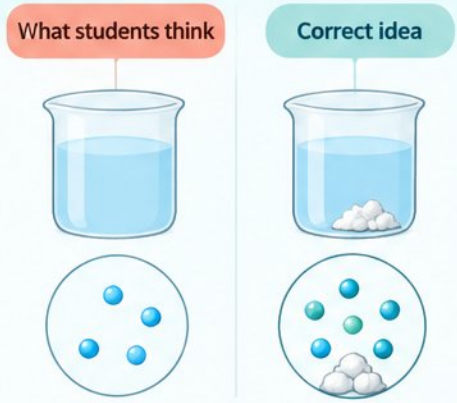
Where did the solute go, and what happens to the mass?

Clear liquids are not always pure: evaporate or boil to test



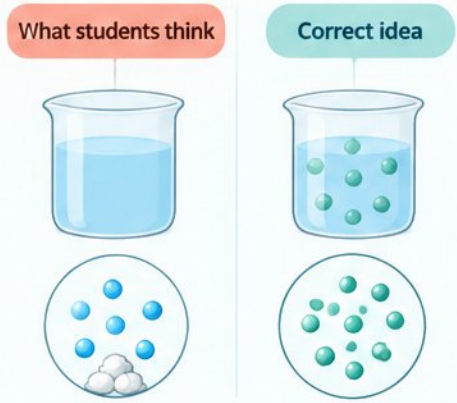
If a liquid looks clear, how can you test whether it is pure?

Solubility rules are heuristics, not laws; recall exceptions and temperature effects



Does this compound always dissolve? What factors could change the result?

Supersaturated solutions contain excess dissolved solute, not undissolved solid

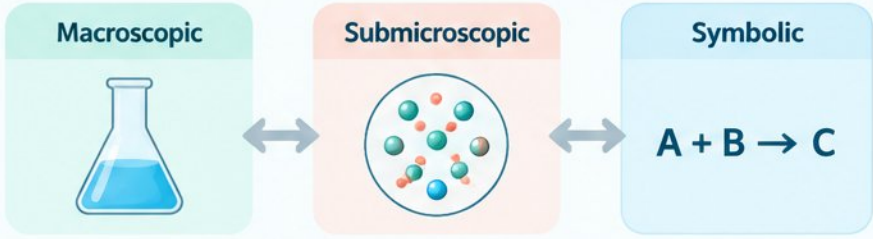


How can a solution contain more dissolved solute than expected?

Formative checks: predict–observe–explain, particle diagrams, net ionic equations



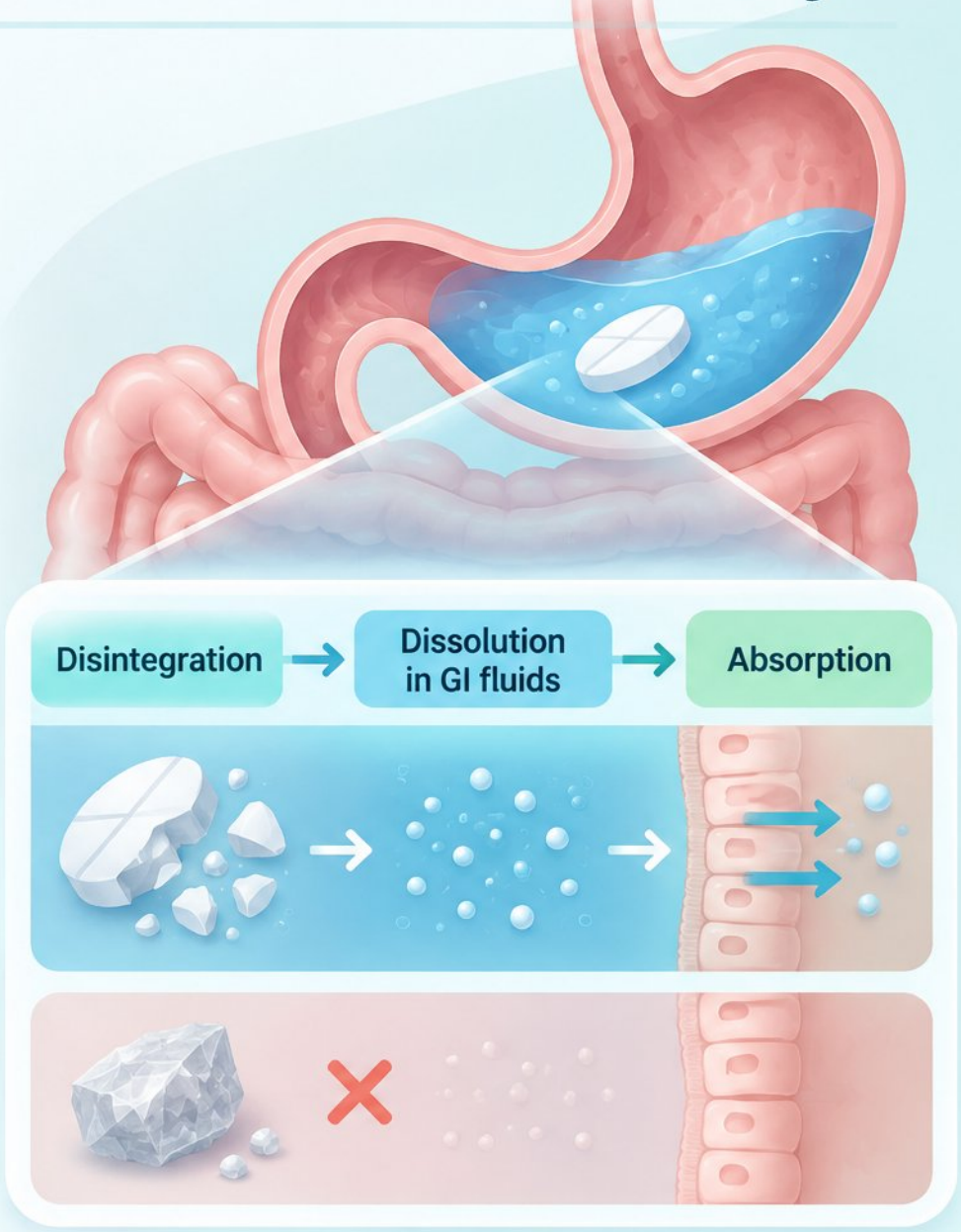
Connect the three levels of representation



Same phenomena. Different lenses. A fuller picture.

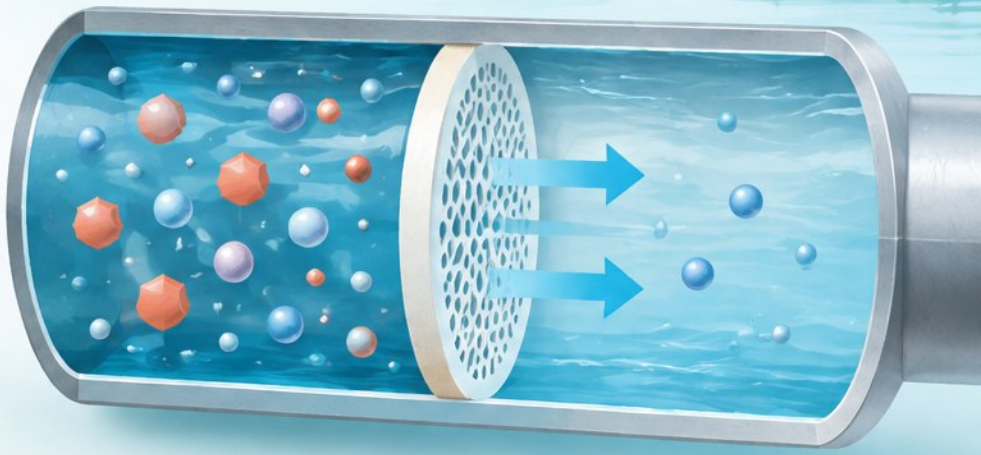
Pharmaceutical Dissolution and Bioavailability

- Up to 40% of approved drugs and 90% of candidates are poorly water-soluble
- Dissolution in GI fluids is the first step before absorption
- Low solubility limits permeability and lowers bioavailability
- Strategies: size reduction, salt forms, co-solvents, solid dispersions, cyclodextrins, lipid carriers
- Poorly soluble candidates may fail or need higher doses without engineered dissolution



Water Treatment, Environmental Solubility, and Scale

- Suspended matter is filtered out; dissolved substances need lime softening, ion exchange, reverse osmosis, or adsorption
- Highly soluble sodium and potassium salts resist precipitation; removal needs membranes or distillation
- Heating pipes and heaters precipitates sparingly soluble calcium carbonate and calcium sulfate as scale
- Warmer water holds less dissolved oxygen; Henry's law predicts risks to aquatic life





Food, Beverage, and Everyday Solubility

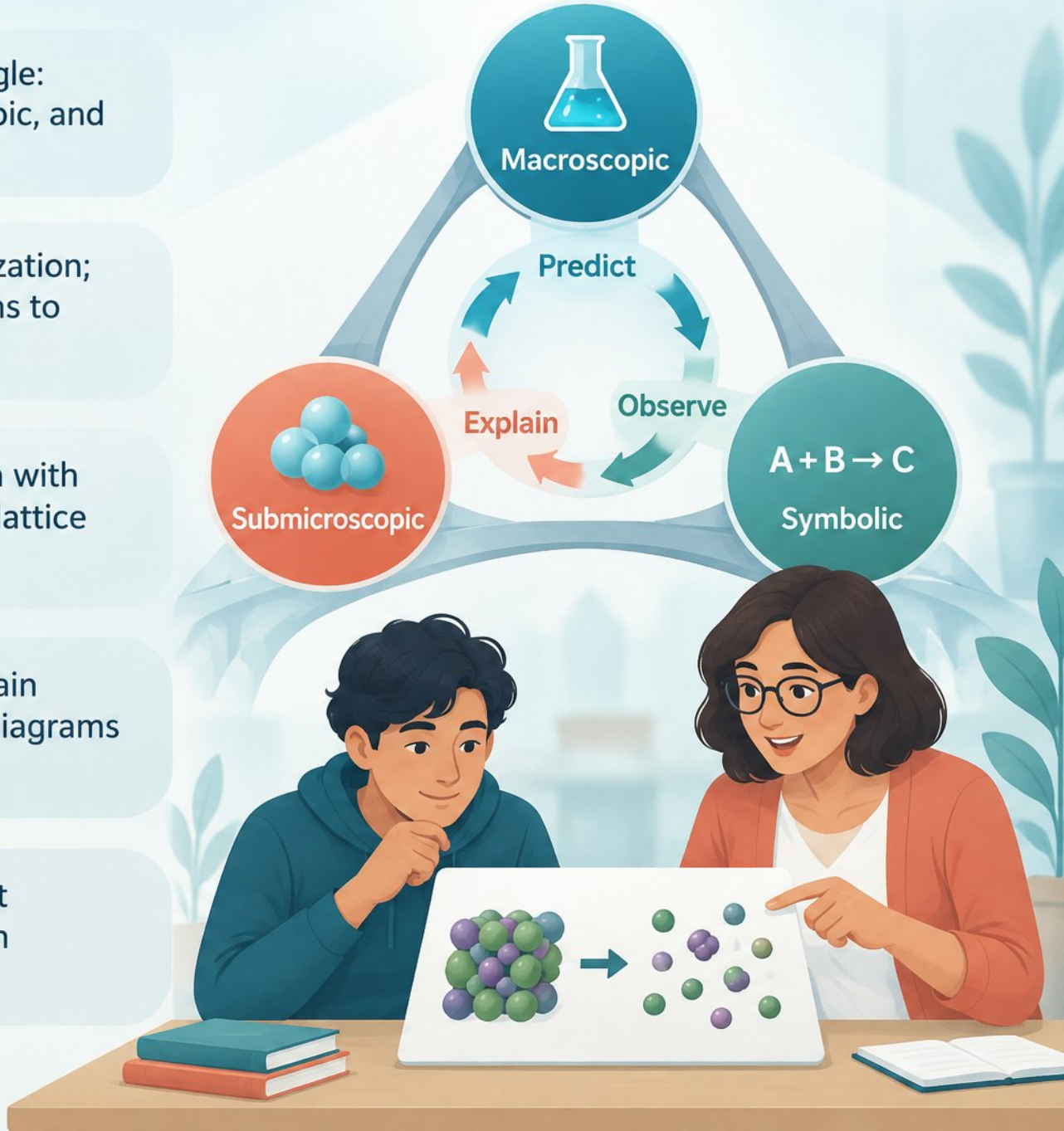
- Carbonated drinks: bottled under high CO_2 pressure; opening lowers pressure, gas escapes (Henry's law)
- Cooking and formulation depend on sugar/salt dissolution and flavor extraction
- Emulsifiers and detergents: amphiphiles bridge polar water and nonpolar grease
- Everyday demos: sugar cube vs. granulated sugar; stirring vs. no stirring
- Connect rate vs. amount to observable kitchen and lab outcomes





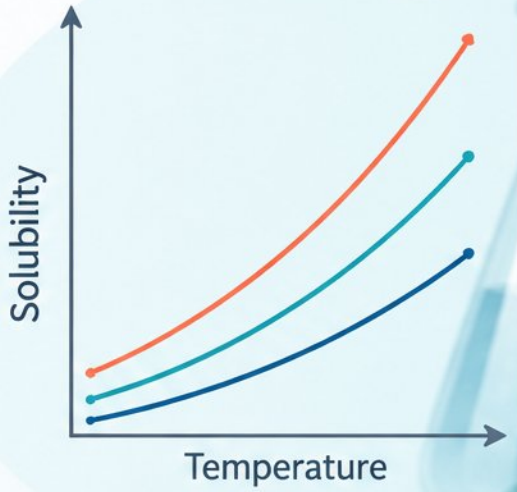
Teaching Sequence: Building Conceptual Understanding

- Integrate Johnstone's triangle: macroscopic, submicroscopic, and symbolic levels.
- Clarify dissociation vs. ionization; connect balanced equations to particle processes.
- Replace rule memorization with reasoning about charges, lattice energy, and hydration.
- Use predict–observe–explain cycles and static particle diagrams before animations.
- Scaffold for students, adult learners, and teachers with targeted supports.

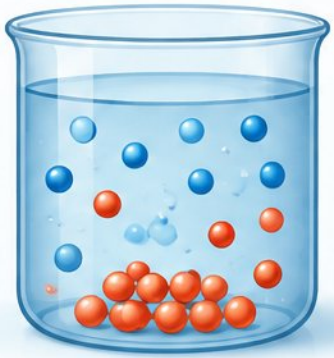


Wrap-Up: Key Ideas and Next Steps

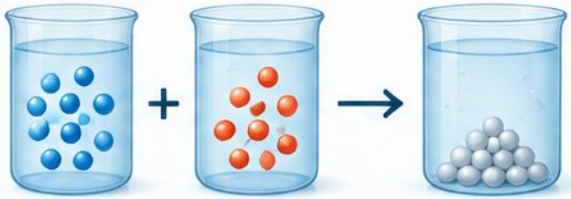
- Solutions are homogeneous mixtures at the particle level
- Dissolution balances solute–solvent interactions and entropy
- Solubility depends on solute–solvent nature, temperature, and pressure
- Distinguish how much dissolves (solubility) from how fast (rate)
- Check: draw a saturated solution; predict a precipitate; explain flat soda
- Next: solubility-curve lab, pharma or water-treatment case study



1. Draw a saturated solution



2. Predict a precipitate



3. Explain flat soda



Next: solubility-curve lab, pharma or water-treatment case study

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