ExamFitter

examfitter.com · Free AP Chemistry quizzes, revision notes and worksheets

Topic 3.3: Solids, Liquids, and Gases

Revision Notes · AP Chemistry

UNIT 3 · PROPERTIES OF SUBSTANCES AND MIXTURES

On ExamFitter.com: Topic 3.3 Quiz · Topic 3.3 Worksheet · Unit 3: All Topics · AP Chemistry Home

One Competition Runs All Three Phases

Every phase is the score of a single contest. Kinetic energy pulls particles apart and keeps them moving; intermolecular forces pull them together and hold them close. Temperature sets the average kinetic energy; the forces were priced in Topic 3.1.

When the forces win clearly, particles lock into fixed positions: a solid. When the two are closely matched, particles stay in contact but slip past each other: a liquid. When kinetic energy wins, particles separate and move independently: a gas.

Changing temperature or pressure changes the score, not the substance: ice, liquid water and steam are all H_2O, differing only in arrangement, spacing and motion. Since temperature measures average kinetic energy per particle, solid iron, liquid mercury and gaseous neon at 298 K share the same average, whatever their phases.

Solids and Liquids: Packed Tight, Moving Differently

In both condensed phases the particles are in contact, which is why their densities are similar and both shrug off ordinary compression: almost no empty space to squeeze out.

A solid's particles hold fixed positions and only vibrate about them: hence its definite shape and definite volume.

A liquid's particles stay in contact but translate, sliding and tumbling past one another. Attractions keep them close, so the volume stays definite, but nothing fixes their arrangement, so the liquid flows and takes its container's shape. That sliding motion is what makes liquids and gases fluids. Heat either phase and the motion grows more vigorous, vibrations widening, collisions hardening, and both expand slightly; the particles themselves never grow.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Gases: Mostly Empty Space

A gas particle travels in straight lines between collisions, far from its neighbours. Attractions barely steer it at ordinary densities, so the gas expands to fill any container, with neither definite shape nor definite volume.

Compression squeezes the gaps, not the particles, so gases compress easily. Diffusion is fast because the paths between collisions are long. Density runs about a thousand times below the matching liquid: the same particles, spread through a vastly larger volume. Gas pressure is the drumbeat of particles striking the walls: more collisions, or harder ones, mean more pressure.

Changing Phase: Rearranging Particles, Not Rebuilding Them

Six changes connect the phases. Melting, vaporization and sublimation absorb energy; freezing, condensation and deposition release it. Separating particles against their attractions costs energy; letting them fall back together pays it out. Each change is a rearrangement: no phase change breaks a covalent bond or alters a single molecule.

At constant pressure a pure substance changes phase at one fixed temperature. Supplied energy rearranges the particles instead of raising their average kinetic energy, so melting ice sits at 0 °C until the last crystal has gone.

The spacing jump is lopsided: melting barely separates particles, while vaporization multiplies the volume roughly a thousandfold, which is why a small pan of water makes so much steam.

Vapour Pressure: A Liquid Pushes Back

The fastest surface particles of a liquid can escape into the space above it. Sealed in, the escaped particles build a pressure of their own, the vapour pressure, settling where escape and return balance: particles leaving and rejoining at equal rates.

Weak forces let particles escape easily, so vapour pressure reads the force ranking backwards. At 25 °C: diethyl ether 537 torr, acetone 230 torr, water 23.8 torr; water's hydrogen bond network holds its molecules back hardest. Heat raises vapour pressure steeply, putting far more particles within reach of escape energy.

Boiling is that meeting point: bubbles survive inside the liquid only when vapour pressure equals external pressure. Cut the external pressure and boiling comes earlier: at 380 torr, about half an atmosphere, water boils at about 82 °C; a pressure cooker near 2 atm holds water liquid to about 120 °C.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Surface Tension, Cohesion and Adhesion

A particle inside a liquid is pulled equally in every direction; a surface particle has no neighbours above it, so it is pulled inward and sideways only. Creating new surface drags particles into that exposed position, which costs energy: surfaces shrink to the smallest area they can, and free droplets pull themselves round.

Cohesion is the liquid's attraction to itself; adhesion is its attraction to another material. Mercury's cohesion, its metallic bonding, dwarfs its adhesion to glass, so it beads into near spheres, with a surface tension of 465 mN/m, about 6.4 times water's 72.8 mN/m.

Water on glass plays the other way: adhesion rivals cohesion, so water spreads, climbs the wall as a meniscus, and rises in narrow tubes by capillary action.

Viscosity: How Hard a Liquid Resists Flow

Flowing means particles sliding past one another, and viscosity measures the resistance to that sliding. Attractions are the friction: every slide drags against them.

Glycerol shows the extreme. Each $C_3H_8O_3$ molecule carries three -OH groups and hydrogen bonds in every direction, so at 20 °C its viscosity is 1,412 mPa·s, about 1,400 times water's 1.00 mPa·s. Size and shape add a second friction: long, tangled molecules resist sliding too. Heat lowers viscosity: extra kinetic energy slips particles out of their neighbours' grip, so warm honey pours and cold honey barely moves.

Worked Examples

> **Example 1: Pricing the empty space. One mole of liquid water fills about 18 cm^3; as a gas at STP it fills 22,400 cm^3, a ratio of 22,400 ÷ 18 ≈ 1,244. Volume per molecule grows by that factor, so spacing grows by its cube root, about 10.8: in steam each molecule sits roughly 11 molecular diameters from its neighbours, against touching in the liquid. Density tells the same story: 18.015 g over 22,400 cm^3 is 8.0×10^{-4} g/cm^3. The molecule never changed size; only the emptiness arrived.**

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Example 2: Reading a vapour pressure table. At 25 °C the vapour pressures run ether 537, acetone 230, ethanol 59, water 23.8 torr. Ether's is 537 ÷ 23.8 ≈ 22.6 times water's, so its molecules escape far more readily: the weakest forces of the four. Boiling points confirm the ranking read backwards: ether 34.6 °C, acetone 56.1 °C, ethanol 78.4 °C, water 100 °C.

Example 3: Boiling on a mountain. Under 380 torr of external pressure, water boils once its vapour pressure reaches 380 torr, at about 82 °C. Nothing about the water changed; the air pressing on it got lighter, so boiling arrived 18 °C early.

Traps That Cost Marks in Topic 3.3

Saying the particles themselves expand on heating. A water molecule in steam is the same size as in ice. Heating raises kinetic energy and spacing; diagrams drawing bigger gas particles are wrong.

Saying boiling breaks molecules apart. Boiling overcomes forces between molecules; the molecules survive whole. Steam is H_2O, not hydrogen and oxygen.

Saying solid particles are motionless. They vibrate about fixed positions, more widely as they are heated; motionless would mean absolute zero.

Saying the temperature rises throughout a phase change. During melting or boiling at constant pressure it holds still: every joule goes into rearranging particles against their attractions.

Swapping cohesion and adhesion. Mercury beads because cohesion beats adhesion; water climbs glass because adhesion competes. Reverse the pair and every prediction built on it reverses too.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Key Relationships to Remember

- Phase is the outcome of one contest: kinetic energy (set by temperature) against intermolecular forces (set by the substance)
- Solids: fixed positions, vibration only; definite shape and volume. Liquids: in contact but translating; definite volume, no definite shape. Both resist compression
- Gases: particles widely separated, moving randomly; no definite shape or volume; expand to fill any container, compress easily, diffuse fast, about a thousand times less dense than the liquid
- Phase changes rearrange particles and never rebuild molecules; melting, vaporization and sublimation absorb energy, freezing, condensation and deposition release it; temperature stays constant during a change at constant pressure
- Vapour pressure rises with temperature and falls as forces strengthen (at 25 °C: ether 537, acetone 230, water 23.8 torr); boiling starts when vapour pressure equals external pressure (water at about 82 °C under 380 torr)
- Surface tension is the energy cost of new surface; cohesion against adhesion decides beading, spreading, meniscus shape and capillary rise (mercury 465 mN/m, water 72.8 mN/m)
- Viscosity is resistance to flow: it rises with force strength and with molecular size and tangle, and falls as temperature rises (glycerol about 1,400 times water at 20 °C)

Continue Revising

Topic 3.3 Quiz: Solids, Liquids, and Gases

Topic 3.3 Worksheet

Unit 3: All Topics

© 2026 ExamFitter.com · Free AP Chemistry revision notes