Science 7–8

Chapter 10 — Chemical sciences A: particles, properties and mixtures

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Contents

The particle and kinetic theories: arrangement, motion and attraction of particles, and what happens at a change of state

What we teach here — `VC2S8U05` (Victorian Curriculum F–10 Version 2.0, Science, Levels 7 and 8): *“the particle and kinetic theories of matter can be used to describe the arrangement and motion of particles in a substance, including the attraction between particles, and to explain the properties and behaviour of substances, including melting point, boiling point, density, compressibility, gas pressure, viscosity, diffusion, sublimation, and expansion and contraction”* **This subtopic owns the first clause only**: the particle and kinetic theories themselves — describing the arrangement and motion of particles in a substance, including the attraction between them — and what happens at a change of state. The second clause — using the model to explain the properties and behaviour of substances (melting point, boiling point, density, compressibility, gas pressure, viscosity, diffusion, sublimation, and expansion and contraction) — belongs to the partner subtopic **10B** († split delivery, D6). Here we *build* the model; 10B uses it. **In our words:** every substance is made of unbelievably tiny particles that are always moving and always pulling on each other. Heat a substance and its particles move faster; cool it and they slow down. And every change of state — melting, freezing, boiling, evaporating, condensation — is just particles speeding up, slowing down, breaking free of each other, or being pulled back together. **Achievement-standard extract served here (D13):** *“They use the particle and kinetic theories of matter to explain the structure, properties and behaviour of substances.”* This subtopic owns the code (†), so the standard is printed here in full: 10A serves the model and what it says about the structure and behaviour of substances, including at a change of state; 10B serves the properties half and cites this header by reference. **Elaborations drawn on:** `VC2S8U05.E01` (using and constructing virtual simulations such as claymation videos, models or diagrams to represent changes in particle arrangement and properties as substances change state), `VC2S8U05.E02` (comparing attractive forces in the solid, liquid and gaseous states of the same substance and relating this to relative position and movement of particles) and `VC2S8U05.E03` (examining how the changing motion and energy of particles are affected by the amount of heat energy absorbed or released). **Maths interlocks (D11):** ratios of lengths, areas and volumes (`VC2M7M06`) carry the scale model in the “how small is a particle?” figure; adding and subtracting integers (`VC2M7N08`) carries the sub-zero temperature change in Worked example 2. Graphs stay qualitative (D11): the heating curve here is read for its shape, never its slope. **Authored from the CD text and the elaboration contexts (D12):** the CD names what the theories describe — the arrangement and motion of particles and the attraction between them — but not the words of the model itself; the model taught here is the standard particle-and-kinetic account (strong attraction locking a solid’s particles in place, weaker attraction letting a liquid’s particles slip, very weak attraction letting a gas’s particles fly free), and the three elaborations above supply the modelling, comparing and energy contexts.

Word watch — *theory*. In everyday talk, a *theory* is a guess. In science, a **theory** is something much stronger: a big, well-tested explanation that ties lots of observations together and has survived many checks. The **particle theory** (matter is made of tiny particles) and the **kinetic theory** (those particles are always moving, and move faster the hotter they are) are theories in this strong sense — they explain melting, freezing, boiling and more with one small idea.

Word watch — *heat* and *temperature*. In everyday talk, *heat* and *temperature* get mixed up. **Heat** is energy on the move from something warmer to something cooler — in this subtopic we say a substance *takes in* energy when heated and *gives out* energy when cooled. **Temperature** is the number that says how hot something is, measured in degrees Celsius (°C). In the particle story, temperature tracks how fast the particles are moving: faster particles, higher temperature.

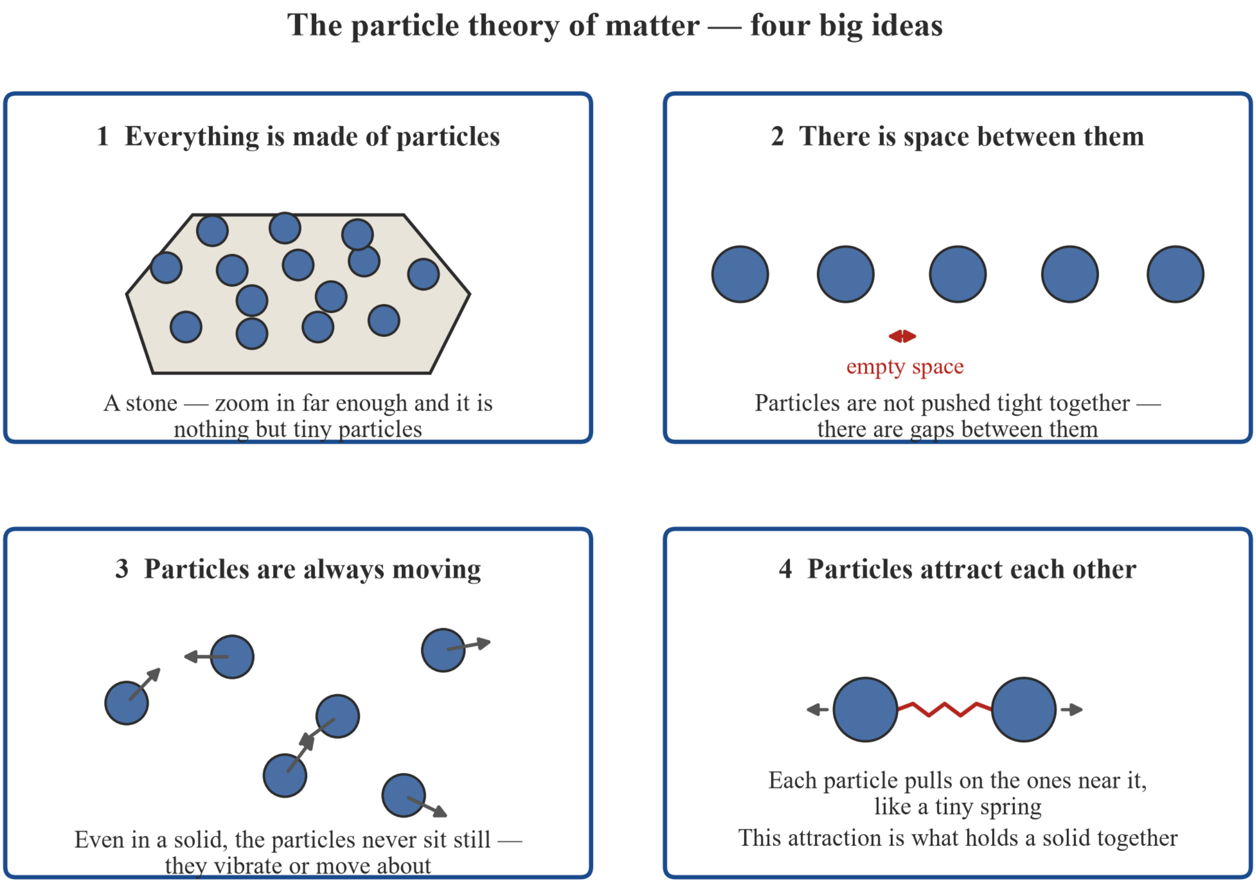
Theory

The particle theory of matter — four big ideas

Everything around you — the air, the water in your bottle, the desk, you — is **matter**, and the particle theory says four big things about it:

1. **Everything is made of particles.** Zoom in far enough on any substance and it is nothing but unbelievably tiny pieces of matter called **particles**.

2. **There is space between the particles.** Particles are not squashed tight together; there are gaps of empty space between them.
3. **The particles are always moving.** This is the kinetic part of the story. In a solid they vibrate in place; in a liquid they slide about; in a gas they fly. They never sit perfectly still.
4. **The particles attract each other.** Each particle pulls on the particles near it, like a tiny spring joining them. This **attraction** is what holds a solid together.

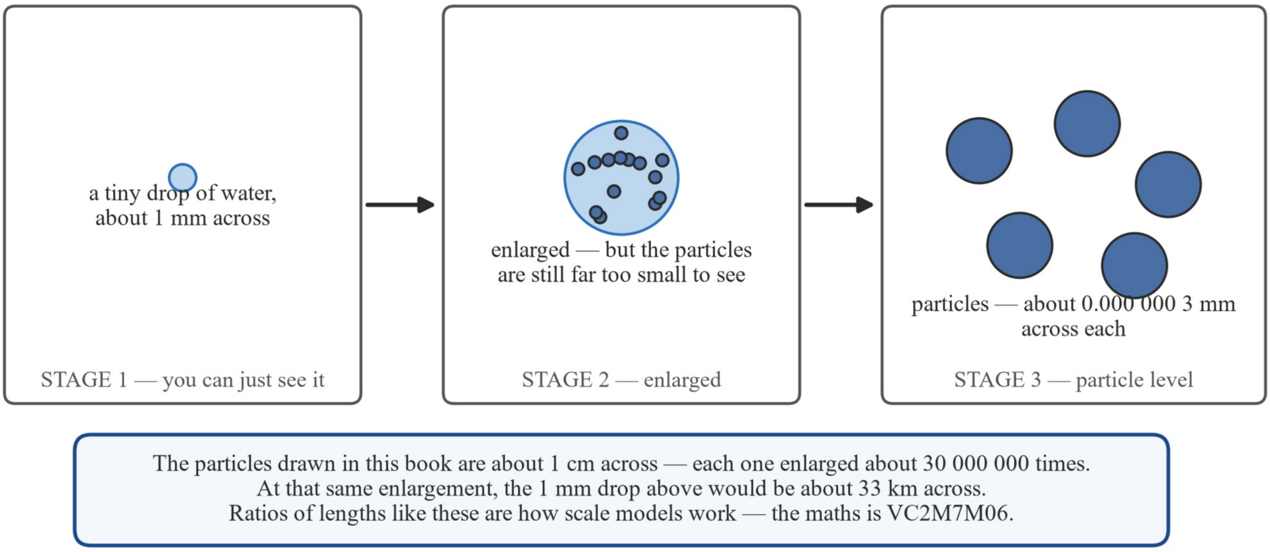


The four big ideas of the particle theory of matter in four panels: 1, everything is made of particles, shown as a stone drawn as a cluster of tiny particles; 2, there is space between them, shown as a row of particles with the empty space marked; 3, particles are always moving, shown with motion arrows; 4, particles attract each other, shown as two particles joined by a tiny spring

How small is a particle? (and how much we enlarge them)

A particle of water is about 0.000 000 3 mm across. That is far beyond any microscope you will use at school, so every particle drawing in this book — including every drawing in this subtopic — is enormously enlarged: the particles drawn here are about 1 cm across, each one enlarged about 30 000 000 times. At that same enlargement, a 1 mm drop of water would be about 33 km across. Comparing sizes like this is a ratio of lengths, the scale-model maths of `VC2M7M06`.

How small is a particle? (and how much we enlarge them)



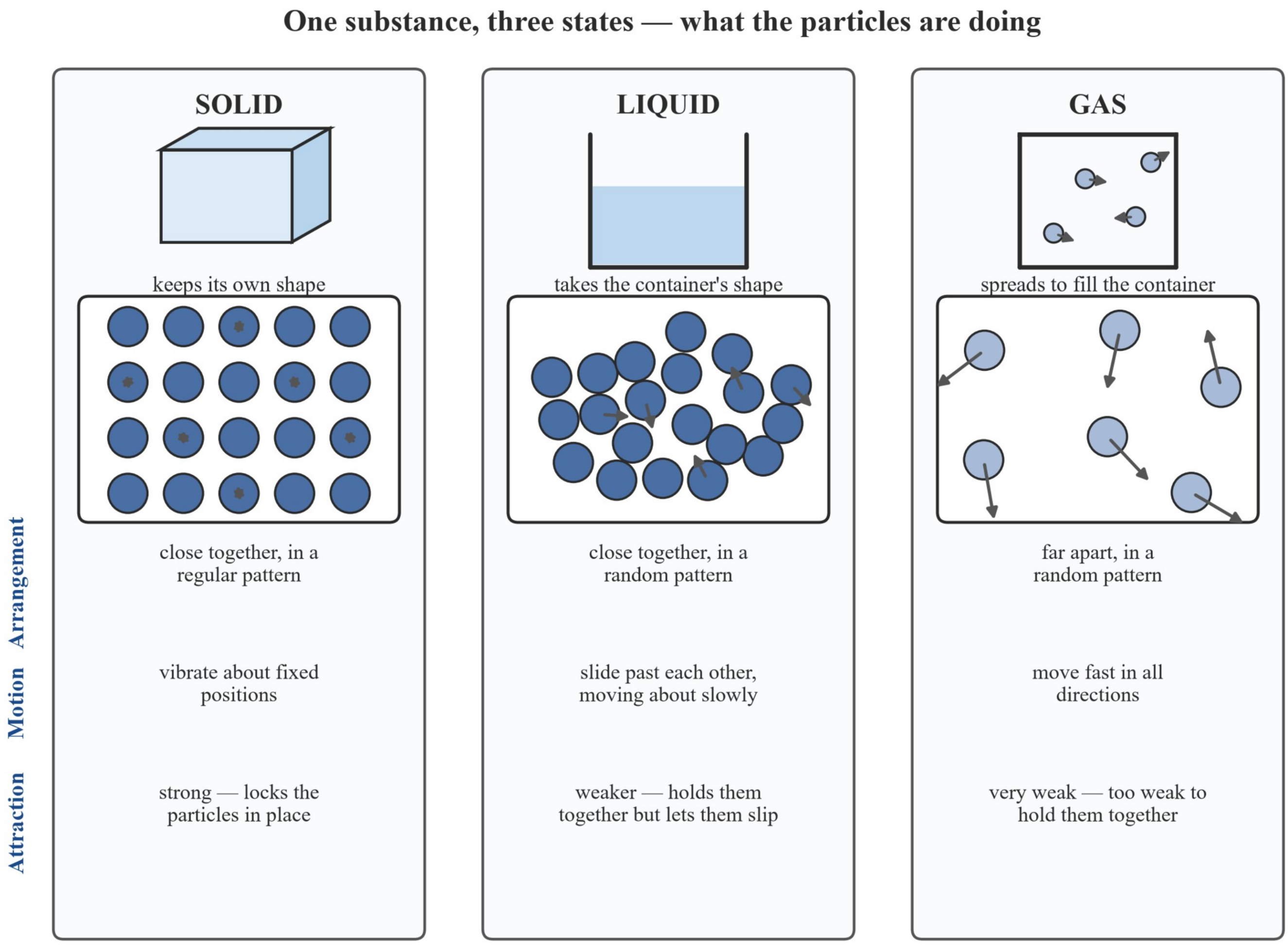
How small a particle is, in three stages: a 1 mm drop of water; the drop enlarged but the particles still far too small to see; and particle level, each particle about 0.000 000 3 mm across; a note says the particles drawn in this book are enlarged about 30 000 000 times, and at that same enlargement the 1 mm drop would be about 33 km across, with the ratio maths cited as VC2M7M06

So when you draw particles in your notebook, remember: the drawing is a **model**, enormously enlarged, and the real gaps between gas particles are far bigger than any drawing shows.

The three states — arrangement and motion

Matter comes in three **states**: solid, liquid and gas. The particle theory describes each state with the same three questions — how are the particles arranged, how do they move, and how strong is the attraction between them?

- **Solid:** particles close together, in a regular pattern; they vibrate about fixed positions; attraction strong, locking them in place. A solid keeps its own shape.
- **Liquid:** particles close together, in a random pattern; they slide past each other, moving about slowly; attraction weaker, holding them together but letting them slip. A liquid takes the container's shape.
- **Gas:** particles far apart, in a random pattern; they move fast in all directions; attraction very weak, too weak to hold them together. A gas spreads to fill its container.



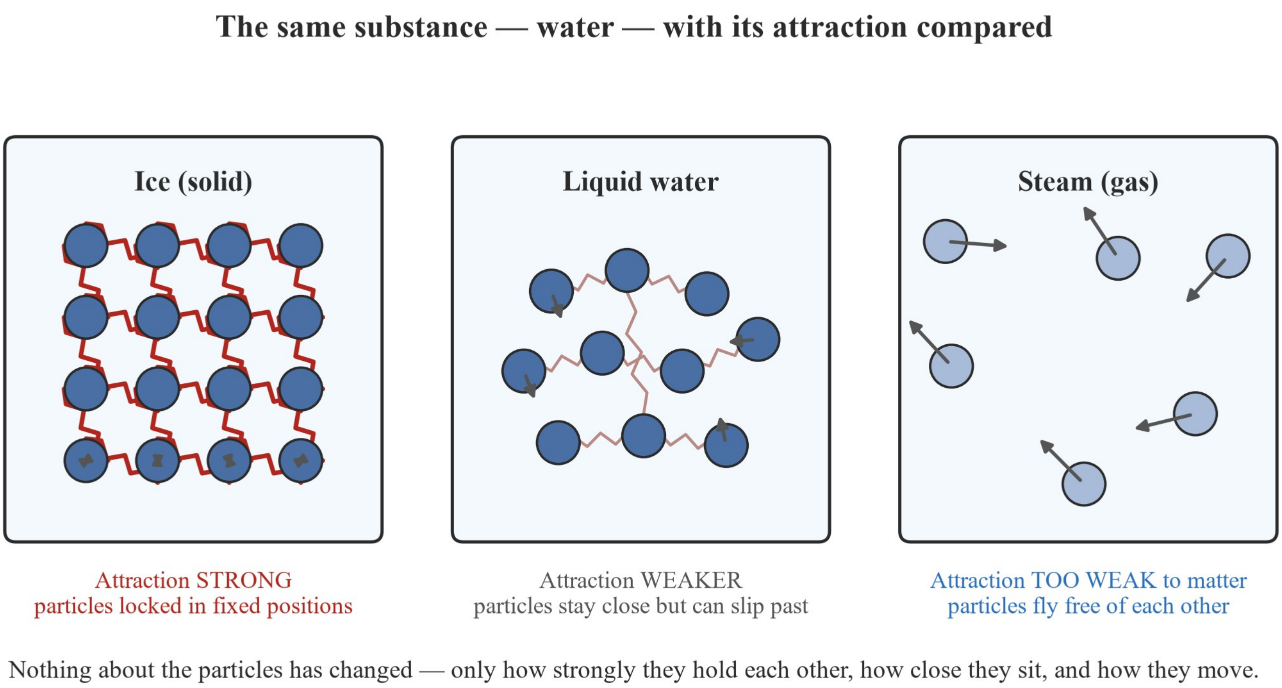
One substance in three states, in three columns for solid, liquid and gas; each column shows the substance as you see it (a cube keeping its shape, a liquid taking the container's shape, a gas spreading to fill a closed jar), a particle picture, and three rows: arrangement (close together in a regular pattern; close together in a random pattern; far apart in a random pattern), motion (vibrate about fixed positions; slide past each other; move fast in all directions), and attraction (strong, locking the particles in place; weaker, holding them together but letting them slip; very weak, too weak to hold them together)

Attraction between particles — the same substance, three states

The attraction between particles is not the same in every state. Compare the three states of the *same* substance — water — and the pattern is clear (this is the comparison of `VC2S8U05.E02`):

- **Ice (solid):** attraction **strong** — the particles are locked in fixed positions and can only vibrate.
- **Liquid water:** attraction **weaker** — the particles stay close together but can slip past each other.
- **Steam (gas):** attraction **too weak to matter** — the particles fly free of each other.

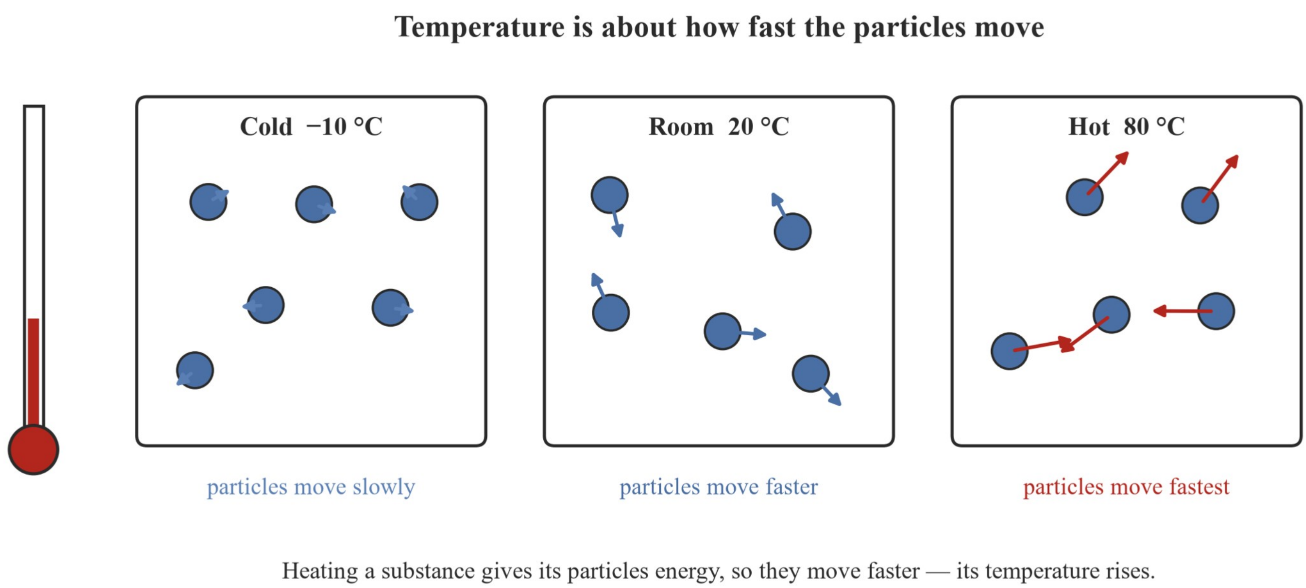
Nothing about the particles themselves has changed from one state to the next — only how strongly they hold each other, how close they sit, and how they move. The strength of the attraction and the position and movement of the particles go together: strong attraction goes with fixed positions and vibration; very weak attraction goes with far-apart, fast-moving particles.



The same substance, water, in its three states with the attraction compared: ice as a regular lattice of particles joined by strong springs (attraction strong, particles locked in fixed positions), liquid water as a close random cluster with weaker links (attraction weaker, particles stay close but can slip past), and steam as far-apart particles with no links (attraction too weak to matter, particles fly free of each other)

The kinetic theory — temperature is about how fast the particles move

The **kinetic theory** adds the energy half of the story: the particles of a substance move faster the hotter the substance is. Heat a substance and its particles take in energy, so they move faster and its temperature rises; cool it and the particles give out energy, slow down, and its temperature falls. At the same temperature, the particles of a gas move fast, the particles of a liquid move more slowly, and the particles of a solid only vibrate — and warming or cooling can tip a substance from one of these patterns into the next (this is the energy-and-motion link of `VC2S8U05.E03`).

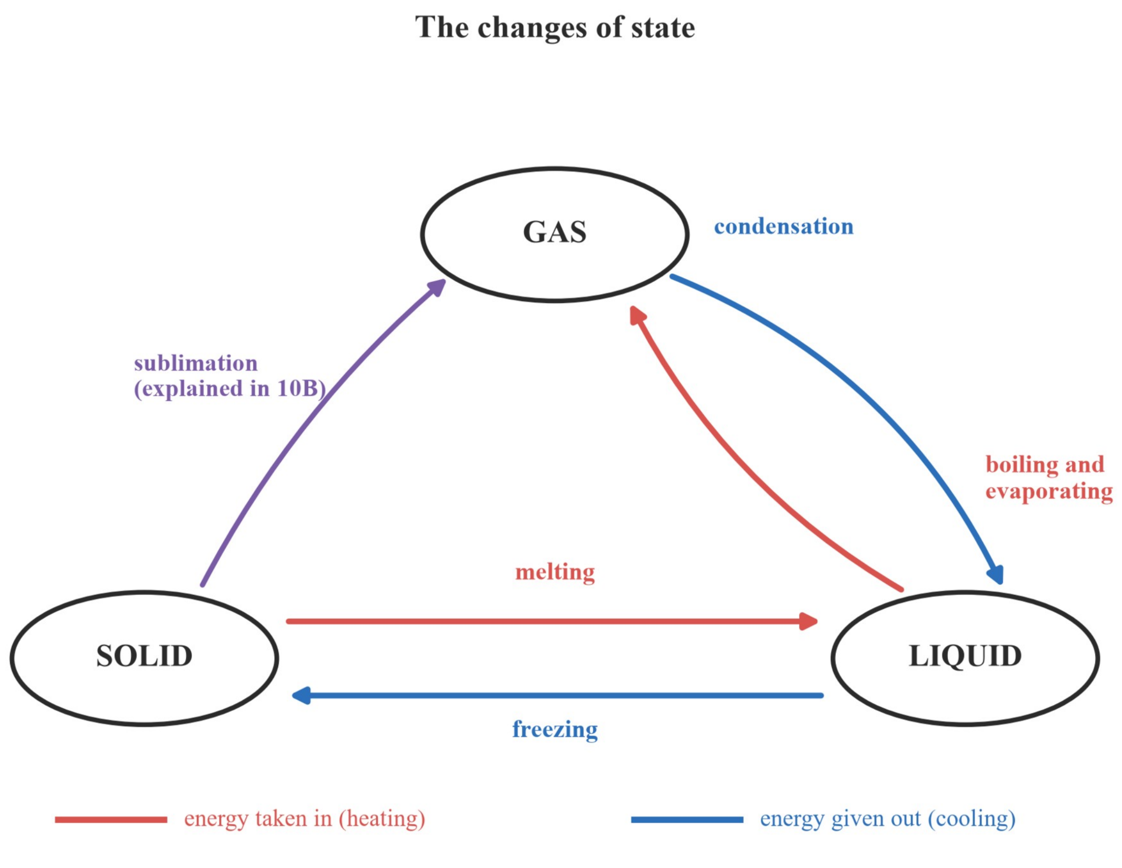


Three boxes of the same gas at cold (−10 °C), room (20 °C) and hot (80 °C); the motion arrows grow longer from cold to hot, showing the particles move slowly when cold, faster at room temperature and fastest when hot

The changes of state — the map

When heating or cooling tips a substance from one state to another, we call it a **change of state**. Each change has a name, and each one either takes energy in (heating) or gives energy out (cooling):

- **melting** — solid → liquid (energy taken in)
- **freezing** — liquid → solid (energy given out)
- **boiling** and **evaporating** — liquid → gas (energy taken in)
- **condensation** — gas → liquid (energy given out)
- **sublimation** — solid straight → gas (named here; explained in 10B)

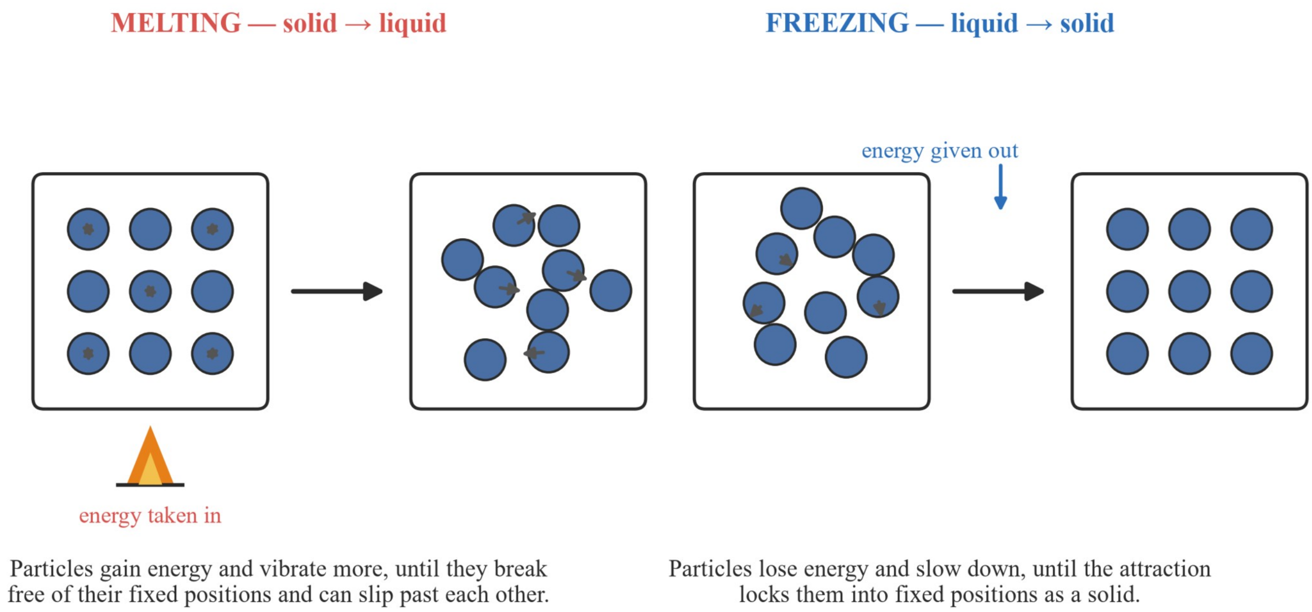


A map of the changes of state between three ovals, solid, liquid and gas: melting (solid to liquid) and boiling and evaporating (liquid to gas) in red as energy taken in by heating; freezing (liquid to solid) and condensation (gas to liquid) in blue as energy given out by cooling; and sublimation (solid straight to gas) marked as explained in 10B

Melting and freezing

Heat a solid and its particles vibrate more and more. At the melting point the vibration is strong enough for the particles to break free of their fixed positions — the solid **melts** to a liquid, and the particles can slip past each other. Cool a liquid and the particles slow down, until the attraction locks them into fixed positions — the liquid **freezes** to a solid.

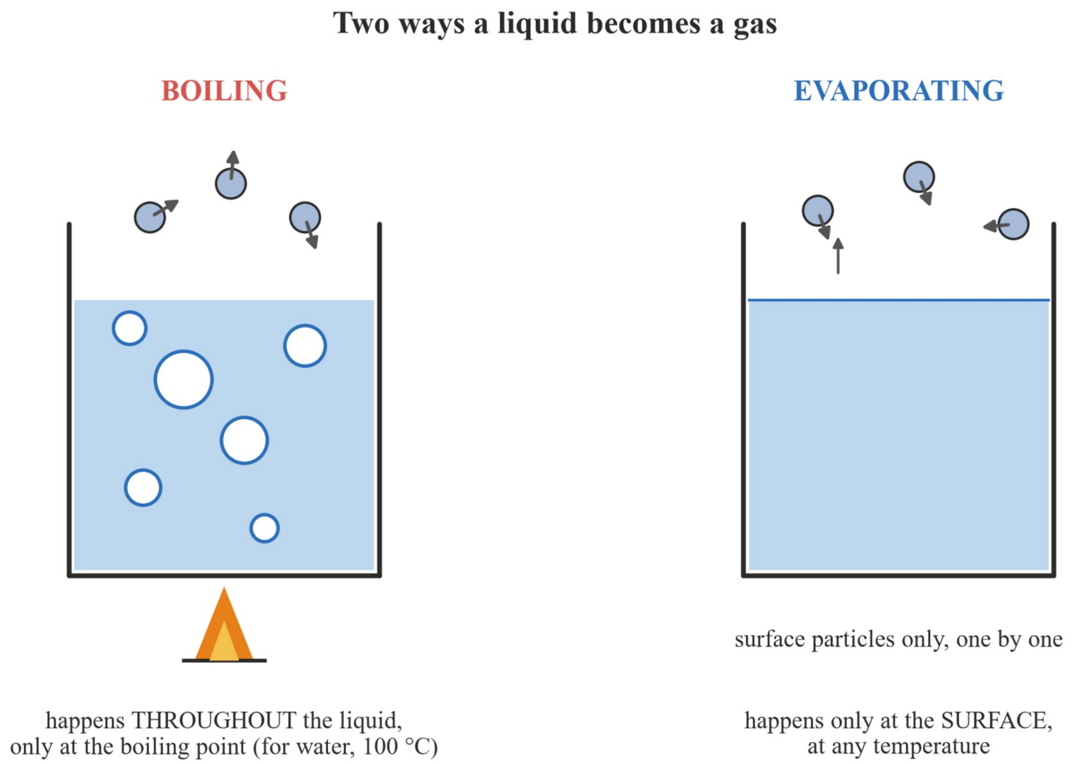
Melting and freezing, particle by particle



Melting and freezing particle by particle: on the left, a heated solid's particles vibrate more until they break free of their fixed positions and slip past each other as a liquid (energy taken in); on the right, a cooled liquid's particles slow down until the attraction locks them into fixed positions as a solid (energy given out)

Boiling and evaporating — two ways a liquid becomes a gas

A liquid becomes a gas in two different ways. **Boiling** happens throughout the liquid, only at the boiling point: bubbles of the gas form inside the liquid and rise (for water, this is 100 °C). **Evaporating** happens only at the surface, at *any* temperature: single surface particles that happen to be moving fast enough break free of the attraction and escape, one by one. That is why a puddle dries up on a cool day, even though the day is far cooler than 100 °C — the water is evaporating, not boiling.



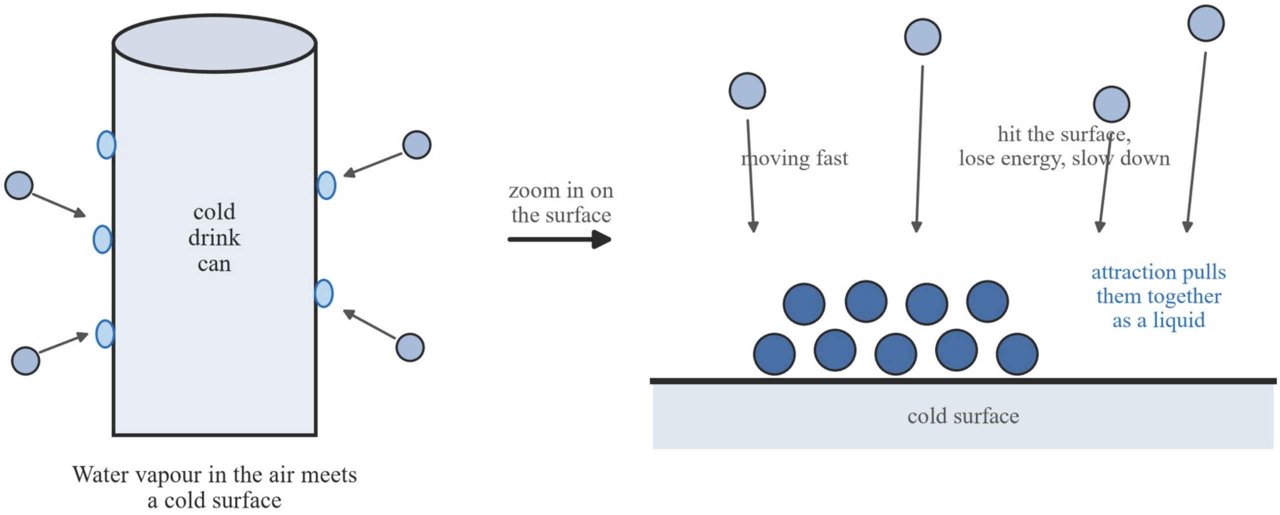
Two ways a liquid becomes a gas: boiling, with bubbles of gas through the whole liquid, happening throughout and only at the boiling point (for water, 100 °C); and evaporating, with single fast particles leaving the surface one by one, happening only at the surface and at any temperature

Because the fastest particles are the ones that escape, evaporating leaves the slower particles behind — the liquid's particles are, on the whole, moving more slowly afterwards, so the liquid cools. Evaporation is a cooling change: it takes in energy from whatever the liquid is touching.

Condensation — a gas turning back to a liquid

Condensation is the reverse of evaporating: gas particles that hit a cold surface lose energy and slow down, and the attraction pulls them back together as a liquid. It is why droplets form on the outside of a cold drink can on a warm day — water vapour in the air meets the cold can, slows, and joins up as liquid water. The water comes *from the air*, not through the can.

Condensation — a gas turning back to a liquid



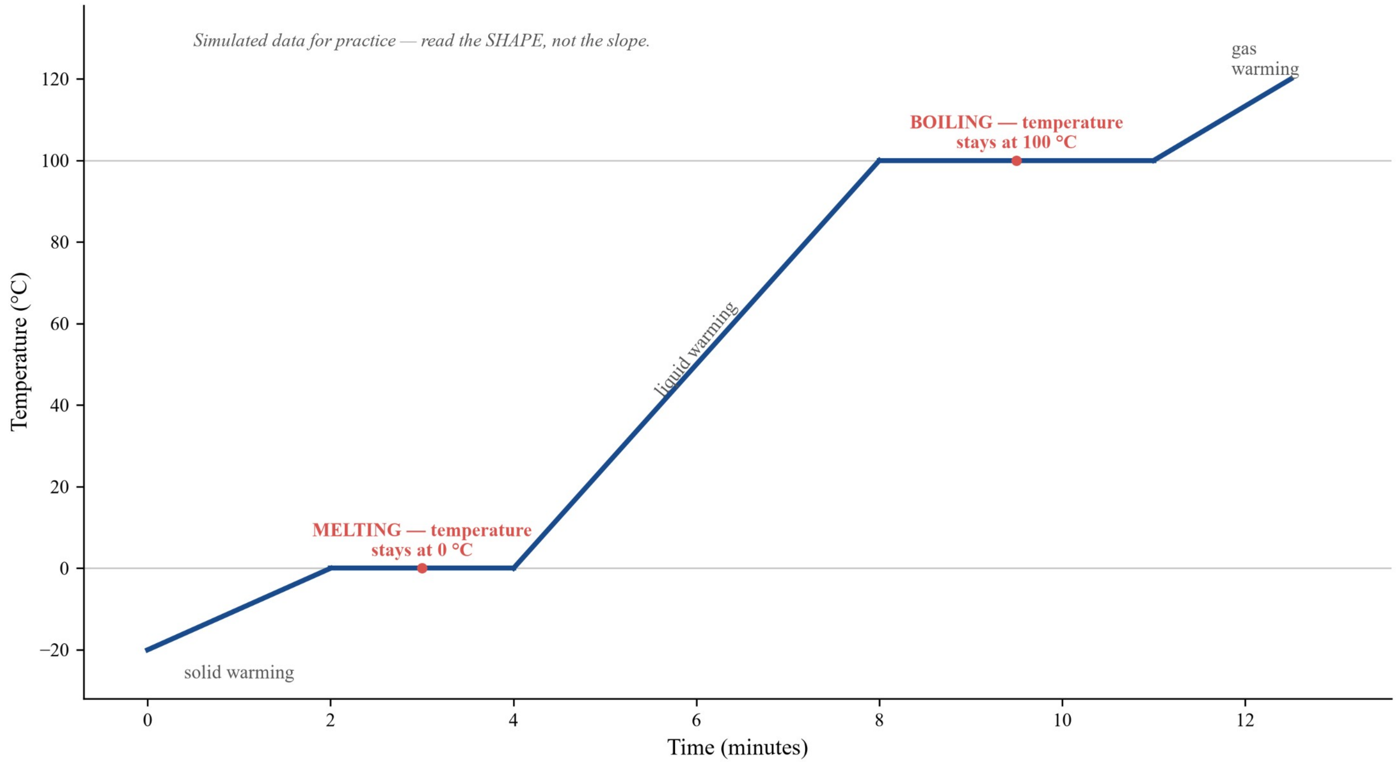
This is why droplets form on the outside of a cold drink can on a warm day — the water comes from the air, not through the can.

Condensation, a gas turning back to a liquid: on the left, water vapour particles in the air meet a cold drink can and droplets form on its outside; on the right, zoomed in on the surface, fast vapour particles hit the cold surface, lose energy and slow down, and the attraction pulls them together as a liquid; the water comes from the air, not through the can

The same story puts droplets on a bathroom mirror after a hot shower, and dew on the grass on a cold morning: water vapour in the air condenses when it meets a surface cooler than itself.

Energy at a change of state

Heat ice from −20 °C and its temperature rises — until melting starts. Then, even though heating continues, the temperature *stays at 0 °C* until every bit of ice has melted. The same happens at boiling: the temperature stays at 100 °C while the water boils. The heating curve below shows the pattern; it is qualitative — read the shape, not the slope (D11).



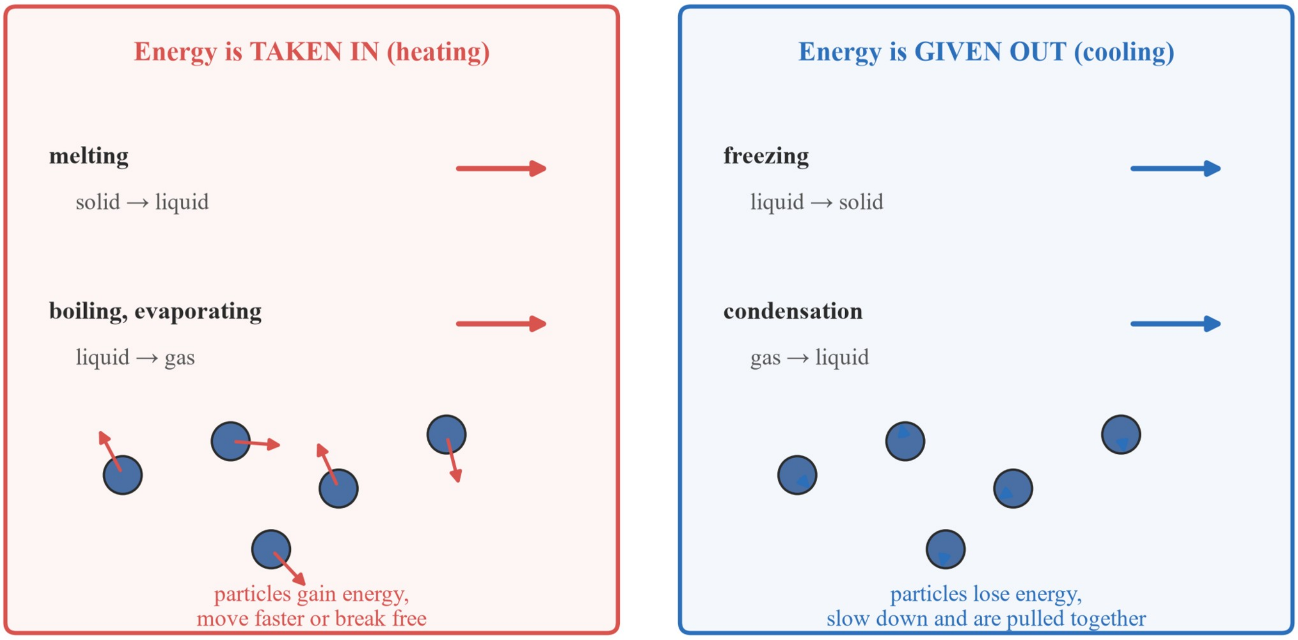
A simulated heating curve for water, temperature in degrees Celsius against time in minutes: the solid warms from −20 °C to 0 °C; the temperature then stays flat at 0 °C while the ice melts; it rises to 100 °C as the liquid warms; it stays flat at 100 °C while the water boils; then it rises again as the gas warms; a note says the data is simulated for practice and to read the shape, not the slope

Where does the energy go while the temperature stays flat? Into the particles' attraction. During melting, the energy taken in lets the particles break free of their fixed positions; during boiling, it lets them break free of each other completely. The energy changes what the particles *do*, not how fast they move — so the temperature does not rise until the change of state is finished.

The rule across all six changes:

- **Energy taken in (heating)** — melting, boiling, evaporating: particles gain energy, move faster or break free.
- **Energy given out (cooling)** — freezing, condensation: particles lose energy, slow down and are pulled together.

Energy at a change of state

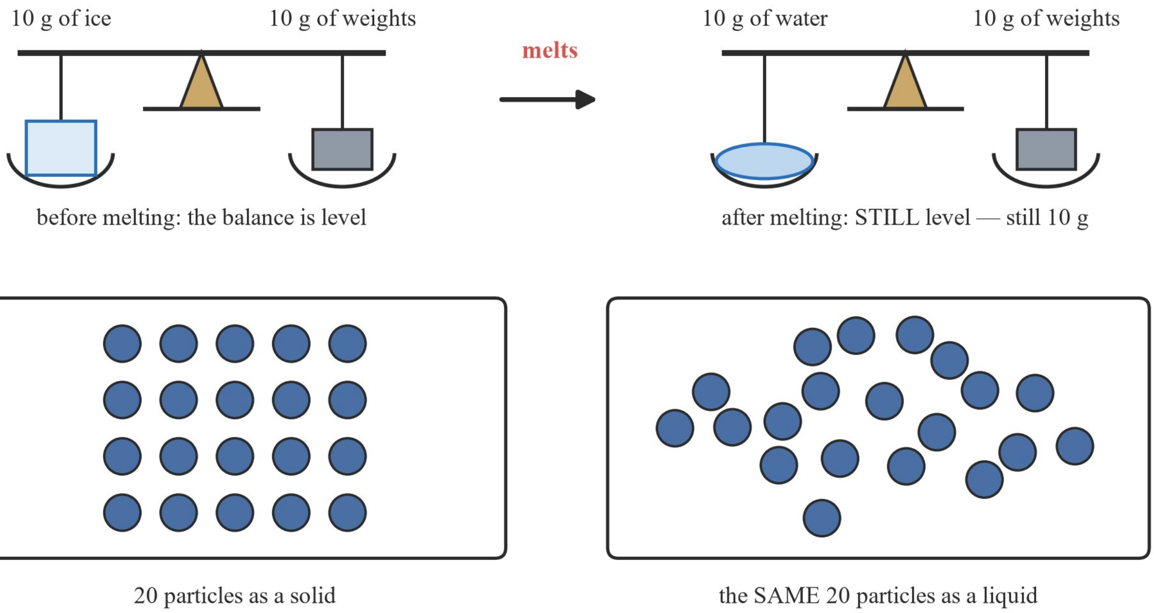


Energy at a change of state in two panels: energy is taken in by heating for melting and for boiling and evaporating, with particles gaining energy and moving faster or breaking free; energy is given out by cooling for freezing and for condensation, with particles losing energy, slowing down and being pulled together

The mass stays the same at a change of state

A change of state rearranges the particles — it does not add or remove any. So the mass does not change: 10 g of ice melts to exactly 10 g of water, and a balance cannot tell the difference. The same 20 particles are there before and after; only their arrangement and motion have changed.

At a change of state, the particles themselves never change

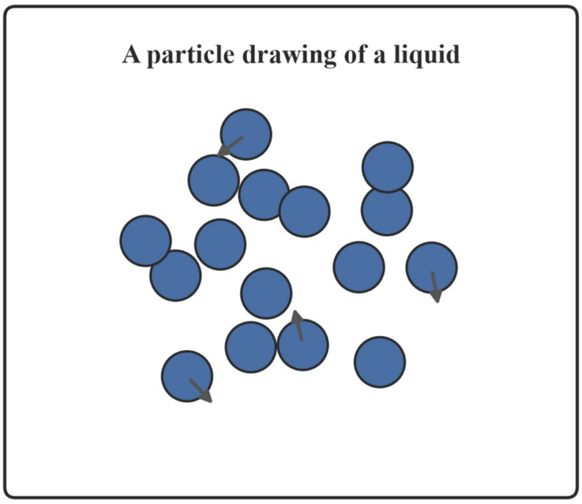


At a change of state the particles themselves never change: a balance holding 10 g of ice against 10 g of weights is level before melting and still level after the ice has melted to 10 g of water; below, two boxes show the same 20 particles arranged in a regular pattern as a solid and in a random pattern as a liquid

What the model shows well — and what it cannot show

The particle model is powerful, but every model has limits, and naming both is what makes a model useful (you met this way of judging models in 4B and 8B). A particle drawing shows the arrangement of the particles, the space between them, and how they move. It falls short on scale (real particles are far smaller, and the gaps in a gas far bigger), on attraction (you cannot see a pull), and on motion itself (a drawing sits still; real particles never do).

The particle model — shows well, and falls short



Shows well

- the arrangement of the particles
- the space between them
- how the particles move

Falls short

- the scale — real particles are far smaller, and the gaps in a gas far bigger
- the attraction — you cannot see a pull
- a drawing sits still; real particles never do

Every model has strengths and limits — naming both is what makes a model useful (you met this in 4B and 8B).

The particle model, what it shows well and where it falls short: a particle drawing of a liquid beside two lists; shows well — the arrangement of the particles, the space between them, and how the particles move; falls short — the scale, because real particles are far smaller and the gaps in a gas far bigger, the attraction, because you cannot see a pull, and that a drawing sits still while real particles never do

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Activity — build a model of a change of state (`VC2S8U05.E01`)

Make a model that shows the particles of one substance as a solid, as a liquid and as a gas, and as it changes state. Two good options: a shallow tray of small beads (shake it gently for a solid, more for a liquid), or a claymation / stop-motion video on a phone, moving modelling-clay particles frame by frame as the substance melts or freezes.

- **Equipment (subtopic 3C):** a shallow tray and about 50 small beads; or a phone or tablet with a stop-motion app and some modelling clay.
- **Risk (subtopic 3B):** a low-risk activity, run with the risk-management guidance from Science ASSIST (see Sources): keep the beads in the tray so they are not a slip hazard on the floor, put nothing in your mouth in the lab, and handle equipment with care.
- **Evaluation (subtopic 5A):** judge your model the way we judged the drawings above — write one thing it shows well (for example, the regular pattern of a solid) and one thing it cannot show (for example, the attraction between particles, which is invisible in a bead tray).

Investigation — does evaporating cool? (`VC2S8U05.E03`)

Wrap cotton wool around the bulb of one thermometer and wet it with water; leave a second thermometer dry. Record both temperatures every 2 minutes for 8 minutes.

- **Variables (subtopic 3A):** change — the wrap is wet with water, or dry; measure — the temperature every 2 minutes; keep the same — the same room, the same starting temperature on both thermometers, and the same timing.
- **Equipment (subtopic 3C):** two thermometers, cotton wool, water, a rubber band, a timer, and a results table.

- **Risk (subtopic 3B):** a low-risk investigation, run with the risk-management guidance from Science ASSIST (see Sources): handle the glass thermometers with care, never use one as a stirrer, and wipe up spills straight away.

Time (minutes)	Dry thermometer (°C)	Wet thermometer (°C)
0	21	21
2	21	19
4	21	18
6	21	17
8	21	16

(Simulated data for practice.)

- **Reading the pattern (subtopic 4C):** the dry thermometer stays at 21 °C while the wet one falls, from 21 °C to 16 °C. Water evaporating from the wet wrap takes in energy from the bulb, so the bulb cools — evaporating is a cooling change.
- **Evaluation (subtopic 5A):** check that both thermometers read the same before you start, and repeat the investigation to see if the pattern holds; a draught would speed the evaporation up, which is why keeping the conditions the same matters.

Words to know in 10A

Word	What it means here
particle	an unbelievably tiny piece of matter; what every substance is made of
particle theory	the theory that matter is made of tiny particles with space between them
kinetic theory	the theory that the particles of matter are always moving, and move faster the hotter it is
matter	anything that takes up space — all substances are matter
state	one of the three forms of matter: solid, liquid or gas
attraction	the pull between particles that holds them together
vibrate	to move a little way from side to side about a fixed position
melting	the change of state from solid to liquid
freezing	the change of state from liquid to solid
boiling	the change of state from liquid to gas throughout the liquid, at the boiling point
evaporating	the change of state from liquid to gas at the surface only, at any temperature
condensation	the change of state from gas to liquid
sublimation	the change of state from solid straight to gas (explained fully in 10B)
change of state	a substance moving between solid, liquid and gas
heat	energy on the move from something warmer to something cooler
temperature	how hot something is, in °C; tracks how fast the particles move
model	a simplified picture or object that stands in for the real thing, with strengths and limits

Worked examples

Example 1 — scaffolded

A student heats ice from −20 °C and records a heating curve like the figure above. Read from the curve: (a) the temperature at which the ice melts; (b) the state of the substance at minute 6; (c) why the temperature stays at 100 °C while the water boils.

Working	Comment
(a) The flat part during melting sits at 0 °C → **melts at 0 °C**.	A change of state shows as a flat part on a heating curve.
(b) Minute 6 is between the two flat parts → **liquid**.	Between the melting flat part and the boiling flat part, the substance is a liquid.
(c) While boiling, the energy taken in lets the particles break free of each other, not move faster → **the temperature stays at 100 °C until all the water is gas**.	Temperature tracks particle speed; during a change of state the energy goes into the attraction, so the speed does not rise.

Example 2 — scaffolded

A block of ice at −18 °C is left in a warm room until it becomes water at 25 °C. (a) Work out the total rise in temperature. (b) Did the substance change state on the way? Give the reason.

Working	Comment
(a) Rise = 25 − (−18) = 25 + 18 = **43 °C**	Subtracting a negative number is adding its positive — the integer maths of `VC2M7N08`.
(b) The temperature passed 0 °C on the way from −18 °C to 25 °C → **yes, the ice melted**.	0 °C is the melting point of water; crossing it means a change of state.

Example 3 — unscaffolded

A puddle disappears on a 15 °C day, even though 15 °C is far below the boiling point of water. Explain, using particles, how the puddle dries.

The water is evaporating, not boiling. The particles of the liquid move at a range of speeds, and a surface particle that happens to be moving fast enough can break free of the attraction holding it and escape as a gas. This can happen at any temperature, so the puddle slowly dries even at 15 °C. ∴ evaporation — fast surface particles escaping one by one — explains drying below the boiling point.

Example 4 — unscaffolded

A cold drink can straight from the fridge soon has droplets on its outside on a warm day. Explain where the water comes from, using particles.

The air holds water vapour — water particles flying free as a gas. When these fast particles hit the cold can they lose energy and slow down, and the attraction between them pulls them together into liquid droplets. That is condensation. ∴ the droplets come from water vapour in the air, not from inside the can — the can is sealed, and the change of state happens in the air's water vapour when it meets the cold surface.

Practice questions

Scaffolded

Q1. State the four big ideas of the particle theory of matter.

Q2. For a solid, state: (a) the arrangement of its particles; (b) their motion; (c) the strength of the attraction between them.

Q3. Name the change of state described: (a) a liquid becomes a gas at its surface on a cool day; (b) a gas becomes a liquid on a cold mirror; (c) a solid becomes a liquid; (d) a liquid becomes a solid.

Q4. Put the three states in order of attraction between particles, weakest first.

Q5. On the heating curve, the temperature stays at 0 °C for a while even though heating continues. State what is happening to the substance, and where the energy is going.

Q6. Complete the sentence: "Heating a gas makes its particles …, so its temperature …"

Unscaffolded

Q7. Compare the particles of a solid with the particles of the same substance as a gas — arrangement, motion and attraction.

Q8. A brick keeps its shape, but a glass of water takes the shape of the glass. Explain both facts using the attraction and motion of the particles.

Q9. A bathroom mirror fogs with droplets after a hot shower. Name the change of state and explain it with particles.

Q10. Wet clothes on a line dry faster on a hot day than on a cold day. Explain why, using the link between temperature and particle motion.

Q11. Explain why the temperature of boiling water stays at 100 °C while heating continues, until all the water has become gas.

Q12. A closed jar holds 10 g of ice. The ice melts completely. State the mass of the water now in the jar, and explain why the mass has not changed.

Q13. A sealed jar of water vapour is cooled, and droplets appear on the inside of the glass. Describe what happens to the motion of the water particles, and name the change of state.

Q14. Give one thing a particle drawing shows well and one thing it cannot show, and say why a drawing can never show the second thing.

Answers

Q1. (1) Everything is made of particles; (2) there is space between the particles; (3) the particles are always moving; (4) the particles attract each other. **Q2.** (a) Close together, in a regular pattern. (b) They vibrate about fixed positions. (c) Strong — it locks the particles in place. **Q3.** (a) Evaporating. (b) Condensation. (c) Melting. (d) Freezing. **Q4.** Gas, then liquid, then solid (weakest to strongest attraction). **Q5.** The ice is melting; the energy taken in lets the particles break free of their fixed positions, so it goes into the attraction, not into raising the temperature. **Q6.** …move faster…, so its temperature rises. **Q7.** Solid: particles close together in a regular pattern, vibrating about fixed positions, strong attraction. Gas: particles far apart in a random pattern, moving fast in all directions, very weak attraction. **Q8.** In the brick (a solid) the strong attraction locks the particles in fixed positions, so it keeps its shape; in the water (a liquid) the weaker attraction lets the particles slide past each other, so it takes the container's shape. **Q9.** Condensation: fast water-vapour particles in the steamy air hit the cooler mirror, lose energy and slow down, and the attraction pulls them together as liquid droplets. **Q10.** On a hot day the water particles move faster, so more surface particles are moving fast enough to break free of the attraction and escape — the water evaporates faster. **Q11.** While boiling, the energy taken in lets the particles break free of each other rather than move faster, so the temperature stays at 100 °C until the change of state is finished. **Q12.** 10 g. A change of state only rearranges the same particles — none are added or removed — so the mass does not change. **Q13.** Cooling makes the water particles lose energy and slow down, and the attraction pulls them together as a liquid on the glass; the change is condensation. **Q14.** Shows well: the arrangement of the particles (or the space between them, or how they move). Cannot show: the attraction — a pull is invisible, and a drawing also sits still while real particles never do.

Fully-worked solutions

Q1. The four big ideas: **(1) everything is made of particles** *(1 mark)*; **(2) there is space between the particles** *(1 mark)*; **(3) the particles are always moving** *(1 mark)*; **(4) the particles attract each other** *(1 mark)*.

Q2. (a) The particles are **close together, in a regular pattern** *(1 mark)*. (b) They **vibrate about fixed positions** *(1 mark)*. (c) The attraction is **strong — it locks the particles in place** *(1 mark)*.

Q3. (a) **Evaporating** *(1 mark)*. (b) **Condensation** *(1 mark)*. (c) **Melting** *(1 mark)*. (d) **Freezing** *(1 mark)*.

Q4. Weakest first: **gas, liquid, solid** — very weak attraction in a gas, weaker in a liquid, strong in a solid *(1 mark for the order, 1 mark for matching the strengths)*.

Q5. The substance is **melting** — the particles are breaking free of their fixed positions *(1 mark)*; the energy taken in **goes into the attraction between the particles, not into raising the temperature**, so the temperature stays at 0 °C *(1 mark)*.

Q6. Heating a gas makes its particles **move faster** *(1 mark)*, so its temperature **rises** *(1 mark)*.

Q7. Solid: particles **close together in a regular pattern** *(1 mark)*, **vibrating about fixed positions** with **strong attraction** *(1 mark)*. Gas: particles **far apart in a random pattern** *(1 mark)*, **moving fast in all directions** with **very weak attraction** *(1 mark)*.

Q8. In the brick the **strong attraction locks the particles in fixed positions**, so they cannot slip past each other and the solid keeps its shape *(1 mark)*. In the water the **weaker attraction lets the particles slide past each other**, so the liquid takes the container's shape *(1 mark)*.

Q9. The change is **condensation** *(1 mark)*: fast **water-vapour particles hit the cooler mirror, lose energy and slow down** *(1 mark)*, and **the attraction pulls them together as liquid droplets** on the glass *(1 mark)*.

Q10. The hotter the substance, **the faster its particles move** *(1 mark)*; on a hot day more surface particles move fast enough to **break free of the attraction and escape**, so the water **evaporates faster** and the clothes dry sooner *(1 mark)*.

Q11. While the water boils, the energy taken in **lets the particles break free of each other** — it goes into the attraction *(1 mark)* — so the particles **do not move faster and the temperature stays at 100 °C** until all the water is a gas *(1 mark)*.

Q12. The mass is **10 g** *(1 mark)*. A change of state **only rearranges the same particles — none are added or removed** — so the total mass does not change *(1 mark)*.

Q13. Cooling makes the water particles **lose energy and slow down** *(1 mark)*; the attraction then **pulls them together as a liquid** on the glass — the change of state is **condensation** *(1 mark)*.

Q14. Shows well: for example **the arrangement of the particles** (regular in a solid, random in a liquid or gas) *(1 mark)*. Cannot show: for example **the attraction** — a pull is invisible, so no drawing can show it (and a drawing sits still, while real particles never do) *(1 mark)*.

Sources

Web sources below were retrieved 2026-08-21.

- Science ASSIST (Australian Science Teachers' Association), "Risk management", n.d. asta.edu.au

The heating curve and the evaporation-investigation table are **simulated data for practice**; the patterns they show — flat parts at the melting and boiling points, and a falling wet-bulb temperature as evaporation cools — are the real behaviour of water. The particle size (about 0.000 000 3 mm across) and the enlargement ratio (about 30 000 000 times) are typical rounded values, given for practice.

Elaboration contexts used: `VC2S8U05.E01` (using and constructing virtual simulations such as claymation videos, models or diagrams to represent changes in particle arrangement and properties as substances change state), `VC2S8U05.E02` (comparing attractive forces in the solid, liquid and gaseous states of the same substance and relating this to relative position and movement of particles) and `VC2S8U05.E03` (examining how the changing motion and energy of particles are affected by the amount of heat energy absorbed or released).

Explaining a substance with its particles: melting and boiling point, density, compressibility, gas pressure, viscosity, diffusion, sublimation, and expansion and contraction

What we teach here — `VC2S8U05` (Victorian Curriculum F–10 Version 2.0, Science, Levels 7 and 8): *"the particle and kinetic theories of matter can be used to describe the arrangement and motion of particles in a substance, including the attraction between particles, and to explain the properties and behaviour of substances, including melting point, boiling point, density, compressibility, gas pressure, viscosity, diffusion, sublimation, and expansion and contraction"* **This subtopic owns the second clause only**: using the particle model to explain the properties and behaviour of substances — melting point, boiling point, density, compressibility, gas pressure, viscosity, diffusion, sublimation, and expansion and contraction. The first clause — the particle and kinetic theories themselves, the arrangement and motion of particles and the attraction between them — belongs to the partner subtopic **10A** († split delivery, D6). Here we *use* the model; 10A builds it. **In our words:** every property of a substance — why iron is heavy for its size, why honey pours slowly, why a sealed can gets harder when it is warm, why a smell crosses a room — comes back to the same three particle ideas: how strongly the particles attract each other, how far apart they sit, and how they move. One model explains the lot. **Achievement-standard extract served here (D13):** cited by reference to the header of the owner subtopic 10A, where the extract appears in full. **Elaborations drawn on:** `VC2S8U05.E04` (comparing the properties of different substances and explaining differences using particle theory), `VC2S8U05.E05` (comparing the viscosity of honey, treacle and oil, and developing representations to suggest an explanation) and `VC2S8U05.E06` (constructing a density column using liquids of different densities). **Maths interlocks (D11):** substituting values into formulas (`VC2M7A01`), density as a rate in g/cm³ (`VC2M8M05`) and the volume of right prisms (`VC2M7M02`, `VC2M8M02`) carry the density work here. No scientific notation is used; the only quantitative display is the pair of number lines placing tabled melting and boiling values on a scale — no graph is plotted or read (D11 keeps graphs qualitative). **Authored from the CD text and the elaboration contexts (D12):** the CD names the properties to be explained but not the explanations; the explanations taught here are the standard particle-model accounts of each property, and the three elaborations above supply the comparing, representing and constructing contexts.

Word watch — *dense* and *heavy*. In everyday talk, *heavy* and *dense* get mixed up. A big bag of foam can be heavy without being dense. **Density** is the mass in a given volume — how much mass is packed into a space. Iron is **denser** than cork because a 1 cm³ cube of iron holds more mass than a 1 cm³ cube of cork. Whether something is heavy only makes sense once you also say how big it is; density compares things at the same size.

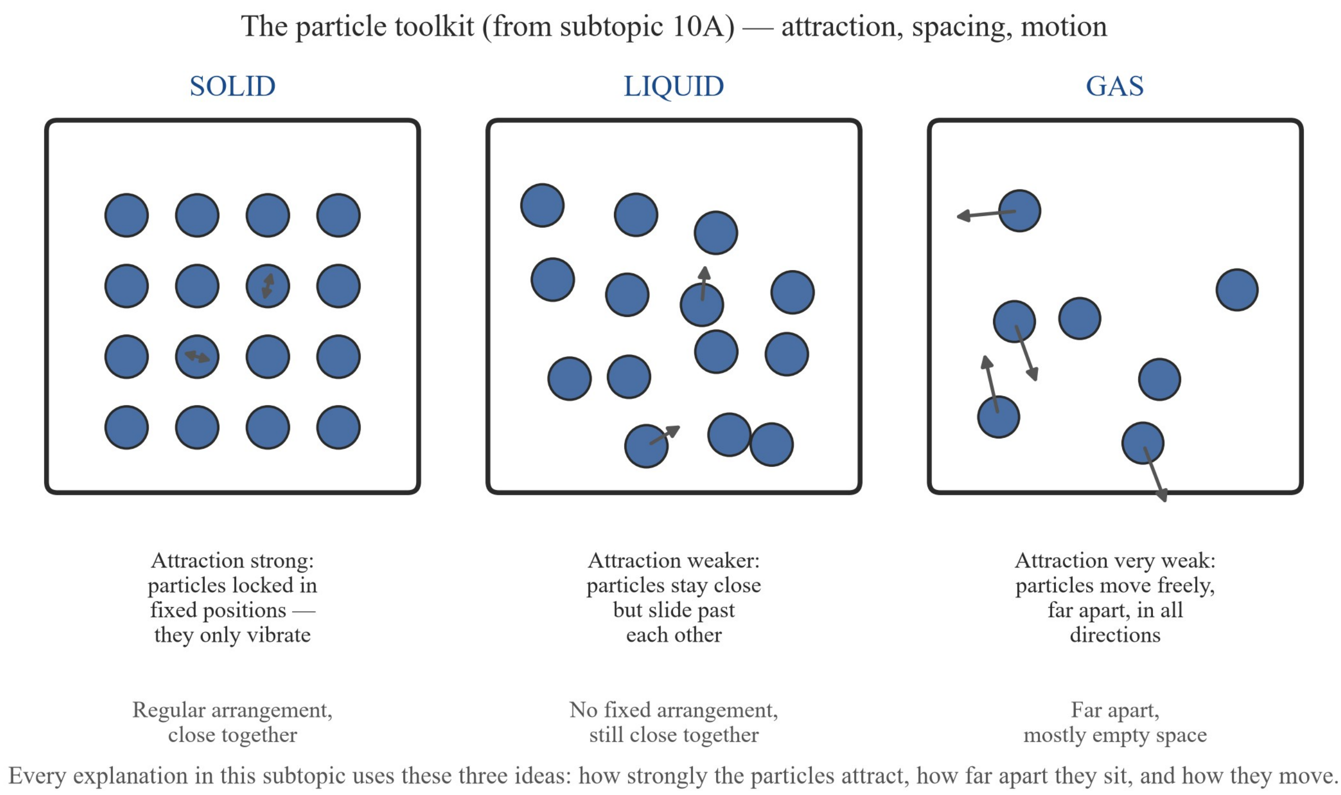
Word watch — *melt* and *dissolve*. Sugar in water is not melting — it is **dissolving**, breaking up and mixing into the water. **Melting** is one substance on its own changing from solid to liquid as it is heated, like ice turning to water. In this subtopic, *melting point* always means the temperature where a solid on its own becomes a liquid.

Theory

The particle toolkit we borrow from 10A

Subtopic 10A builds the particle and kinetic theories of matter: every substance is made of tiny particles that attract each other, sit with gaps between them, and move. Here is the short version this subtopic leans on.

- **Solid:** attraction strong; particles locked in fixed positions, close together; they only vibrate in place.
- **Liquid:** attraction weaker; particles still close together but able to slide past each other.
- **Gas:** attraction very weak; particles far apart, moving easily in all directions.

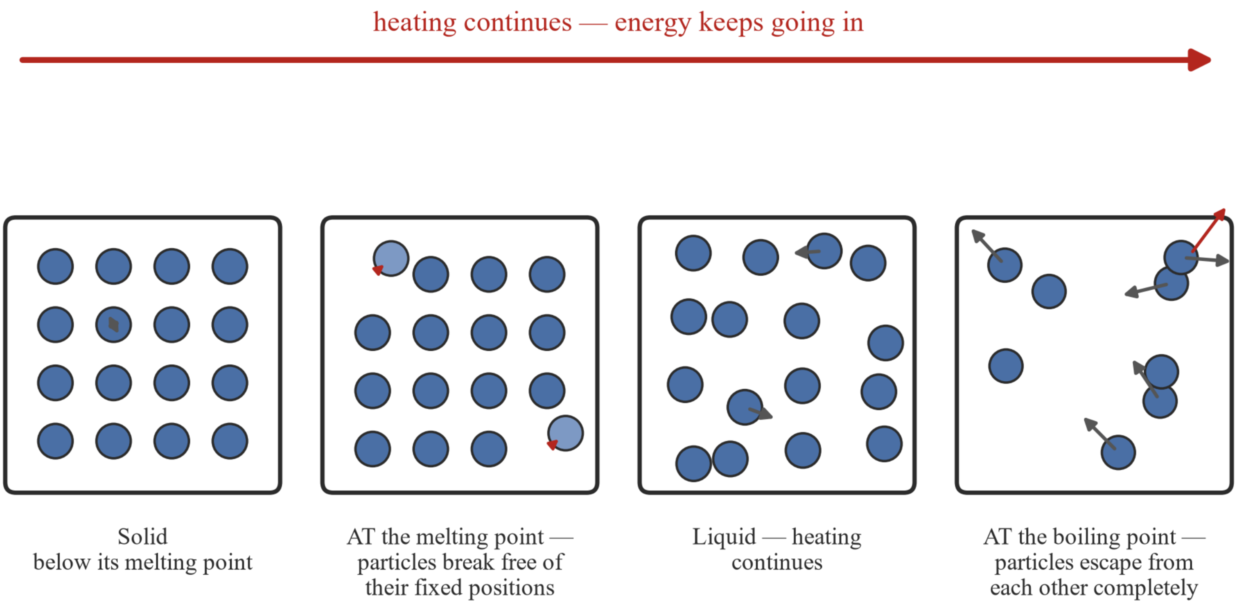


The particle toolkit from subtopic 10A: three boxes for solid, liquid and gas; the solid shows particles in a regular, close pattern with tiny vibration arrows, the liquid shows close particles sliding past each other, and the gas shows far-apart particles moving in all directions

Every explanation in this subtopic uses the same three ideas: how strongly the particles attract, how far apart they sit, and how they move.

Melting point and boiling point

Heat a solid and its particles vibrate more and more. At the **melting point** the vibration is strong enough for the particles to break free of their fixed positions — the solid becomes a liquid. Keep heating and, at the **boiling point**, the particles break free of each other completely — the liquid becomes a gas. The stronger the attraction between the particles, the more heating it takes, so the higher the melting point and boiling point.

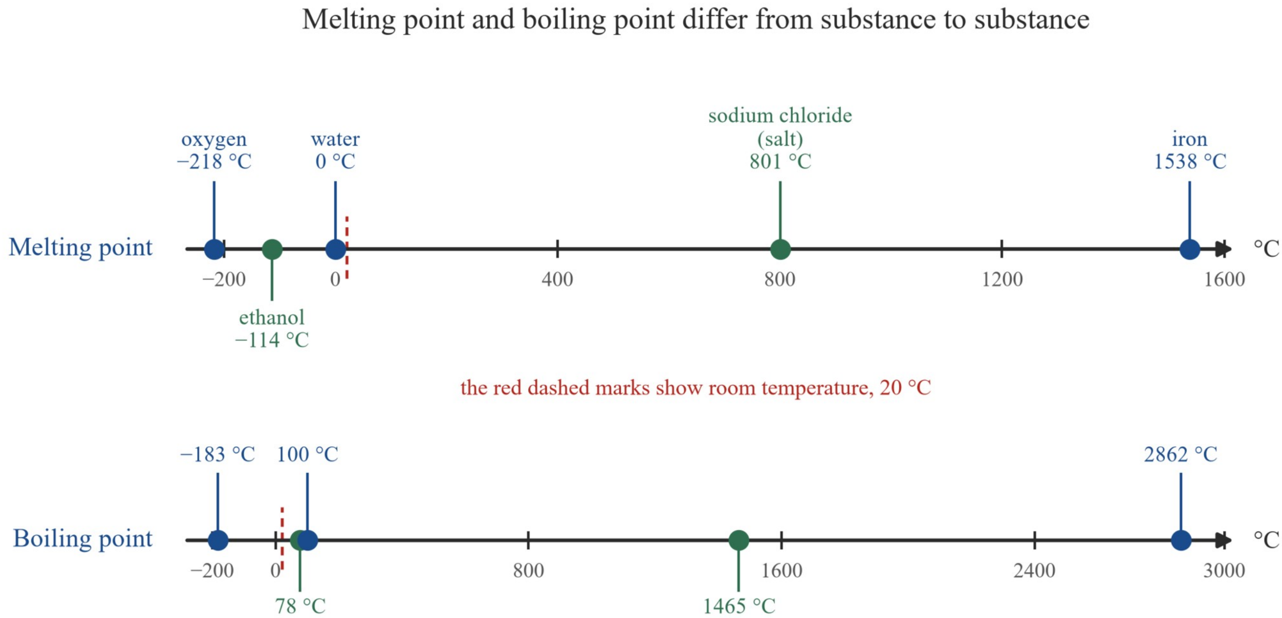


A pure substance melts and boils at its own fixed temperatures: melting point and boiling point.
Between them the substance is a liquid; below the melting point a solid; above the boiling point a gas.

Four frames along a heating arrow: below the melting point the particles sit in a fixed pattern; at the melting point some particles break free of their fixed positions; as a liquid the particles stay close and slide; at the boiling point the particles escape from each other completely as a gas

A pure substance melts and boils at its own fixed temperatures. That is why melting point and boiling point help identify a substance, and why they let us work out the state of a substance at any temperature:

- below the melting point → solid
- between the melting point and the boiling point → liquid
- above the boiling point → gas



The attractions between particles are different in different substances: the stronger the attraction,
the higher the temperature needed to melt the solid or to boil the liquid. Values are typical values, given for practice.

Two number lines in degrees Celsius, one for melting point and one for boiling point, with oxygen, ethanol, water, sodium chloride and iron marked at their tabled values; red dashed marks show room temperature, 20 degrees

Substance	Melting point	Boiling point	State at room temperature (20 °C)
oxygen	−218 °C	−183 °C	gas
ethanol	−114 °C	78 °C	liquid
water	0 °C	100 °C	liquid
sodium chloride (salt)	801 °C	1465 °C	solid
iron	1538 °C	2862 °C	solid

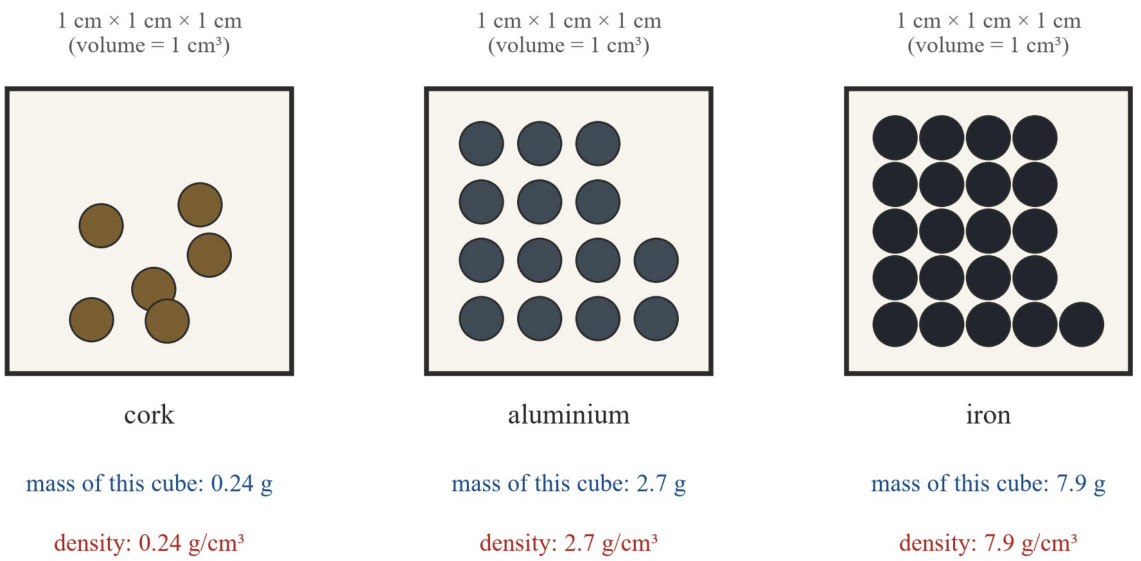
(Typical values, given for practice.)

Read the table with the rules above. Oxygen boils at −183 °C, far below room temperature, so at 20 °C oxygen is a gas. Iron melts at 1538 °C, far above room temperature, so at 20 °C iron is a solid. And the particle story behind the pattern: salt and iron hold their particles together with much stronger attraction than oxygen does, so they need much higher temperatures to melt and boil.

Density — how much mass is packed into a space

Density is the mass of a substance per unit volume. Two cubes the same size, one of cork and one of iron, have very different masses: the iron cube packs more mass of particles into the same space. Density is that comparison made exact — mass per unit volume.

Same volume, different mass — that is what density measures



Each cube is the same size, but the iron cube packs the most mass of particles into that space.
Density = mass per unit volume. Values are typical values, given for practice.

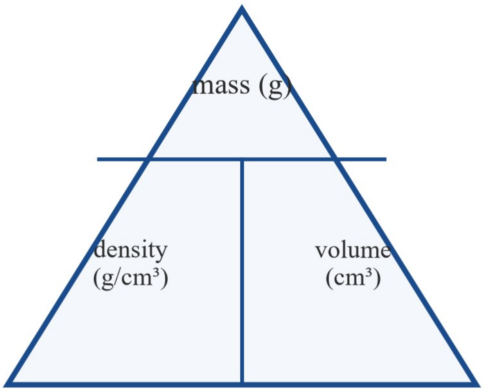
Three 1 cm cubes of cork, aluminium and iron, each drawn with its particles; the cork cube holds few particles, the aluminium cube more and the iron cube the most; each cube is labelled with its mass and its density in grams per cubic centimetre

Density is worked out as mass divided by volume:

density = mass ÷ volume

With mass in grams (g) and volume in cubic centimetres (cm^3), density comes out in g/cm^3. The formula triangle says the same three facts: cover the quantity you want, and read off mass = density × volume, volume = mass ÷ density, or density = mass ÷ volume. (Substituting the measured values into the formula is the maths of `VC2M7A01`; density as mass per unit volume is the rate idea of `VC2M8M05`.)

Density, mass and volume



Cover the quantity you want:
mass = density × volume, volume = mass ÷ density,
density = mass ÷ volume

Worked substitution — an aluminium block

1. Measure the sides: 2.0 cm × 3.0 cm × 5.0 cm
2. Volume = 2.0 × 3.0 × 5.0 = 30 cm^3
3. Measure the mass: 81 g
4. density = mass ÷ volume = 81 ÷ 30
5. density = 2.7 g/cm^3

(The two measured values set the answer's precision: 2.7 g/cm^3.)

The density formula triangle with mass on top and density and volume below, beside a worked substitution for an aluminium block: volume 2.0 cm × 3.0 cm × 5.0 cm = 30 cm^3, mass 81 g, density = 81 ÷ 30 = 2.7 g/cm^3

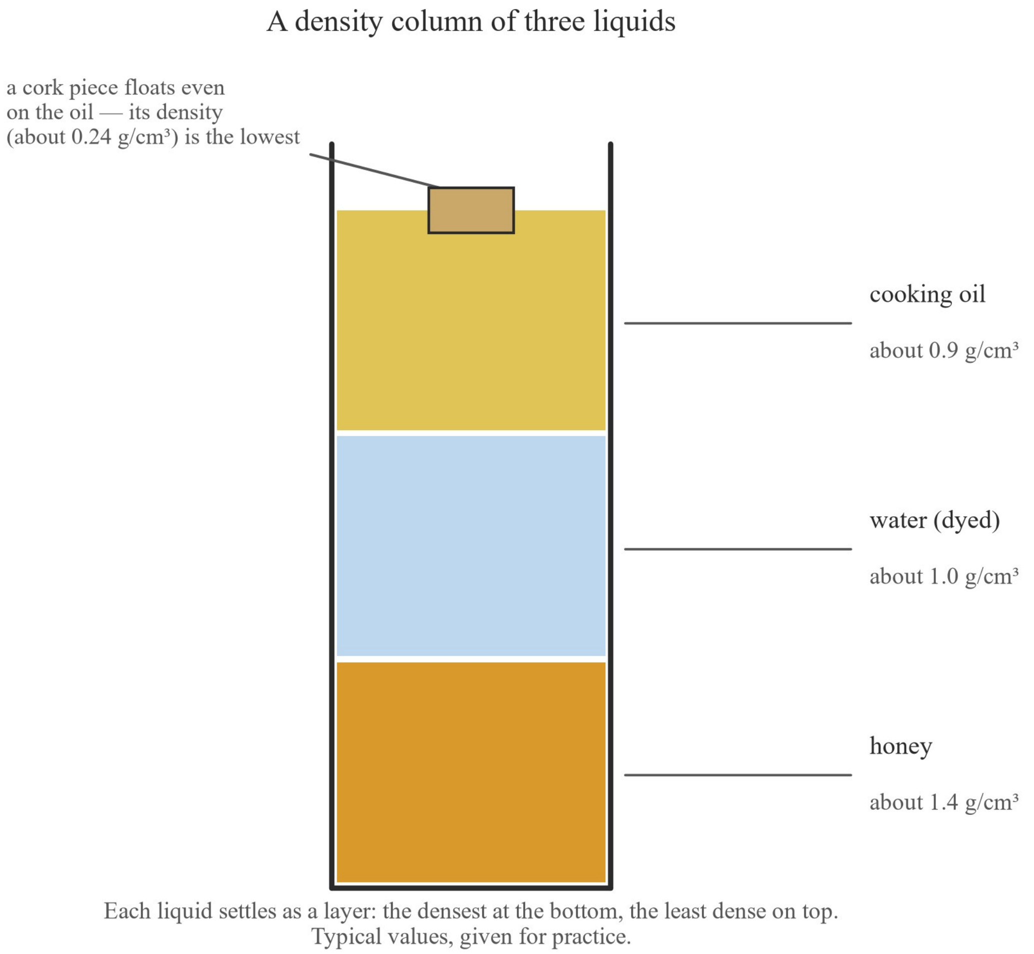
The volume of a rectangular block is length × width × height — the right-prism volume from `VC2M7M02` and `VC2M8M02`.

One famous density fact: ice floats on liquid water because ice is *less* dense than the water under it. Most substances are denser as solids than as liquids; water is the odd one out, and that oddness is why lakes freeze from the top down.

Building a density column (`VC2S8U05.E06`)

Pour honey, then dyed water, then cooking oil slowly down the side of a clear cylinder and the liquids settle as three layers, with a cork piece floating on top of the lot.

- **Equipment:** a clear cylinder or tall glass, a spoon for slow pouring, honey, water dyed with food colouring, cooking oil, and a small cork piece.
- **Risk:** a low-risk activity, run with the risk-management guidance from Science ASSIST (see Sources): wear safety glasses as for any lab work, taste nothing in the lab, wipe spills straight away so nobody slips, and handle glass with care.

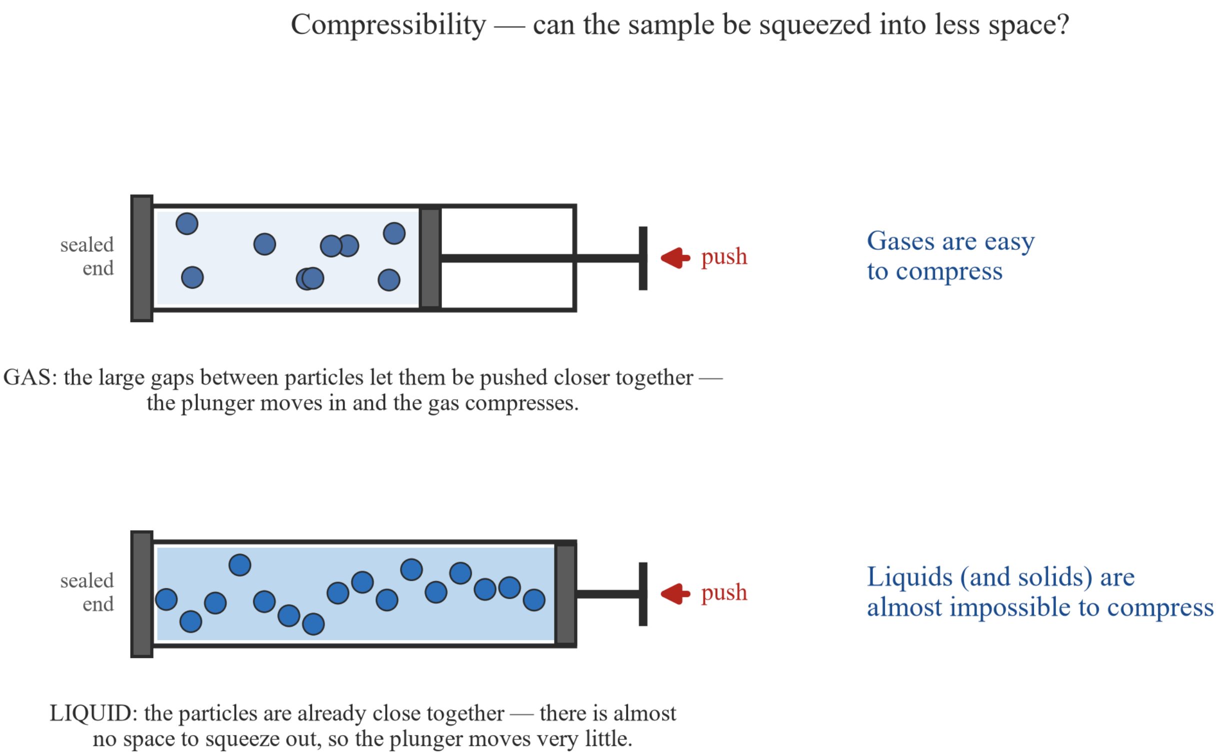


A density column in a cylinder: honey at the bottom (about 1.4 g/cm³), dyed water in the middle (about 1.0 g/cm³) and cooking oil on top (about 0.9 g/cm³), with a cork piece floating on the oil

The column is density in front of your eyes: each liquid settles where its density puts it — the densest at the bottom, the least dense on top.

Compressibility — can the sample be squeezed into less space?

Compressibility is how easily a sample can be squeezed into a smaller space. Push the plunger of a sealed syringe of air and it moves in a long way; the same push on a sealed syringe of water moves it very little. Gases are easy to compress; liquids (and solids) are almost impossible to compress. The particle story is spacing: gas particles sit far apart with large empty gaps between them, so there is plenty of space to squeeze out, while the particles of a liquid or a solid already sit close together with almost no space left to remove.



Two sealed syringes with push arrows: in the gas syringe the plunger has moved in because the far-apart particles can be pushed closer together, and in the liquid syringe the plunger has moved very little because the close-together particles cannot be squeezed closer

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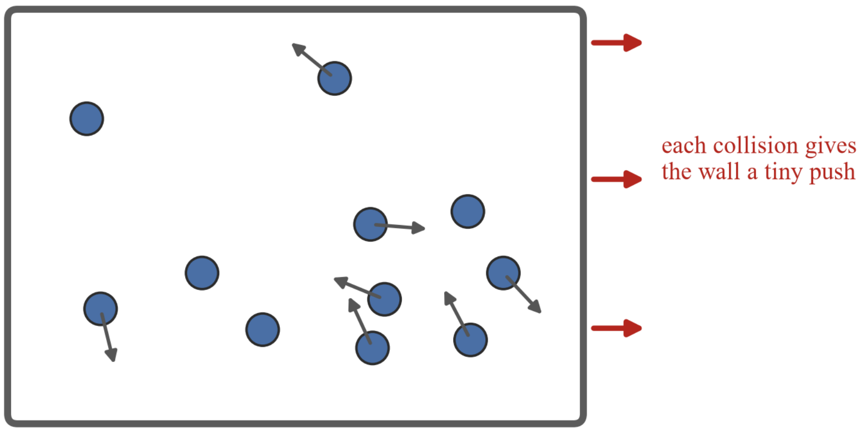
Gas pressure — billions of tiny pushes

Gas particles fly in all directions and collide with the walls of their container. Every collision gives the wall a tiny push. **Gas pressure** is all of those tiny pushes added together over the whole inside surface. It is why a blown-up balloon stays up: the gas inside pushes the skin outward as hard as the outside air pushes in.

Where gas pressure comes from



Gas particles fly in all directions and collide with the walls of their container.
Every collision pushes the wall outward a tiny amount.

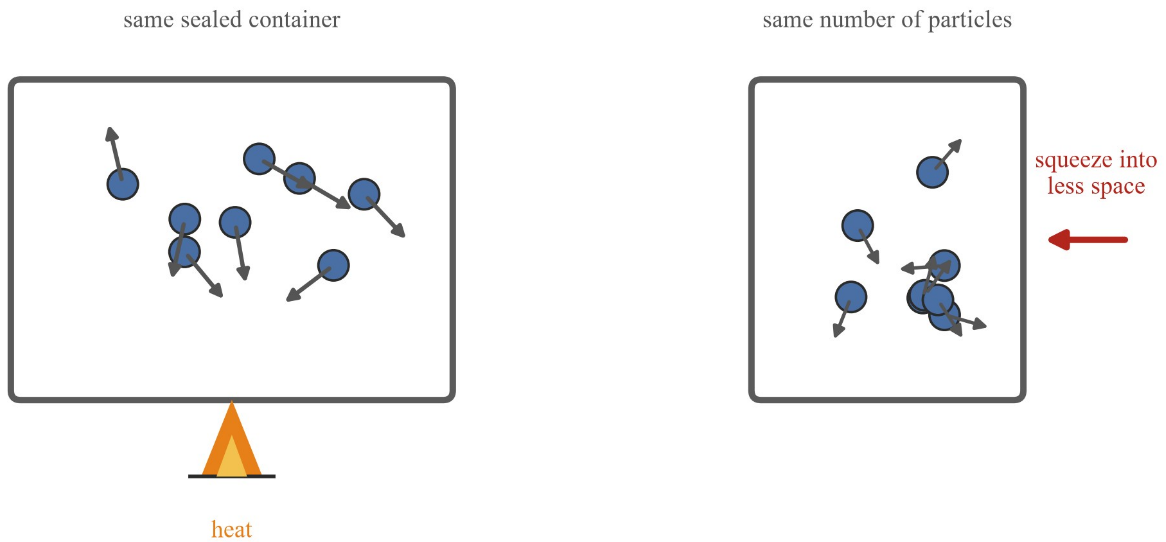
Gas pressure is all of those billions of tiny pushes, added together and spread over the whole inside surface of the container.

A sealed container with gas particles moving in all directions; red arrows at the right wall show the tiny outward push each collision gives the wall

Two changes raise the pressure of a sealed gas, and both follow from the same story:

- **HEAT it** — the particles move faster, so they hit the walls harder and more often.
- **SQUEEZE it into less space** — the same particles hit the walls more often because the walls are closer.

Two ways to raise the pressure of a sealed gas



1 HEAT the gas: particles move faster, so they hit the walls harder and more often — the pressure rises.

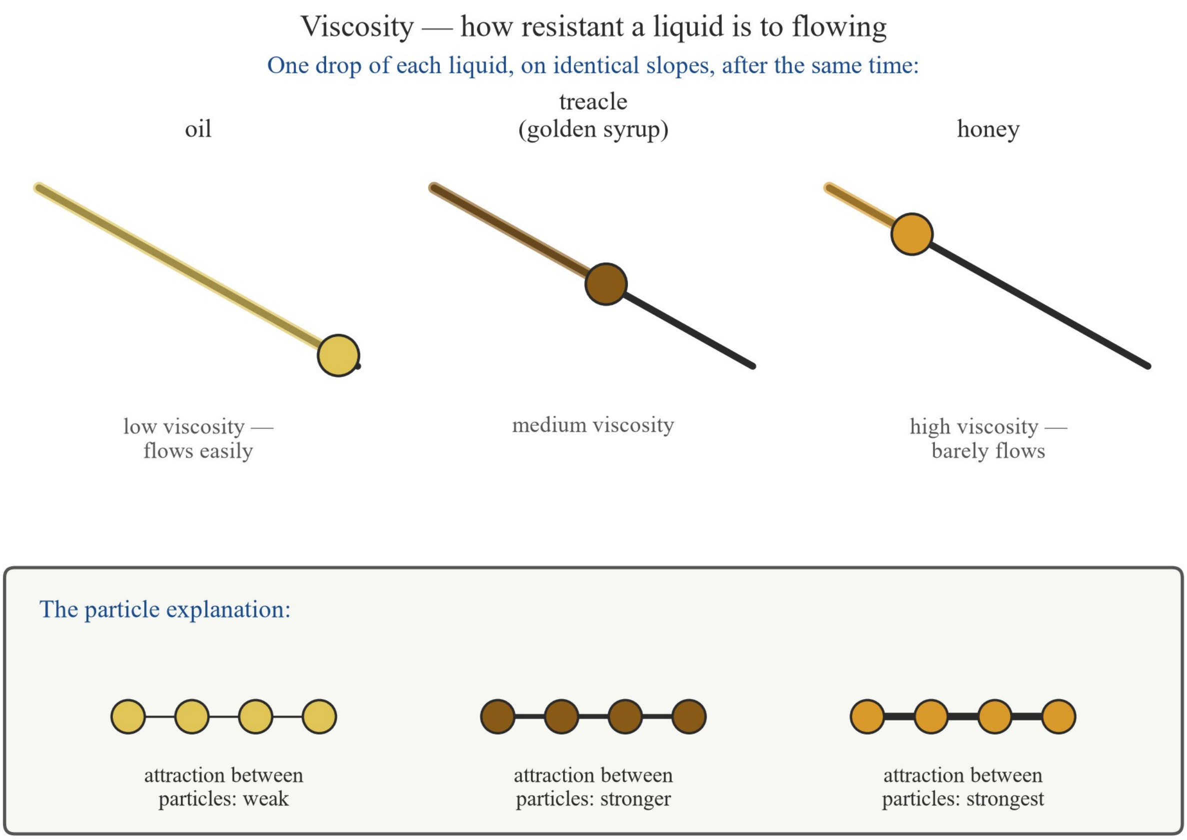
2 SQUEEZE it into less space: the same particles hit the walls more often because the walls are closer — the pressure rises.

Two sealed containers: one heated by a flame, its faster particles hitting the walls harder and more often; one squeezed smaller, the same number of particles hitting the closer walls more often; both changes raise the pressure

This is the science behind the warning on aerosol cans and gas canisters — *do not burn or puncture*. Heating or squeezing makes the pressure inside climb until the container can burst.

Viscosity — how easily a liquid flows

Viscosity is how strongly a liquid resists flowing. Race one drop each of oil, treacle and honey down identical slopes: the oil runs away, the treacle follows slowly, and the honey moves very little. The particle story is attraction: the stronger the attraction between a liquid's particles, the harder it is for them to slide past each other, and the more slowly the liquid flows (this is the comparison of `VC2S8U05.E05`).



Stronger attraction between particles makes it harder for them to slide past each other — the liquid flows more slowly.

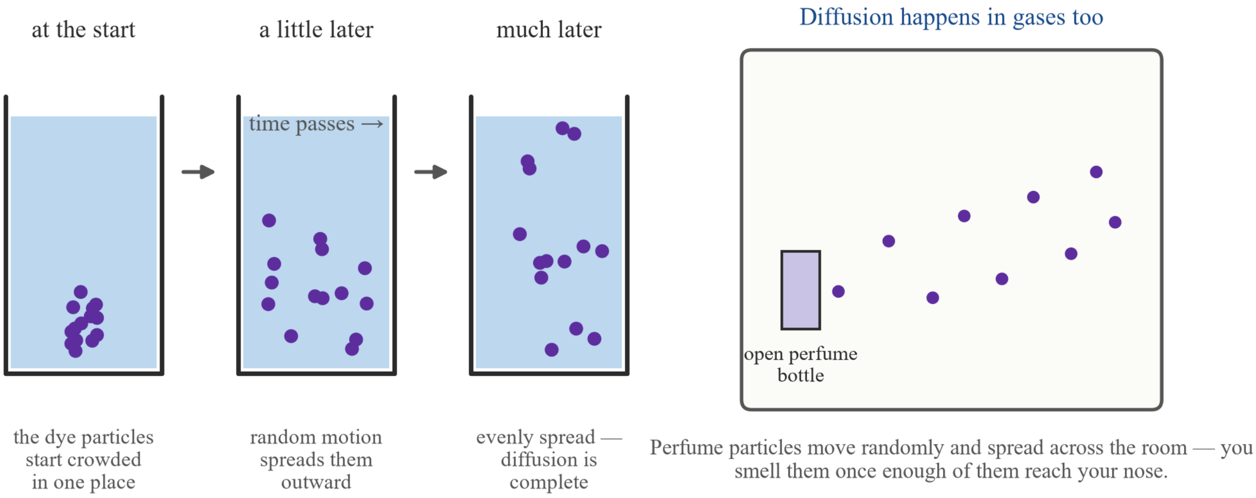
Three identical slopes with one drop of each liquid after the same time: the oil drop has run furthest, the treacle drop part way and the honey drop has moved very little; below, particle strips show the attraction between particles weak in oil, stronger in treacle and strongest in honey

Warmth thins a liquid: warm honey pours far more easily than cold honey, because warming lets the particles slide past each other more easily. It is why a honey jar says to stand it in warm water if the honey has gone thick.

Diffusion — spreading from crowded to uncrowded

You met **diffusion** earlier in this book (subtopic 8B): the spreading of a substance from where there is a lot of it to where there is little, until it is even. Drop dye into still water and, without any stirring, it spreads until the colour is even. Open a perfume bottle and, from across the room, you can smell it. Both are diffusion — the particles move randomly and spread out. In a gas the particles are far apart and move fast, so diffusion is quick; in a liquid it is slower but it still happens. Warmth speeds diffusion up, because warmer particles move faster.

Diffusion — particles spreading out from where they are crowded



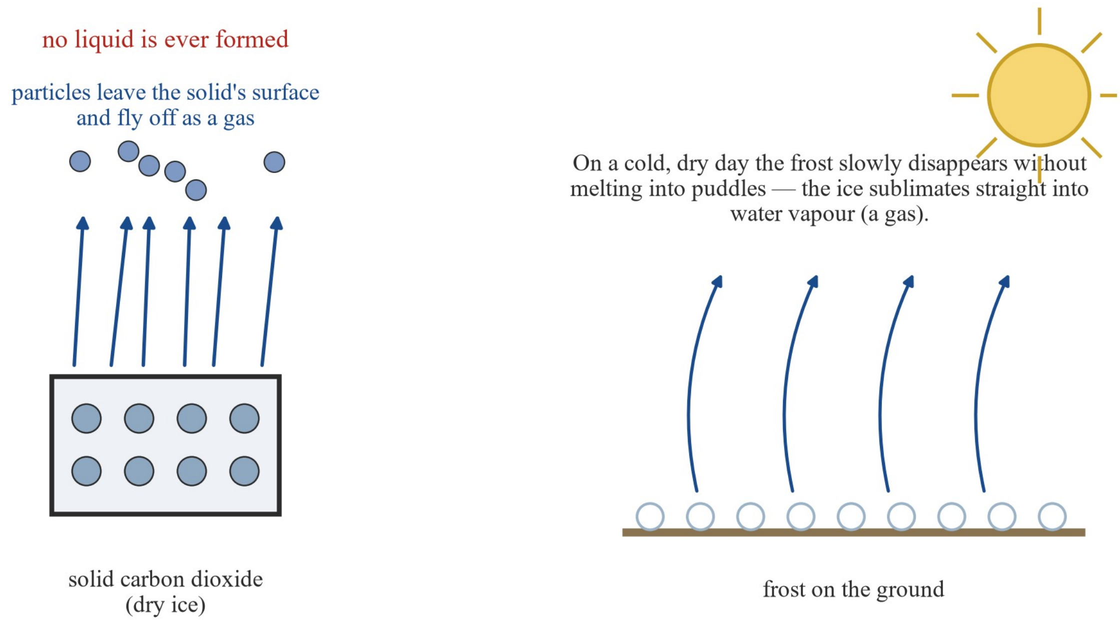
Left: three beakers over time show a drop of dye starting crowded in one place, spreading outward, then evenly spread through the water; right: a room with an open perfume bottle, its particles spreading across the room

The particle story: nothing pushes the dye or the perfume out. Each particle moves randomly, and random movement starting from a crowded place ends up spread out.

Sublimation — solid straight to gas

Sublimation is a solid turning straight into a gas, with no liquid stage in between. Solid carbon dioxide (dry ice) does this at ordinary room conditions: it shrinks away as a gas and never leaves a puddle, which is why dry ice is used for fog effects. Frost on a cold, dry day slowly disappears the same way — the ice sublimes straight into water vapour.

Sublimation — a solid turns straight into a gas, with no liquid stage

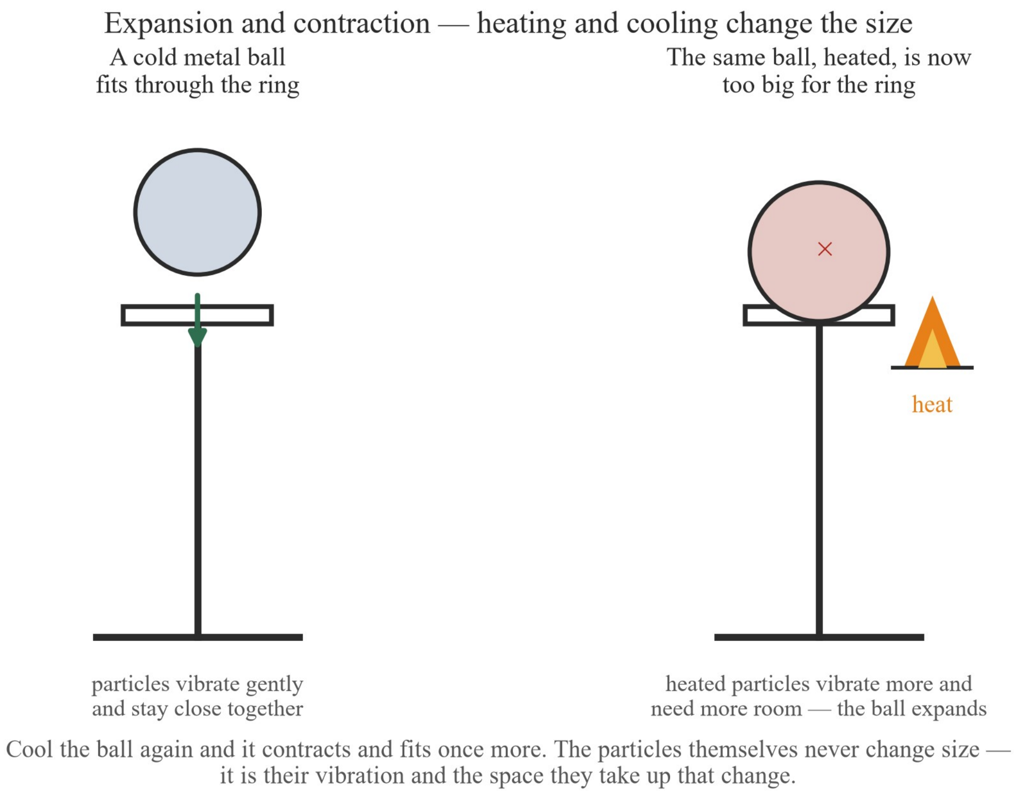


Left: a block of solid carbon dioxide (dry ice) with surface particles leaving the solid and flying off as a gas — no liquid is ever formed; right: frost on the ground on a cold, dry day, with ice particles subliming straight into water vapour

The particle story: even in a solid, the surface particles vibrate; in a substance that sublimes, the attraction holding the surface particles is weak enough that some break straight free as a gas.

Expansion and contraction — heating and cooling change the size

Most substances **expand** (get bigger) when heated and **contract** (get smaller) when cooled. The classic show is the ball and ring: a cold metal ball fits through the ring; heat the ball and it no longer fits; cool it and it fits again.



The ball and ring: a cold metal ball fits through the ring, and the same ball heated is too big and rests on the ring; captions note that the heated particles vibrate more and need more room, and that cooling the ball makes it fit once more

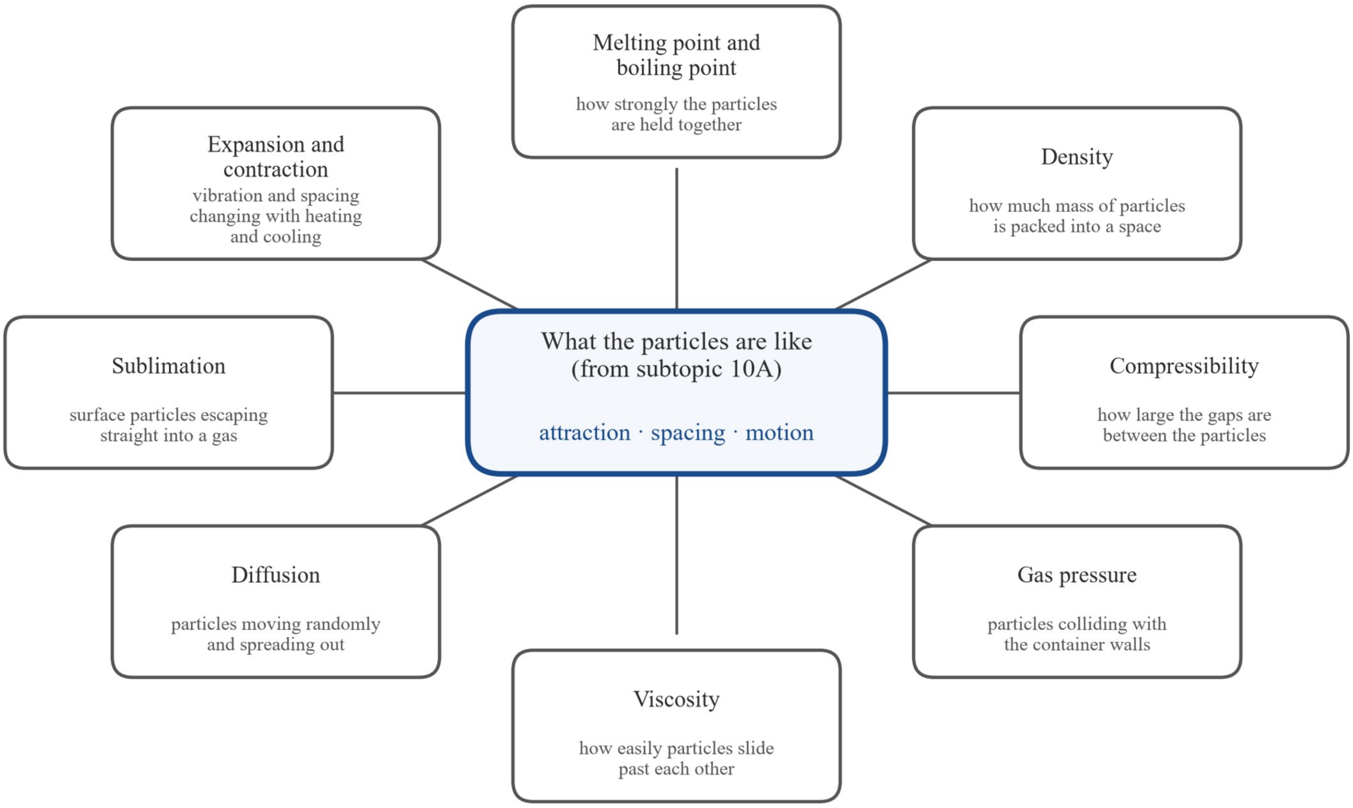
The particle story: heating makes the particles vibrate more, and they need a little more room, so the substance takes up more space; cooling does the reverse. The important fine point: **the particles themselves never change size** — only their vibration and the space they take up change.

The same idea sits behind everyday design: bridges and railway lines are built with gaps so summer expansion has somewhere to go; power lines are hung slack so winter contraction does not pull them tight; and a stuck jar lid loosens under hot water as the metal lid expands.

One model explains the lot

Every property in this subtopic — melting point and boiling point, density, compressibility, gas pressure, viscosity, diffusion, sublimation, and expansion and contraction — is explained with the same three particle ideas from 10A: attraction, spacing and motion. That is the power of the particle and kinetic theories of matter: one small model explains a great deal (this is the compare-and-explain move of `VC2S8U05.E04`).

One model explains the lot



A summary map: a central box, what the particles are like (from subtopic 10A) — attraction, spacing, motion, with spokes to eight boxes, one for each property, each giving its particle explanation in one line

Words to know in 10B

Word	What it means here
melting point	the temperature where a solid on its own becomes a liquid
boiling point	the temperature where a liquid becomes a gas throughout
density	the mass of a substance per unit volume (here in g/cm^3)
mass	how much matter something has, in grams (g) or kilograms (kg)
volume	the space something takes up, in cubic centimetres (cm^3) or millilitres (mL)
compressibility	how easily a sample can be squeezed into a smaller space
gas pressure	the push of gas particles colliding with a surface, added together
viscosity	how strongly a liquid resists flowing
diffusion	the spreading of a substance from where there is a lot of it to where there is little
sublimation	a solid turning straight into a gas, with no liquid stage
expansion	getting bigger when heated
contraction	getting smaller when cooled

Worked examples

Example 1 — scaffolded

An aluminium block measures 2.0 cm × 3.0 cm × 5.0 cm and its mass is 81 g. Work out its density.

Working	Comment
1. Volume = 2.0 × 3.0 × 5.0 = 30 cm^3	Volume of a rectangular block = length × width × height (`VC2M7M02/VC2M8M02`).
2. density = mass ÷ volume = 81 ÷ 30	Substitute the two measured values into the formula (`VC2M7A01`).
3. density = 2.7 g/cm^3	∴ the block's density is 2.7 g/cm^3 — the tabled value for aluminium.

Example 2 — scaffolded

Use the melting-point and boiling-point table to work out the state at room temperature (20 °C) of (a) oxygen, (b) ethanol and (c) iron.

Working	Comment
(a) Oxygen: 20 °C is above its boiling point (−183 °C) → **gas**.	Above the boiling point, the substance is a gas.
(b) Ethanol: 20 °C is above its melting point (−114 °C) and below its boiling point (78 °C) → **liquid**.	Between the two points, the substance is a liquid.
(c) Iron: 20 °C is below its melting point (1538 °C) → **solid**.	Below the melting point, the substance is a solid.

Example 3 — unscaffolded

A sealed syringe of air can be pushed in a long way; a sealed syringe of water moves very little. Explain the difference using particles.

Gas particles sit far apart, with large empty gaps between them, so a push can bring the particles closer together — the gas compresses. Liquid particles already sit close together, with almost no spare space between them, so there is almost nothing to squeeze out — the liquid compresses very little. ∴ the difference in compressibility is a difference in the spacing of the particles.

Example 4 — unscaffolded

A dented table-tennis ball (not cracked) pops back into shape when it is stood in warm water. Explain why, using gas pressure and particles.

The ball traps a sealed pocket of gas. Warming the ball makes those gas particles move faster, so they hit the inside walls harder and more often, and the pressure inside rises. The extra push from inside presses the dent back out. ∴ heating a sealed gas raises its pressure — the same story as the heated container in the pressure figure.

Practice questions

Scaffolded

Q1. State what *density* means, in words.

Q2. A liquid sample has a mass of 95 g and a volume of 50 cm^3. Calculate its density.

Q3. Iron has a density of 7.9 g/cm^3. Calculate the mass of a piece of iron with a volume of 20 cm^3.

Q4. Ethanol melts at −114 °C and boils at 78 °C. (a) State the state of ethanol at room temperature (20 °C). (b) Give the reason, using its melting and boiling points.

Q5. Complete the explanation: “A gas compresses easily because its particles …, while a liquid compresses very little because its particles …”

Q6. A density column is built from honey, dyed water and cooking oil. (a) List the three layers from the bottom up. (b) State the reason for that order.

Unscaffolded

Q7. A bottle of perfume is opened at the front of a room, and soon people at the back can smell it. Explain how, using particles.

Q8. A sealed can of gas is warmed over a flame. Explain why the pressure inside the can rises.

Q9. Honey flows more slowly than oil. Explain why, using the attraction between particles.

Q10. A block of dry ice shrinks on the bench and never leaves a puddle. Name the change of state and explain it with particles.

Q11. A metal ball fits through a ring when cold, will not fit after heating, and fits again after cooling. Explain all three observations, and state clearly whether the particles themselves change size.

Q12. A stone is lowered into a measuring cylinder of water, and the water level rises from 40 cm^3 to 52 cm^3. The stone’s mass is 36 g. Calculate the density of the stone.

Q13. Cooking oil has a density of about 0.92 g/cm^3. Calculate the mass of 250 cm^3 of this oil.

Q14. The label on an aerosol can says *do not burn*. Explain this warning using what happens to a sealed gas when it is heated.

Answers

Q1. Density is the mass of a substance per unit volume. **Q2.** 95 ÷ 50 = 1.9 g/cm³. **Q3.** mass = density × volume = 7.9 × 20 = 158 g. **Q4.** (a) Liquid. (b) 20 °C is above ethanol's melting point (−114 °C) and below its boiling point (78 °C). **Q5.** …sit far apart with large empty gaps between them, so they can be pushed closer together; …already sit close together with almost no space to squeeze out. **Q6.** (a) Honey, then water, then oil. (b) The densest liquid settles at the bottom and the least dense on top; each liquid floats on the one denser than itself. **Q7.** The perfume particles move randomly and spread out (diffusion) from where they are crowded (the bottle) through the rest of the room; you smell them when enough of them reach your nose. **Q8.** Warming makes the gas particles move faster, so they hit the walls harder and more often — the pressure rises. **Q9.** The attraction between honey's particles is stronger than between oil's, so honey's particles find it harder to slide past each other — honey flows more slowly (it is more viscous). **Q10.** The change is sublimation: surface particles of the solid break straight free as a gas, with no liquid stage — so no puddle is left. **Q11.** Heated, the particles vibrate more and need more room, so the ball expands and will not fit; cooled, the vibration eases and the ball contracts and fits again. The particles themselves never change size. **Q12.** Volume of the stone = 52 − 40 = 12 cm³; density = 36 ÷ 12 = 3.0 g/cm³. **Q13.** mass = density × volume = 0.92 × 250 = 230 g. **Q14.** Burning heats the sealed gas inside; the particles move faster and hit the walls harder and more often, so the pressure rises until the can can burst.

Fully-worked solutions

Q1. Density is **the mass of a substance per unit volume** *(1 mark)*.

Q2. density = mass ÷ volume = 95 ÷ 50 *(1 mark)* = **1.9 g/cm³** *(1 mark)*.

Q3. mass = density × volume = 7.9 × 20 *(1 mark)* = **158 g** *(1 mark)*.

Q4. (a) Ethanol is a **liquid** at 20 °C *(1 mark)*. (b) 20 °C is **above its melting point** (−114 °C) **and below its boiling point** (78 °C), which is the liquid range *(1 mark)*.

Q5. A gas compresses easily because its particles **sit far apart with large empty gaps between them, so they can be pushed closer together** *(1 mark)*, while a liquid compresses very little because its particles **already sit close together, with almost no space to squeeze out** *(1 mark)*.

Q6. (a) From the bottom up: **honey, water, oil** *(1 mark)*. (b) The liquids settle in density order — **the densest at the bottom and the least dense on top**, each liquid floating on the one denser than itself *(1 mark)*.

Q7. The perfume particles **move randomly and spread out** — diffusion — from the crowded bottle through the room *(1 mark)*; people at the back smell the perfume **when enough particles reach their noses** *(1 mark)*.

Q8. Warming makes the gas particles **move faster** *(1 mark)*, so they **hit the walls harder and more often, and the pressure rises** *(1 mark)*.

Q9. The attraction between honey's particles is **stronger** than between oil's *(1 mark)*, so honey's particles **find it harder to slide past each other and the liquid flows more slowly** *(1 mark)*.

Q10. The change of state is **sublimation** *(1 mark)*: surface particles of the solid **break straight free as a gas, with no liquid stage**, so the block shrinks and leaves no puddle *(1 mark)*.

Q11. Heated, the particles **vibrate more and need more room, so the ball expands** and will not fit *(1 mark)*; cooled, the vibration eases and **the ball contracts**, so it fits again *(1 mark)*; the **particles themselves never change size** — only their vibration and the space they take up change *(1 mark)*.

Q12. Volume of the stone = 52 − 40 = **12 cm³** *(1 mark)*; density = mass ÷ volume = 36 ÷ 12 *(1 mark)* = **3.0 g/cm³** *(1 mark)*.

Q13. mass = density × volume = 0.92 × 250 *(1 mark)* = **230 g** *(1 mark)*.

Q14. Burning **heats the sealed gas** inside the can *(1 mark)*; the particles **move faster and hit the walls harder and more often** *(1 mark)*; the **pressure rises until the can can burst**, so the can warns *do not burn (1 mark)*.

Sources

Web sources below were retrieved 2026-08-20.

- Science ASSIST (Australian Science Teachers' Association), "Risk management", n.d. asta.edu.au

The melting-point, boiling-point and density values in the table and figures are **typical rounded values, given for practice** (simulated data for practice); the patterns they show — stronger attraction going with higher melting and boiling points, and denser liquids settling lower — are the real behaviour of substances.

Elaboration contexts used: `VC2S8U05.E04` (comparing the properties of different substances and explaining differences using particle theory), `VC2S8U05.E05` (comparing the viscosity of honey, treacle and oil, and developing representations to suggest an explanation) and `VC2S8U05.E06` (constructing a density column using liquids of different densities).

Pure substances and mixtures: elements, compounds, solutions, and uniform against non-uniform composition, modelled with particles

What we teach here — `VC2S8U06` (Victorian Curriculum F–10 Version 2.0, Science, Levels 7 and 8): *"matter can be classified as pure substances such as elements and compounds or impure substances such as mixtures (including solutions), and can be modelled using the particle model; mixtures may have a uniform (homogeneous) or non-uniform (heterogeneous) composition and can be separated based on the properties of their components using techniques including filtration, decantation, evaporation, crystallisation, magnetic separation, distillation and chromatography"* **This subtopic owns the classification limb**: matter classified as pure substances (elements and compounds) or impure substances (mixtures, including solutions), uniform (homogeneous) against non-uniform (heterogeneous) composition, all modelled with particles. The second limb — separating mixtures based on the properties of their components, using the seven named techniques — belongs to the partner subtopic **10D** († split delivery, D6). Here we *sort* matter into its families; in 10D we pull the mixtures back apart. **In our words:** every sample of matter is either one substance only — a **pure substance**, and either an **element** or a **compound** — or two or more substances together without chemical joining, a **mixture**. Look at the parts of a mixture: if every part of it has the same mix, it is **homogeneous**; if different parts have different mixes, it is **heterogeneous**. Draw any of these as particles and the differences become pictures you can see. **Achievement-standard extract served here (D13):** *"They distinguish between pure substances and mixtures, and design procedures to separate mixtures."* This subtopic owns the code (†), so the standard is printed here in full: 10C serves the "distinguish between pure substances and mixtures" move — the decision key at the end is exactly that move practised; the "design procedures to separate mixtures" move is exercised by the partner subtopic 10D, which cites this header by reference. **Elaborations drawn on:** `VC2S8U06.E01` (using representations of particles to show the difference between samples of pure substances and mixtures, and identifying examples of each) and `VC2S8U06.E02` (using coloured beads or buttons to represent different substances, and then mixing these 'particles' in different containers to demonstrate both uniform (homogeneous) and non-uniform (heterogeneous) mixtures, and to demonstrate the difference between dilute, concentrated, saturated and supersaturated solutions). **ICIP (D10):** no Aboriginal or Torres Strait Islander content is delivered in this subtopic. The only `VC2S8U06` elaboration that carries such content, `VC2S8U06.E05`, sits in the separation limb belonging to 10D and is reserved there under the ICIP decision; see the teacher-facing note at the foot of this subtopic. **Maths interlocks (D11):** none are listed for this subtopic — the work stays qualitative. We count particles in models (3 against 9) and compare amounts by eye; no rates, ratios or graphs are computed. **Authored from the CD text and the elaboration contexts (D12):** the CD names the four families — elements, compounds, mixtures, solutions — and the uniform/non-uniform distinction, but not the definitions or examples; those are authored here from the particle model built in subtopic 10A and the property ideas of subtopic 10B. The two elaborations above supply the particle-representation context (E01) and the bead-model context (E02), including dilute, concentrated, saturated and supersaturated solutions.

Word watch — *pure*. In everyday talk, *pure* means something like "nothing added that shouldn't be there" — a carton labelled *pure orange juice* has had nothing added to it. Chemistry uses the word in a stricter sense, and we set that sense here: **a pure substance is made of one substance only**. Orange juice contains water, sugars, acids and more — several substances — so to a chemist it is a mixture, however pure the carton claims it is. In this subtopic, *pure* always means the chemistry sense: one substance only. Keep the two senses apart and the whole classification follows.

Word watch — *homogeneous* and *heterogeneous*. These two words are the curriculum's own, and they say one thing each about a mixture's **composition** — what it is made of, and in what amounts. **Homogeneous** means the composition is **uniform**: take any sample from any part of the mixture and it has the same mix as any other sample. **Heterogeneous** means the composition is **non-uniform**: samples from different parts have different mixes. Salt water is homogeneous; muddy water is heterogeneous. The test is always the same: *is the mix the same in every part?*

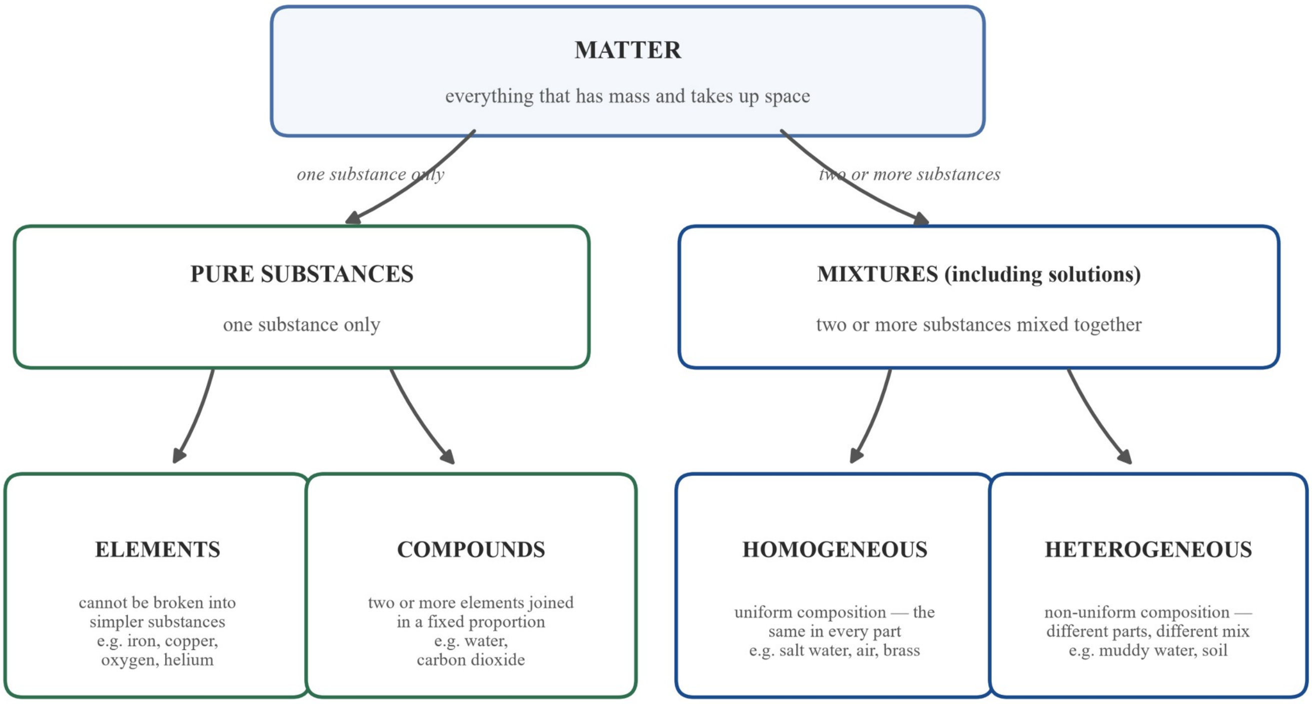
Word watch — *solution*. In everyday talk a *solution* is an answer to a problem. In chemistry a **solution** is a particular kind of mixture: a **homogeneous mixture that forms when one substance dissolves in another**. The substance that dissolves is the **solute**; the substance it dissolves in is the **solvent**. In salt water, salt is the solute and water is the solvent. When this book says *solution*, it always means the chemistry sense.

Theory

The big sort — pure substances against mixtures

Everything around you is **matter**, and in subtopic 10A you met the particle model that describes it: matter is made of unbelievably tiny particles, with space between them, always moving and always attracting each other. Now we use that model to sort matter into families. The first question to ask of any sample is simple: **is it one substance only, or two or more substances mixed together?**

- A **pure substance** is matter made of **one substance only** — one kind of particle, or one kind of joined particle-group, all the way through. Pure substances come in two families: **elements** and **compounds**.
- A **mixture** is matter made of **two or more substances mixed together** without being chemically joined. Mixtures are sometimes called **impure substances** — "impure" here just means "more than one substance", not "dirty" or "bad". **Solutions are mixtures** — they get their own family name because they are the special case where the mixing is so even that the mixture looks like one substance.



The sorting of matter taught in this subtopic: pure substances (elements and compounds) against mixtures (homogeneous and heterogeneous).

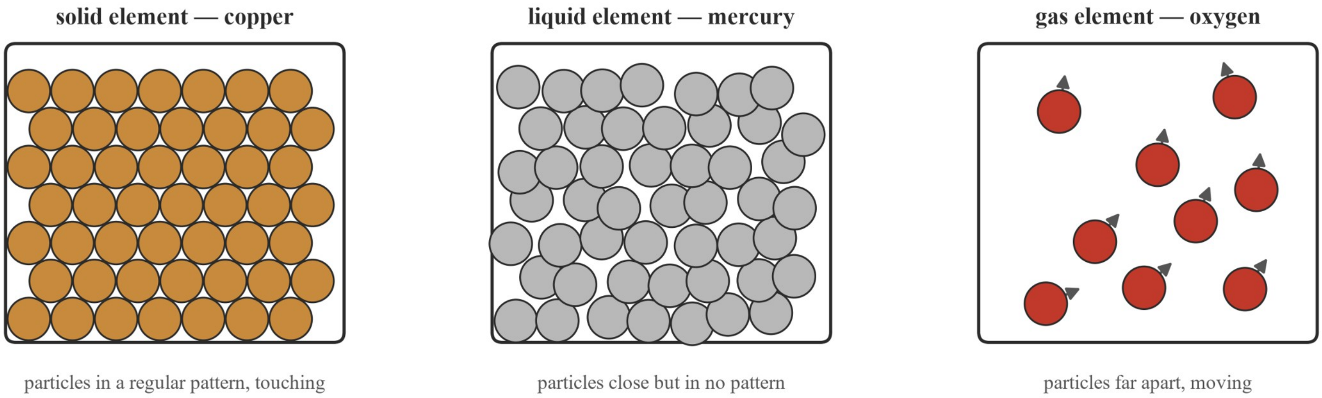
The classification of matter taught in this subtopic, as a tree: MATTER at the top, splitting into PURE SUBSTANCES, one substance only, and MIXTURES, including solutions, two or more substances mixed together; pure substances split into ELEMENTS, which cannot be broken into simpler substances, with examples iron, copper, oxygen and helium, and COMPOUNDS, two or more elements joined in a fixed proportion, with examples water and carbon dioxide; mixtures split into HOMOGENEOUS, uniform composition the same in every part, with examples salt water, air and brass, and HETEROGENEOUS, non-uniform composition with different parts having different mix, with examples muddy water and soil

Every classification you make in this subtopic is a walk down that tree, and the decision key near the end turns the walk into steps anyone can follow.

Elements — one kind of particle, and nothing simpler

An **element** is a pure substance that **cannot be broken down into simpler substances**. It is the simplest kind of matter there is: in an element, **every particle is the same kind**. Copper, oxygen, helium, iron, gold, aluminium — each is an element, and each is one kind of particle all the way through.

Elements are not all solids, and they are not all alike in any other simple way. At room temperature (about 20 °C) the element copper is a solid, the element mercury is a liquid, and the element oxygen is a gas — and in every one of them the particles are all one kind:



In an element every particle is the same kind — whatever the state. Elements can be solids, liquids or gases at room temperature.

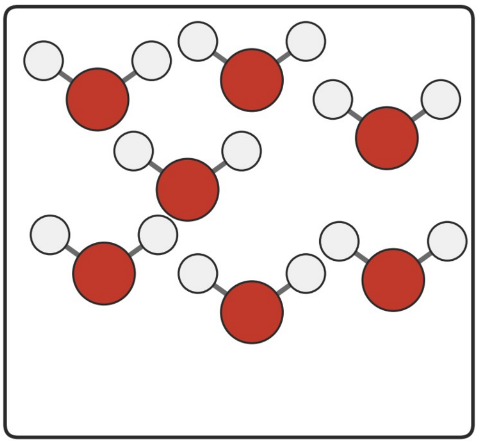
Three particle panels of elements in three different states at room temperature: solid copper as one kind of particle in a regular pattern, touching; liquid mercury as one kind of particle close together but in no pattern; and gas oxygen as one kind of particle far apart with motion arrows; the caption notes that in an element every particle is the same kind, whatever the state

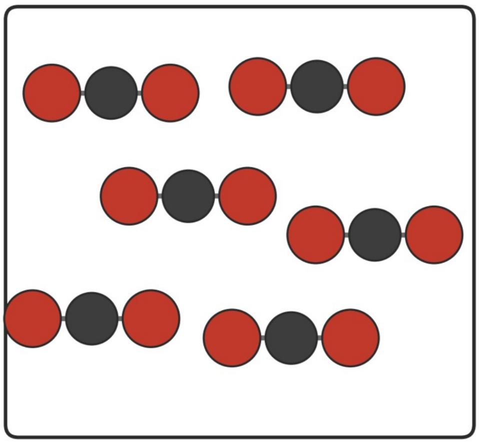
The numbers tell you how different one element can be from another. Copper melts at 1085 °C, so a copper wire stays solid in any heat your home can make. Mercury melts at −39 °C, which is far below any winter night in Victoria — that is why mercury is a liquid at room temperature, and why it was once used inside thermometers. (These melting points are standard table values, given for practice.) Chapter 11 will return to the elements and meet the short symbols chemists use to write their names; here, their names in words are enough.

Compounds — parts joined, always the same recipe

A **compound** is a pure substance whose particles are made of **two or more different kinds of smaller parts joined together — always in the same fixed proportion**. Every particle of a given compound is identical to every other particle of it: same parts, same numbers of parts, same recipe.

Take water. Every particle of water is two hydrogen parts joined to one oxygen part — never one and one, never three and one. Carbon dioxide works the same way: every particle is one carbon part joined to two oxygen parts. The recipe never varies, and that fixed recipe is what makes each compound one single substance.





A compound behaves differently from the elements inside it: hydrogen burns, oxygen feeds fires — joined together they make water, the substance used to put fires out.

Two particle panels of compounds: water, where every particle is two small hydrogen parts joined to one larger oxygen part in a bent shape, and carbon dioxide, where every particle is one carbon part joined between two oxygen parts in a line; both panels show all particles identical, one substance only; a footer notes that a compound behaves nothing like the elements inside it, hydrogen burns and oxygen feeds fires, but joined together they make water, the substance used to put fires out

The surprise about compounds is that **a compound behaves nothing like the parts it is made from**. Hydrogen is a gas that burns; oxygen is a gas that feeds fires — join them in water's fixed recipe and you get the liquid we use to put fires out. In the same spirit, look at an old steel nail: the iron in the nail joins with oxygen from the air to make rust — a crumbly, red-brown coating, nothing like the hard, shiny metal it came from. When parts join to make a compound, the old properties go and new ones arrive. That is how you can tell a compound is not just a mixture: in a mixture the parts keep their own properties, and in a compound they do not.

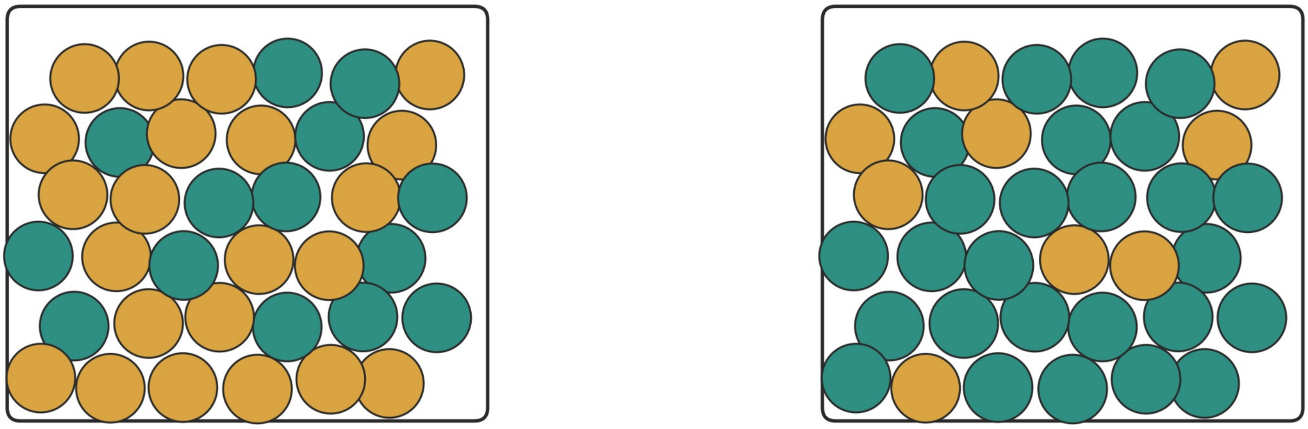
One more idea to hold for Chapter 11: an element cannot be broken into simpler substances, but a compound can be broken apart — into the simpler parts it is made from — by chemical change. Breaking a compound apart takes more than stirring or heating gently, and how to recognise that kind of change is the work of subtopics 11B and 11C.

Mixtures — together, not joined

A **mixture** is two or more substances together **without chemical joining**. The particles of each substance sit side by side, but nothing joins them into new particles. Two big ideas follow from that:

- **The amounts can vary.** Add a little salt to water or a lot — either way it is still “salt and water”, the same kind of mixture. A compound has a fixed recipe; a mixture has none.
- **Every part keeps its own properties.** The salt in salt water is still salty; the iron filings mixed through sand are still magnetic. That single fact is what makes separation possible — in the next subtopic, 10D, we use a property the parts differ in to pull every mixture back apart.

a mixture of two substances | **the same two substances — different amounts**



gold and teal particles mixed together, not joined

a mixture's amounts can vary and still be the same kind of mixture

In a mixture the particles of each substance keep their own properties. No joining, no fixed proportion.

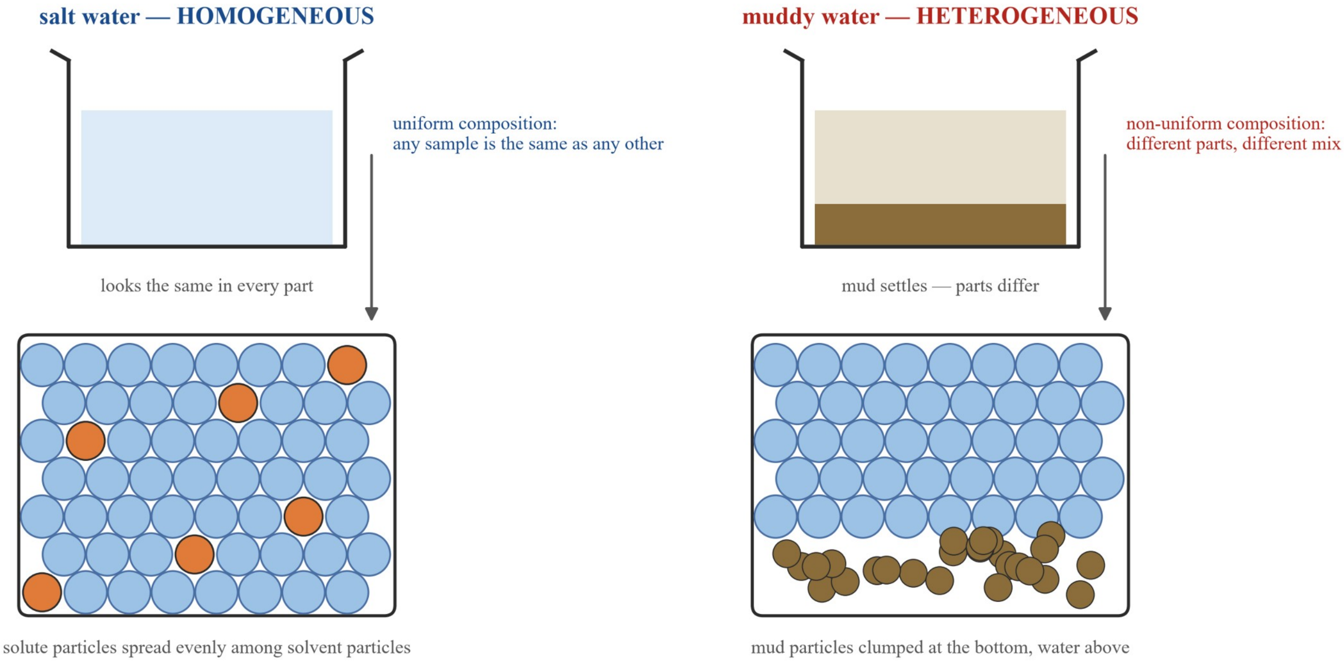
Two particle panels of the same mixture in different proportions: gold and teal particles mixed together without joining, first with many gold and few teal, then with few gold and many teal; the caption notes that a mixture's amounts can vary and still be the same kind of mixture, with no joining and no fixed proportion

Most of the matter you meet in a day is mixture, not pure substance: the air you breathe, sea water, soil, milk in your cereal, the steel in a spoon. Truly pure substances are rarer than you think — even rainwater carries dissolved gases from the air.

Uniform against non-uniform — homogeneous and heterogeneous

Mixtures come in two kinds, and the test between them is one question: **is the composition the same in every part?**

- A **homogeneous** mixture has a **uniform composition** — every sample, from any part of it, has the same mix of substances. Salt water is homogeneous: a drop from the top and a drop from the bottom are both the same salt water. So is the air in this room, and so is brass.
- A **heterogeneous** mixture has a **non-uniform composition** — different parts of it have different mixes. Muddy water is heterogeneous: given time, the mud sinks and the water above it is clearer than the water near the bottom. So is soil, and so is a fruit cake.



The same test on any mixture: is the composition the same in every part (homogeneous), or do the parts differ (heterogeneous)?

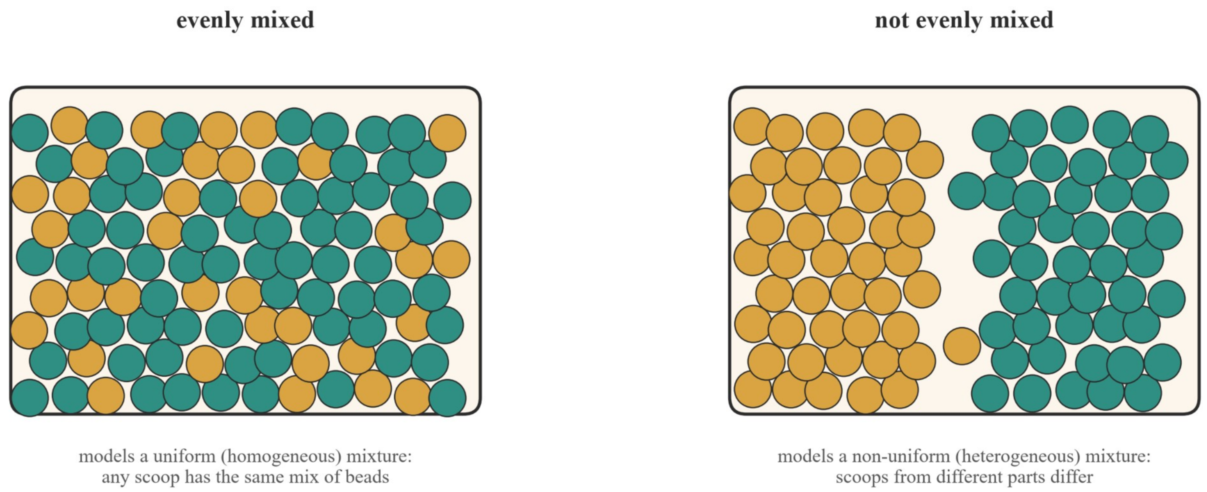
Two side-by-side comparisons: salt water as a HOMOGENEOUS mixture, shown as a beaker that looks the same in every part above a particle panel with solute particles spread evenly among solvent particles, labelled uniform composition, any sample is the same as any other; and muddy water as a HETEROGENEOUS mixture, shown as a beaker with mud settled at the bottom above a particle panel with mud particles clumped at the bottom and water particles above, labelled non-uniform composition, different parts, different mix

Look at the particle panels in that figure and the two words become pictures: **homogeneous means the different kinds of particles are spread evenly through each other; heterogeneous means they are clumped, settled or layered in places**. The eye test — "does it look the same everywhere?" — is a good first guide, but it has limits: some mixtures look uniform to the eye even though their particles are not spread evenly at all. Solutions, coming next, are the important case where the mixing is genuinely even, right down to particle level.

Modelling the sort with beads (E02)

You can model this whole classification on a bench with a handful of coloured beads or buttons. Let each colour stand for one kind of particle, and let each bead stand for one particle — exactly the move of `VC2S8U06.E02`.

1. Mix gold and teal beads **evenly** through a tray. Any scoop you take has about the same mix of colours as any other scoop — the tray models a **homogeneous** mixture.
2. Heap the gold beads on one side and the teal on the other. Now a scoop from the left is mostly gold and a scoop from the right is mostly teal — the tray models a **heterogeneous** mixture. Same beads; the difference is only how they are spread.



Modelling with beads (each bead = one kind of particle). The same two bead colours, mixed differently: that difference is homogeneous against heterogeneous.

Two trays of beads modelling mixtures: one evenly mixed, with gold and teal beads spread through each other, modelling a uniform homogeneous mixture where any scoop has the same mix; the other not evenly mixed, with gold beads heaped on one side and teal on the other, modelling a non-uniform heterogeneous mixture where scoops from different parts differ

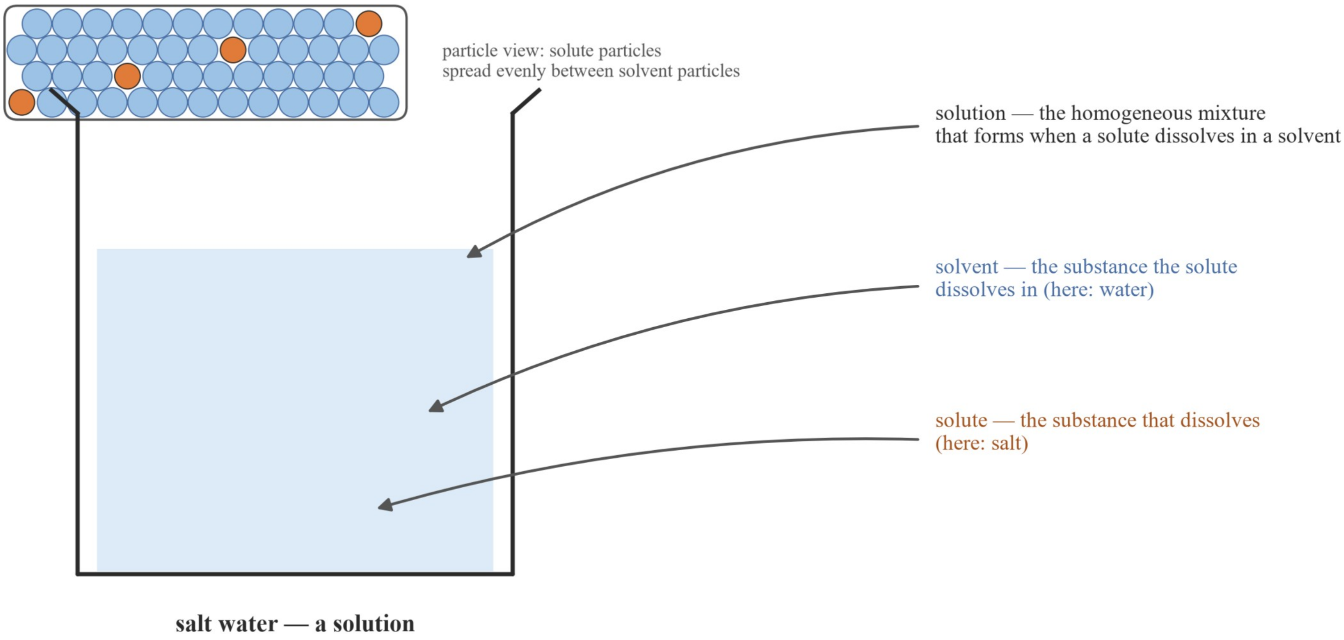
The same beads model solutions too: one colour as the solvent and a few of the other as the solute. More solute beads in the same tray — a more concentrated solution; so many solute beads that no more could fit — saturated.

Every model has limits, and this one does too (the strengths-and-limits habit is subtopic 4B). The beads are big enough to see and pick up, while real particles are far smaller than any microscope at school; the beads sit still unless you shake them, while real particles are always moving; and the beads in this model are not joined into groups the way a compound's particles are. The model shows you the *arrangement* — which is exactly the idea being taught — and nothing more.

Solutions — the mixture that looks like one substance

A **solution** is a **homogeneous mixture that forms when one substance dissolves in another**. Three words come as a set:

- the **solute** — the substance that dissolves (salt, in salt water);
- the **solvent** — the substance the solute dissolves in (water, in salt water);
- the **solution** — the homogeneous mixture that results.



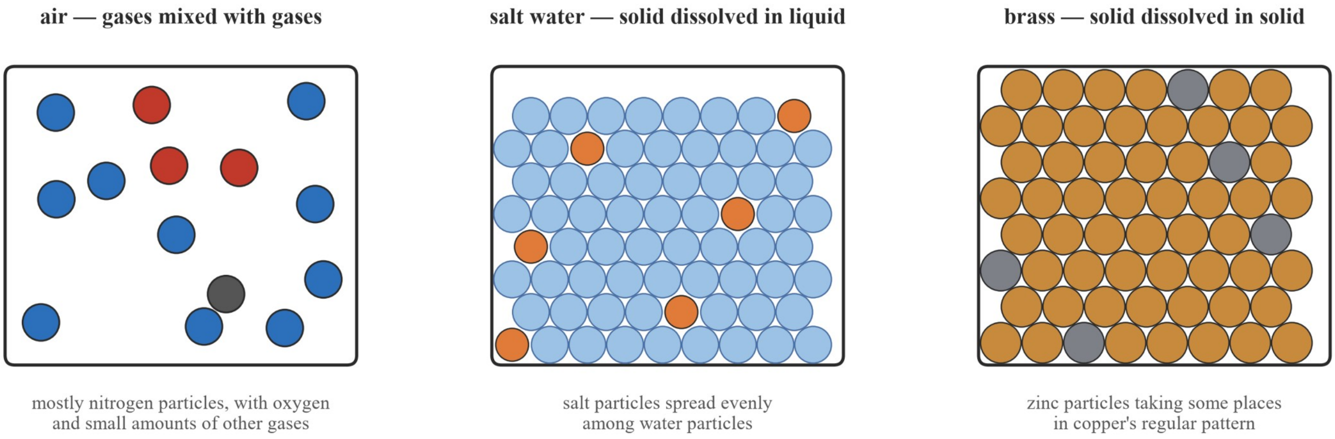
The three parts of a solution. The solute disappears into the solvent — at particle level its particles are simply spread evenly through it.

A labelled beaker of salt water as a solution, with leader lines to three definitions: the solution is the homogeneous mixture that forms when a solute dissolves in a solvent, the solvent is the substance the solute dissolves in, here water, and the solute is the substance that dissolves, here salt; a small particle inset shows solute particles spread evenly between solvent particles

Dissolving has a precise meaning in the particle model. When salt dissolves, its particles **do not vanish** — they spread out, evenly, between the water's particles, one salt particle here and one there, until they are scattered through the whole liquid. The salt is still in there: evaporate the water and the salt is left behind, which is exactly the trick subtopic 10D will use to get it back. Because the solute's particles are spread evenly among the solvent's, a solution is homogeneous — any drop of it has the same mix as any other drop.

If a substance does not dissolve — sand in water, for example — no solution forms. The sand's particles stay as clumps the eye or a filter can catch, and the mixture is heterogeneous. Whether a substance dissolves or not is one of its properties, and it decides which family the mixture lands in.

Solutions are not always liquids. What makes a solution is one substance spread evenly through another — not the state it is in:



Solutions are not always liquids. A solution can be a gas, a liquid or a solid — what makes it a solution is one substance spread evenly through another.

Three particle panels showing solutions in three states: air as gases mixed with gases, mostly nitrogen particles with oxygen and small amounts of other gases spread evenly; salt water as a solid dissolved in a liquid, salt particles spread evenly among water particles; and brass as a solid dissolved in a solid, zinc particles taking some places in copper's regular pattern

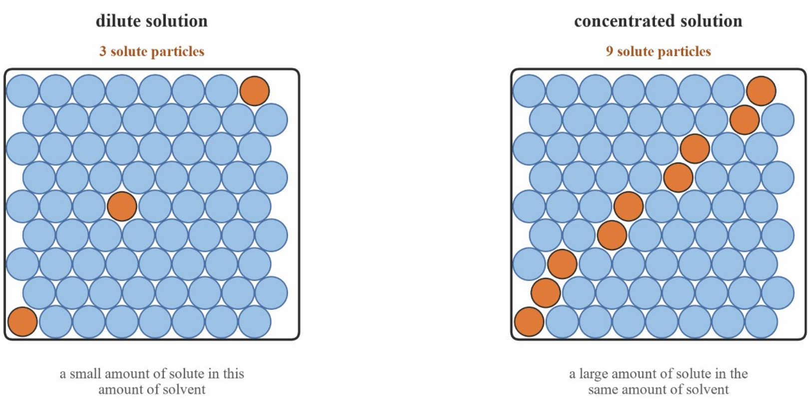
Air is a solution of gases in gases — mostly nitrogen, with oxygen and small amounts of other gases spread evenly through it. Brass is a solution of a solid in a solid — zinc spread evenly through copper, particle by particle, which is why any piece of brass has the same mix as any other.

How much dissolves — dilute, concentrated, saturated, supersaturated (E02)

Once a solution exists, the next question is *how much* solute is in it. These four words answer it, from least to most (this is the ladder of `VC2S8U06.E02`):

- **Dilute** — a small amount of solute in this amount of solvent.
- **Concentrated** — a large amount of solute in the same amount of solvent.
- **Saturated** — holding as much solute as can dissolve at this temperature; extra solute will not dissolve.
- **Supersaturated** — holding *more* solute than a saturated solution could at this temperature.

Dilute and concentrated compare amounts: same solvent, more solute means more concentrated. Cordial works the same way — a pale glass is dilute, a dark glass is concentrated.

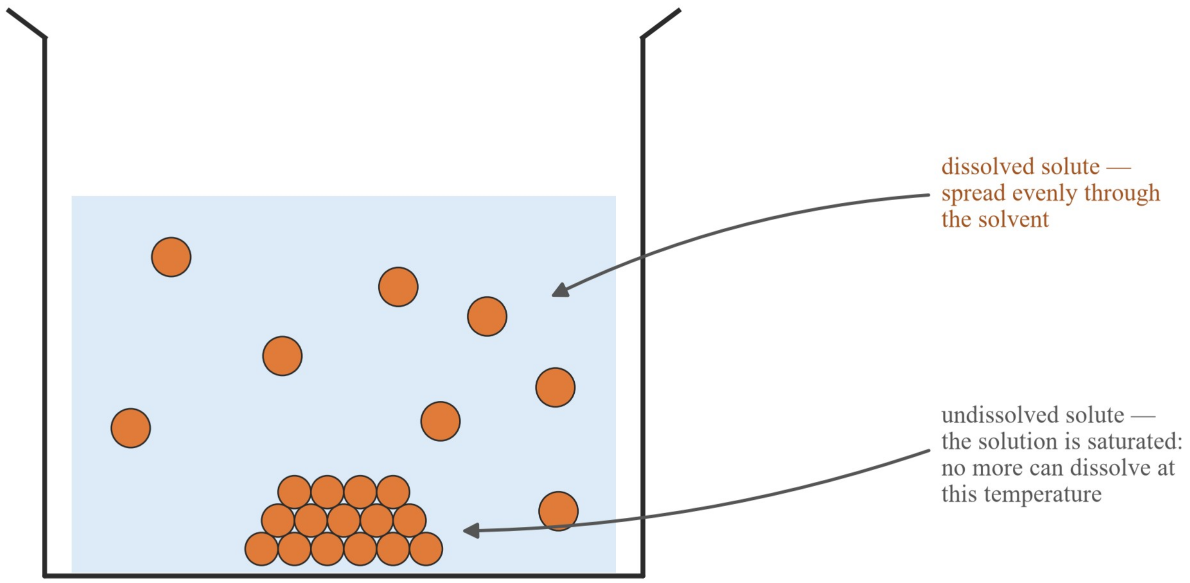


Concentration compares how much solute is dissolved in the same amount of solvent. Same solvent, more solute → more concentrated. Cordial works the same way: a pale glass is dilute, a dark glass is concentrated.

Two particle panels comparing concentration: a dilute solution with three solute particles among solvent particles, and a concentrated solution with nine solute particles among the same number of solvent particles; the caption notes *that concentration compares how much solute is dissolved in the same amount of solvent, as with a pale glass of cordial against a dark one*

A **saturated** solution has reached its limit *at that temperature*. Keep adding salt to a glass of water and stirring: at first each lot dissolves, but once the solution is saturated, every extra grain just sits at the bottom, undissolved, no matter how long you stir.

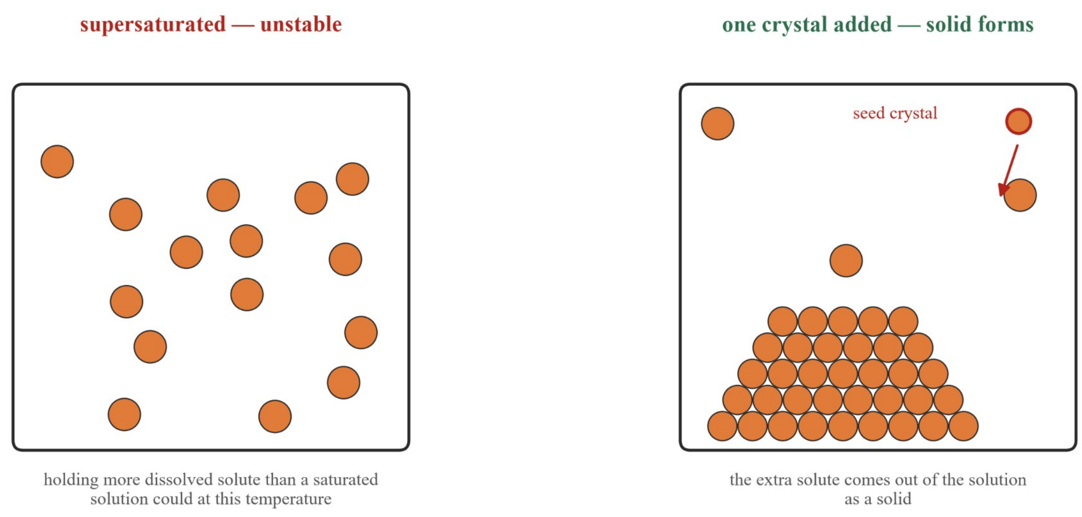
a saturated solution of salt in water



Add salt and stir: it dissolves — until the solution is saturated. From then on, extra salt sits undissolved at the bottom.

A beaker of a saturated salt solution: dissolved solute particles spread evenly through the solvent, and a pile of undissolved solute sitting at the bottom, labelled as the solution being saturated with no more able to dissolve at this temperature

Temperature matters: for most solids, **more solute can dissolve in hot solvent than in cold solvent**. That one fact is the key to the fourth kind. A **supersaturated** solution is made by dissolving extra solute in hot solvent and then cooling the solution carefully, so it holds more than a saturated solution could at the lower temperature. It is **unstable** — holding more than it should, and waiting for a reason to let go. Drop in one tiny seed crystal and the extra solute comes out of the solution as a solid, fast.



A supersaturated solution is made by dissolving extra solute at a high temperature and cooling the solution carefully. It holds until one small crystal starts the solid forming.

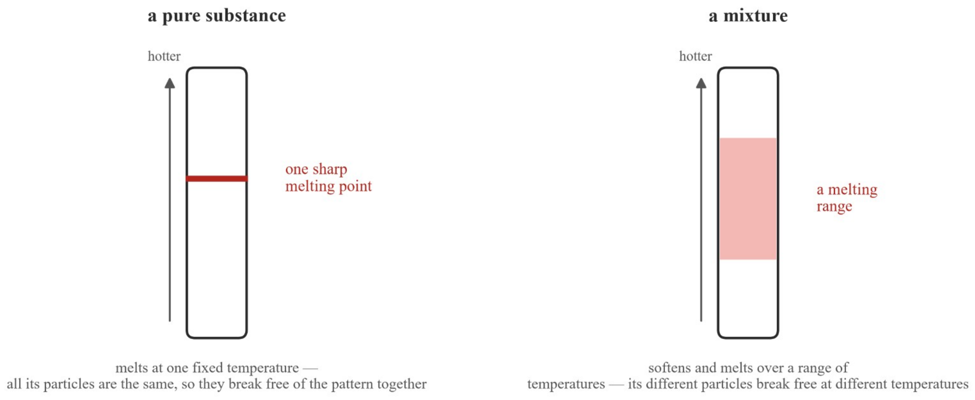
Two particle panels of a supersaturated solution: first, the unstable solution holding more dissolved solute than a saturated solution could at this temperature; second, one seed crystal added and the extra solute coming out of the solution as a solid heap, with only a few solute particles left dissolved

Some click-to-warm hand warmers work on exactly this trick: inside is a supersaturated solution, and clicking the metal disc drops in the seed that starts the crystallising — which is also when the pack warms up.

Telling pure from impure — the melting test

How would you check whether a white powder is a pure substance or a mixture? A reliable answer uses an idea subtopic 10B already taught you: **a pure substance has fixed melting and boiling points**. The particle model explains why, and the difference is a test:

- A **pure substance** melts at **one fixed temperature**. All its particles are the same, so they all break free of the solid's pattern at the same temperature — the solid goes to liquid sharply, at one reading of the thermometer.
- A **mixture** softens and melts over a **range of temperatures**. Its different particles break free at different temperatures, so melting starts at one reading and finishes at a higher one.



A melting-point test for purity (the fixed-temperature behaviour of pure substances is from subtopic 10B). Numbers are not shown: the point is the shape of the behaviour — one temperature against a range.

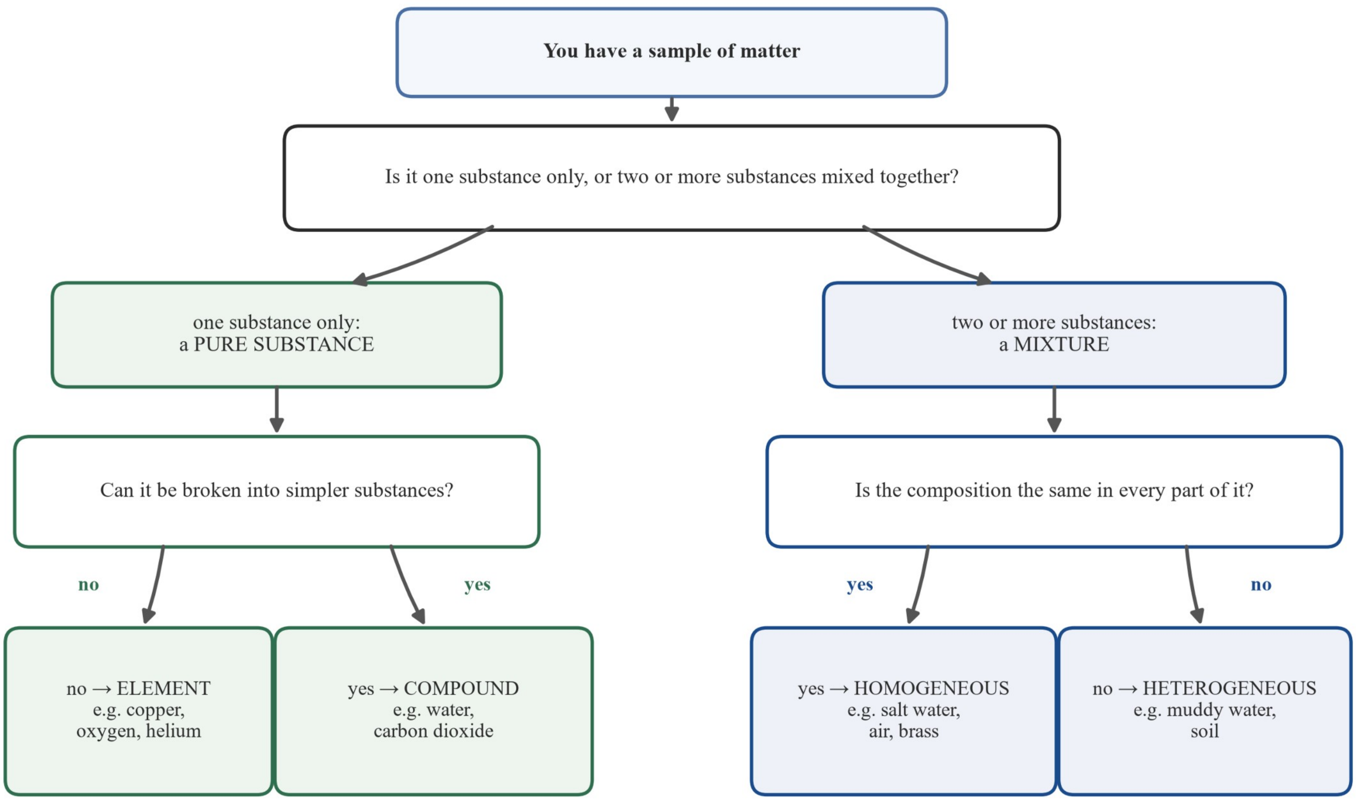
Two thermometer strips comparing melting behaviour: a pure substance melting at one sharp melting point, marked as a single line on the strip, and a mixture melting over a range of temperatures, marked as a band on the strip; the caption notes the point is the shape of the behaviour, one temperature against a range

If a powder begins melting at 70 °C and is not fully liquid until 82 °C, the powder is a mixture — a pure substance would have melted at one temperature. (The temperatures here are data for practice.) The same logic works with boiling points, also from 10B.

Risk note: a melting test means heating, and heating practicals follow the safe routines of subtopic 10B — a teacher demonstration or small supervised groups, safety glasses on, equipment clamped and treated as hot. Follow the risk-management guidance from Science ASSIST (see Sources).

The decision key — classifying any sample

Everything in this subtopic fits into one walking order. Start at the top, answer each question honestly, and the sample lands in its family:



A decision key for classifying a sample. Each step asks one question; the answers walk the sample to its category.

A decision key for classifying a sample of matter, flowing top to bottom: from You have a sample of matter, to Is it one substance only or two or more substances mixed together; one substance only leads to a PURE SUBSTANCE, and two or more substances leads to a MIXTURE; the pure substance branch asks Can it be broken into simpler substances, with no leading to ELEMENT, examples copper, oxygen, helium, and yes leading to COMPOUND, examples water, carbon dioxide; the mixture branch asks Is the composition the same in every part of it, with yes leading to HOMOGENEOUS, examples salt water, air, brass, and no leading to HETEROGENEOUS, examples muddy water, soil

Two tips for using the key well:

- **"One substance only" means one substance everywhere** — not "it looks like one thing". Salt water looks like one thing and is two substances; that is why the composition question sits on the mixture branch.
- **"Can it be broken into simpler substances?" is about the particles.** A compound's particles hold two or more kinds of joined parts; an element's particles are one kind only.

The achievement standard asks you to *distinguish between pure substances and mixtures* — this key, used out loud with a reason at each step, is that distinction made visible. Worked example 1 below walks four samples down it.

Words to know in 10C

Word	What it means here
pure substance	matter made of one substance only — an element or a compound
element	a pure substance that cannot be broken into simpler substances; one kind of particle
compound	a pure substance whose particles hold two or more kinds of parts joined in a fixed proportion
mixture (impure substance)	two or more substances together without chemical joining; amounts can vary
composition	what a sample is made of, and in what amounts
homogeneous	(of a mixture) uniform composition — the same mix in every part
heterogeneous	(of a mixture) non-uniform composition — different parts, different mix
solution	a homogeneous mixture formed when a solute dissolves in a solvent
solute	the substance that dissolves
solvent	the substance the solute dissolves in
dissolve	(of a solute) to spread, particle by particle, evenly through a solvent
dilute	a small amount of solute in this amount of solvent
concentrated	a large amount of solute in the same amount of solvent
saturated	holding as much solute as can dissolve at this temperature
supersaturated	holding more solute than a saturated solution could at this temperature; unstable

Worked examples

Example 1 — scaffolded

Classify each sample using the decision key: (a) a piece of copper wire; (b) a sample of pure water; (c) salt water; (d) muddy water.

Working	Comment
(a) Copper wire is one substance only → a pure substance. Copper cannot be broken into simpler substances — its particles are one kind only. → **Element**.	Walk the key: one substance, then “can it be broken down?” decides element against compound.
(b) Pure water is one substance only → a pure substance. Its particles hold two kinds of parts joined together (hydrogen parts and oxygen parts), so it can be broken into simpler substances. → **Compound**.	A compound is still one substance — every particle has the same joined parts, the same recipe.
(c) Salt water is salt and water — two substances together, not joined → a mixture. Its composition is the same in every part. → **Homogeneous** mixture (a solution).	Salt dissolves and spreads evenly, so any drop has the same mix.
(d) Muddy water is water with mud in it — two or more substances, not joined → a mixture. Its composition differs from part to part (the mud settles). → **Heterogeneous** mixture.	The composition test decides homogeneous against heterogeneous.

Example 2 — scaffolded

A student draws four particle boxes. Box W contains particles each made of two kinds of parts joined together, with every particle identical. Box X contains one kind of particle only. Box Y contains two kinds of whole particles, spread evenly through each other, not joined. Box Z contains two kinds of whole particles, with one kind clumped at the bottom. Classify each box.

Working	Comment
Box W: every particle holds joined parts in the same recipe → one substance only, breakable into simpler parts → **compound**.	Joined parts inside every particle is the picture of a compound.
Box X: one kind of particle only, nothing to break down → **element**.	One kind of particle is the picture of an element.
Box Y: two substances, not joined → mixture; spread evenly → **homogeneous** mixture.	Even spreading is what makes a mixture homogeneous — a solution, if one substance is dissolved in the other.
Box Z: two substances, not joined → mixture; clumped, so parts differ → **heterogeneous** mixture.	Clumping or settling means the composition is non-uniform.

Example 3 — unscaffolded

A student stirs one spoon of sugar into a glass of iced tea and it dissolves. They add a second spoon and stir for a long time, but some of the sugar still sits at the bottom. Explain, using the word *saturated*, why the second spoon does not dissolve, and name one thing that would let the tea hold more sugar.

At this temperature the tea can only hold so much dissolved sugar. The first spoon dissolved, and the solution reached its limit — it became **saturated**: holding as much solute as can dissolve at this temperature. Once saturated, no amount of stirring will dissolve more sugar, so the extra sugar sits undissolved at the bottom. ∴ to make the tea hold more sugar, warm it up — for most solids, more solute can dissolve in hot solvent than in cold.

Example 4 — unscaffolded

A student says: "When I stir salt into water, the salt disappears — so salt water is a pure substance." Use the particle model to explain where the salt really went, and say whether salt water is an element, a compound, or a mixture — giving the reason.

The salt has not disappeared. In the particle model, the salt's particles spread out evenly between the water's particles — one salt particle here, one there — until they are scattered through the whole glass. The particles are far too small to see, which is why the water looks clear, but the salt is still there: evaporate the water and the salt is left behind. And salt water is a **mixture** — specifically a homogeneous mixture, a solution. It holds two substances (salt and water) together without chemical joining, and its amounts can vary: add more salt and it is still salt water. That is exactly what separates a mixture from a compound — a compound has one recipe with its parts joined, and salt water has none of that. ∴ the student's classification is wrong in two ways: the salt did not vanish, and salt water is a mixture, not a pure substance.

Practice questions

Scaffolded

Q1. (a) State what *pure* means in chemistry. (b) Name the two families of pure substance.

Q2. Classify each sample as an element or a compound: copper, water, oxygen, carbon dioxide.

Q3. (a) State what a mixture is. (b) Give one example of a homogeneous mixture and one example of a heterogeneous mixture.

Q4. In a solution of salt in water, name (a) the solute, (b) the solvent, and (c) the word for the mixture that forms.

Q5. (a) State what a saturated solution is. (b) Name one way to make a saturated solution of a solid hold more solute.

Q6. Complete the sentence: "A pure substance melts at …, but a mixture melts over …"

Unscaffolded

Q7. Use the particle model to explain why salt water is classified as a mixture rather than a compound. *(2 marks)*

Q8. A bottle of salad dressing is made of oil and vinegar. Left standing, it separates into two layers. State whether the dressing is homogeneous or heterogeneous, and give the reason your answer is based on. *(2 marks)*

Q9. Air is mostly nitrogen gas, with oxygen gas and small amounts of other gases spread evenly through it. Classify air — is it an element, a compound, or a mixture — and give two reasons for your answer. *(3 marks)*

Q10. You model mixtures with gold and teal beads in a tray, each bead standing for one particle. (a) Describe how you would arrange the beads to model a homogeneous mixture. (b) Describe how you would arrange the same beads to model a heterogeneous mixture. (c) State one way this bead model does not represent real particles well. *(3 marks)*

Q11. Two beakers hold the same amount of water at the same temperature. Beaker A has one spoon of salt dissolved in it; beaker B has three spoons. (a) Which beaker holds the more concentrated solution, and why, in terms of particles? (b) More salt is stirred into beaker B until no more will dissolve. What word now describes beaker B's solution? *(3 marks)*

Q12. A sample of sea water collected near a river mouth contains water, dissolved salts, and fine mud floating through it. Classify the sample: is it a pure substance or a mixture, and if a mixture, homogeneous or heterogeneous? Give the reason. *(2 marks)*

Q13. A student heats a white powder and records that it starts melting at 70 °C and is not fully liquid until 82 °C *(data for practice)*. State whether the powder is a pure substance or a mixture, and explain how the melting behaviour tells you. *(2 marks)*

Q14. Some click-to-warm hand warmers contain a supersaturated solution. Clicking the metal disc starts the solution crystallising. (a) State what *supersaturated* means. (b) Say what the click starts, and what happens to the extra solute. *(2 marks)*

Answers

Q1. (a) Made of one substance only. (b) Elements and compounds. **Q2.** Copper — element; water — compound; oxygen — element; carbon dioxide — compound. **Q3.** (a) Two or more substances together without chemical joining. (b) Any valid pair, e.g. salt water (homogeneous) and muddy water (heterogeneous). **Q4.** (a) Salt. (b) Water. (c) A solution (a homogeneous mixture). **Q5.** (a) A solution holding as much solute as can dissolve at that temperature. (b) Warm the solvent (heat the solution). **Q6.** … one fixed temperature …; … a range of temperatures. **Q7.** The salt's particles and the water's particles are spread through each other but not joined, and the amounts can vary — a compound has its parts joined in one fixed recipe. **Q8.** Heterogeneous — the composition is non-uniform: samples from the oil layer and the vinegar layer have different mixes. **Q9.** Mixture (homogeneous / a solution): it holds several gases together without joining; the gases are spread evenly; and the amounts can vary. Any two of these. **Q10.** (a) Spread the two colours evenly through each other. (b) Heap or clump the colours into different regions. (c) Any one valid limit, e.g. the beads are much bigger than particles, the beads sit still while particles always move, or the beads do not show joined parts inside a compound's particles. **Q11.** (a) Beaker B — more solute particles in the same amount of solvent. (b) Saturated. **Q12.** A heterogeneous mixture — it holds several substances (water, salts, mud) and the floating mud means the composition differs from part to part. **Q13.** A mixture — a pure substance melts at one fixed temperature; this powder melted over a range (70–82 °C). **Q14.** (a) Holding more solute than a saturated solution could at that temperature (unstable). (b) The click drops in a seed crystal; the extra solute comes out of the solution as a solid (crystallises).

Fully-worked solutions

Q1. (a) In chemistry, *pure* means **made of one substance only** *(1 mark)*. (b) The two families are **elements** and **compounds** *(1 mark each)*.

Q2. Copper is an **element** — one kind of particle, nothing simpler *(1 mark)*. **Water** is a **compound** — its particles hold hydrogen parts and oxygen parts joined in a fixed recipe *(1 mark)*. **Oxygen** is an **element** *(1 mark)*. **Carbon dioxide** is a **compound** — every particle is one carbon part joined to two oxygen parts *(1 mark)*.

Q3. (a) A mixture is **two or more substances together without chemical joining** — the parts keep their own properties and the amounts can vary *(1 mark)*. (b) For example: **salt water is a homogeneous mixture** and **muddy water is a heterogeneous mixture** *(1 mark each)*.

Q4. (a) The solute is the substance that dissolves: **salt** *(1 mark)*. (b) The solvent is the substance it dissolves in: **water** *(1 mark)*. (c) The mixture that forms is a **solution** — a homogeneous mixture *(1 mark)*.

Q5. (a) A saturated solution is **holding as much solute as can dissolve at that temperature** — extra solute sits undissolved *(1 mark)*. (b) **Warm the solvent** — for most solids, more solute dissolves in hot solvent than in cold *(1 mark)*.

Q6. A pure substance melts at **one fixed temperature**, but a mixture melts over **a range of temperatures** *(1 mark each)*.

Q7. In salt water, the salt's particles and the water's particles are **spread through each other but not joined** into new particles *(1 mark)*, and the **amounts can vary** — more or less salt and it is still salt water. A compound, by contrast, is one substance whose parts are joined in one fixed recipe *(1 mark)*.

Q8. The dressing is **heterogeneous** *(1 mark)*. The reason is its **composition is non-uniform**: it separates into an oil layer and a vinegar layer, so samples from different parts have **different mixes** *(1 mark)*.

Q9. Air is a **mixture** (a homogeneous mixture — a solution of gases) *(1 mark)*. Reasons, any two: it holds **two or more gases together without chemical joining** *(1 mark)*; the gases are **spread evenly**, so the composition is the same in every part *(1 mark)*; the **amounts can vary** from place to place, which a compound's fixed recipe does not allow *(1 mark)*.

Q10. (a) **Spread the gold and teal beads evenly through each other** so any scoop has about the same mix *(1 mark)*. (b) **Heap or clump the colours into different regions** so scoops from different parts differ *(1 mark)*. (c) Any one valid limit of the model, for example: the beads are **far larger than real particles**, the beads **sit still while real particles are always moving**, or the beads **do not show the joined parts inside a compound's particles** *(1 mark)*.

Q11. (a) **Beaker B** is more concentrated *(1 mark)*: it has **more solute particles dissolved in the same amount of solvent** *(1 mark)*. (b) Once no more salt will dissolve, beaker B's solution is **saturated** *(1 mark)*.

Q12. The sample is a **mixture** — water, dissolved salts and mud together without chemical joining *(1 mark)*. It is **heterogeneous**, because the fine mud floating through it means the **composition differs from part to part** — it is not the same mix everywhere *(1 mark)*.

Q13. The powder is a **mixture** *(1 mark)*. A **pure substance melts at one fixed temperature**, but this powder melted **over a range of temperatures** (70 °C to 82 °C) — its different parts break free of the solid at different temperatures, which is the melting behaviour of a mixture *(1 mark)*.

Q14. (a) **Supersaturated** means the solution is **holding more solute than a saturated solution could at that temperature** — it is unstable *(1 mark)*. (b) The click **drops in a seed crystal**, and the extra solute **comes out of the solution as a solid** — it crystallises *(1 mark)*.

Sources

Web sources below were retrieved 2026-08-21.

- Science ASSIST (Australian Science Teachers' Association), "Risk management", n.d. asta.edu.au

The melting points quoted for copper (1085 °C) and mercury (−39 °C) are standard table values, given for practice; the 70–82 °C melting range in the melting-test paragraph and in Q13 is data for practice, not sourced measurements. No simulated data tables are used in this subtopic — the particle figures and the bead model are qualitative by design (D11), and every count in them (such as 3 solute particles against 9) is the value the text teaches.

Elaboration contexts used: `VC2S8U06.E01` (particle representations distinguishing pure substances and mixtures, with examples of each) and `VC2S8U06.E02` (coloured beads or buttons modelling uniform and non-uniform mixtures, and dilute, concentrated, saturated and supersaturated solutions).

Teacher-facing note — reserved elaboration (not student text). `VC2S8U06.E05`, the elaboration placing separation techniques in Aboriginal and Torres Strait Islander contexts, belongs to the separation limb of `VC2S8U06` — the partner subtopic 10D's bank — and is reserved under the ICIP decision (D10; CONTENT_POLICY rule 1): no Aboriginal or Torres Strait Islander content is delivered in this book. Nothing in this subtopic's own bank (`VC2S8U06.E01`, `VC2S8U06.E02`) carries such content, and nothing is drawn on here in its place.

Separating a mixture on the properties of its components: filtration, decantation, evaporation, crystallisation, magnetic separation, distillation and chromatography

What we teach here — `VC2S8U06` (Victorian Curriculum F–10 Version 2.0, Science, Levels 7 and 8): *"matter can be classified as pure substances such as elements and compounds or impure substances such as mixtures (including solutions), and can be modelled using the particle model; mixtures may have a uniform (homogeneous) or non-uniform (heterogeneous) composition and can be separated based on the properties of their components using techniques including filtration, decantation, evaporation, crystallisation, magnetic separation, distillation and chromatography"* **This subtopic carries the separation limb only**: mixtures can be separated based on the properties of their components, using the seven named techniques. The first limb — classifying matter as pure substances or mixtures, uniform (homogeneous) and non-uniform (heterogeneous) composition, and the particle model — belongs to the partner subtopic **10C**, which owns `VC2S8U06` († split delivery, D6). 10C classifies matter; here we *un-mix* it. **In our words:** the parts of a mixture were never chemically joined, so each part keeps its own properties. To un-mix, find a property the parts differ in — size, density, boiling point, magnetism, or how they travel in a solvent — and pick the technique that exploits that difference. **Achievement-standard extract served here (D13):** cited by reference to the header of the owner subtopic 10C, where the extract appears in full. The standard's "design procedures to separate mixtures" move is exercised here in the separating-machine design task (`VC2S8U06.E06`). **Elaborations drawn on:** `VC2S8U06.E03` (analysing how the physical properties of substances in mixtures, such as particle size, density and volatility, determine the separation technique used), `VC2S8U06.E04` (using paper chromatography to separate the components of different coloured inks or food dyes), `VC2S8U06.E06` (designing, making, testing and refining a 'separating machine' to separate the components of a mixture) and `VC2S8U06.E07` (exploring and comparing separation methods used in homes, recycling industries and for purifying water). **ICIP (D10):** no Aboriginal or Torres Strait Islander content is delivered here. `VC2S8U06.E05` is reserved under the ICIP decision and is not taught; see the teacher-facing note at the foot of this subtopic. **Maths interlocks (D11):** none are listed for this subtopic — the work stays qualitative. Chromatography matches spots by eye; no ratio is computed and no graph is plotted or read (D11 keeps graphs qualitative). **Authored from the CD text and the elaboration contexts (D12):** the CD names the seven techniques but not the procedures; the procedures taught here are the standard school-laboratory version of each technique, and the four elaborations above supply the analysing, chromatography, designing and real-world contexts.

Word watch — *residue* and *filtrate*. Filtration has two specialist names for what comes out of it. The solid caught on the paper is the **residue** — what *resides*, stays, on the paper. The liquid that passes through is the **filtrate** — the liquid made *by* the filtering. Sand and water filtered: sand is the residue, the water is the filtrate.

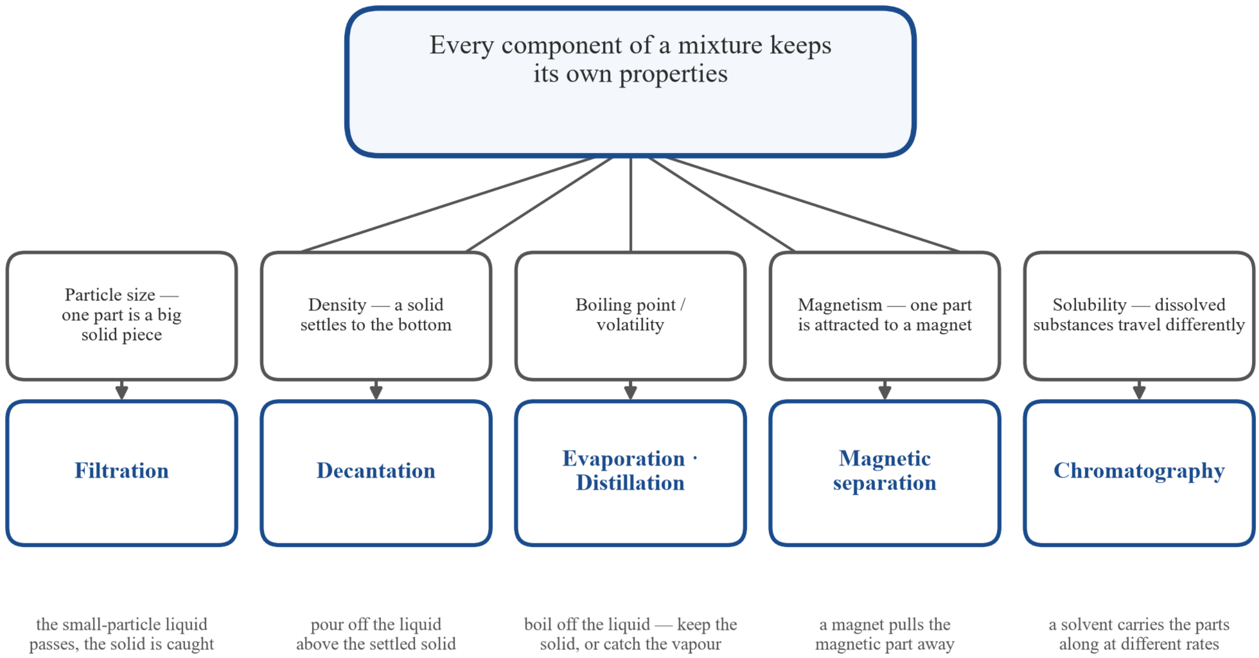
Word watch — *volatile*. A **volatile** liquid is one that evaporates easily and boils easily. **Volatility** is the name of that property. In salt water, the water is volatile (it boils at 100 °C and turns to vapour) and the salt is not (it does not boil away at any temperature the burner can reach). That one difference is what evaporation and distillation exploit.

Theory

One idea runs the whole subtopic — every part keeps its own properties

Subtopic 10C teaches that a mixture is two or more substances together without chemical joining — from non-uniform mixtures like sand and water, to uniform mixtures (solutions) like salt water. Because nothing chemically joins the parts, **every part of a mixture keeps its own properties**: the sand in muddy water is still sand, and the salt in salt water is still salt. That is the key that unlocks every separation: if the parts keep their own properties, then a property the parts *differ* in gives you a handle to pull them apart.

Pick the technique from the property that makes the components different



Crystallisation is evaporation done slowly — the solid comes back as crystals

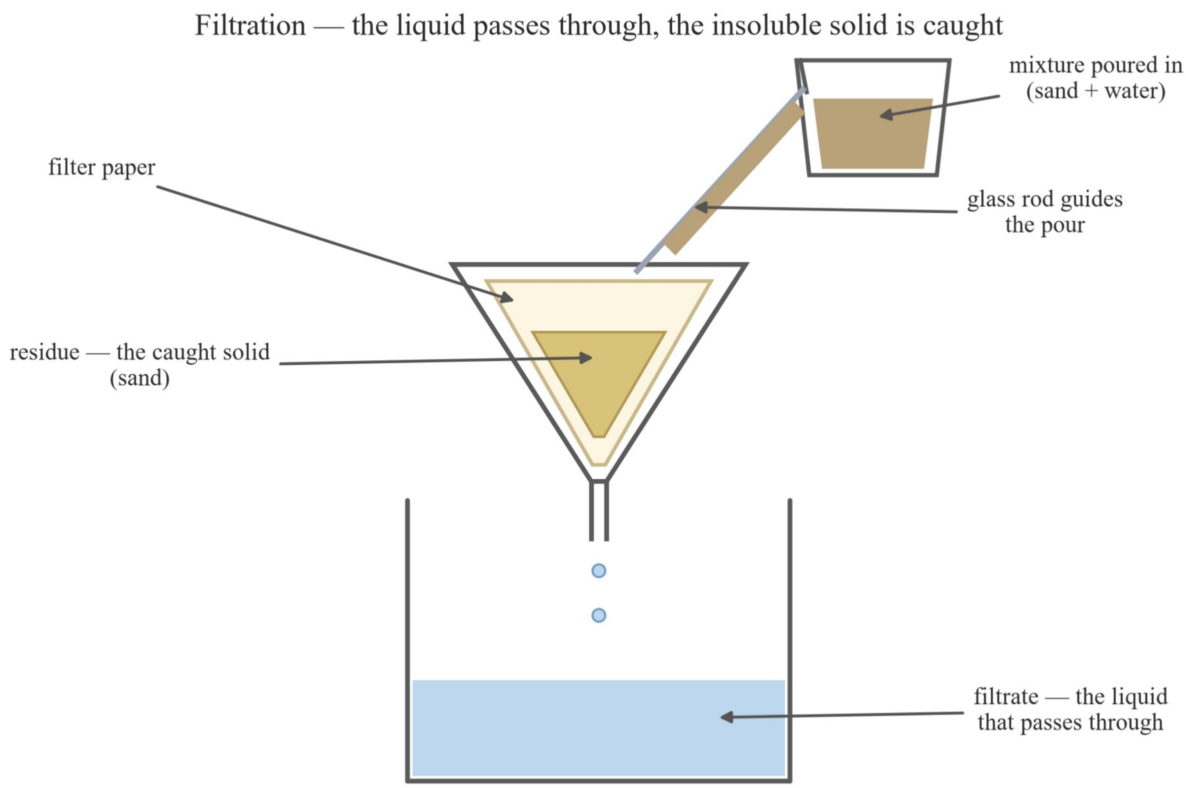
A map with one central box, every component of a mixture keeps its own properties, and five branches; each branch pairs a difference between the components (particle size, density, boiling point or volatility, magnetism, solubility) with the technique that uses it (filtration, decantation, evaporation and distillation, magnetic separation, chromatography), and a footer line notes that crystallisation is evaporation done slowly

If the parts differ in …	then use …	because …
particle size — one part is an insoluble solid	filtration	the liquid passes through the paper; the solid is caught
density — a solid settles to the bottom	decantation	the liquid above the settled solid can be poured off
boiling point / volatility	evaporation, or distillation	the liquid boils off and the non-volatile part stays
magnetism	magnetic separation	a magnet pulls only the magnetic part away
how they travel in a solvent	chromatography	a solvent carries dissolved parts along at different rates

Choosing a separation is therefore a two-step habit: **name the property the parts differ in, then name the technique that uses it** (this is the analysing move of `VC2S8U06.E03`). Every technique below is that habit applied.

Filtration — catch the solid, pass the liquid

Filtration separates an insoluble solid from a liquid by pouring the mixture through filter paper in a funnel. The paper has tiny holes: the liquid and anything dissolved in it pass through, but the solid pieces are too big and are caught. The caught solid is the **residue**; the liquid that passes through is the **filtrate** (Word watch above).



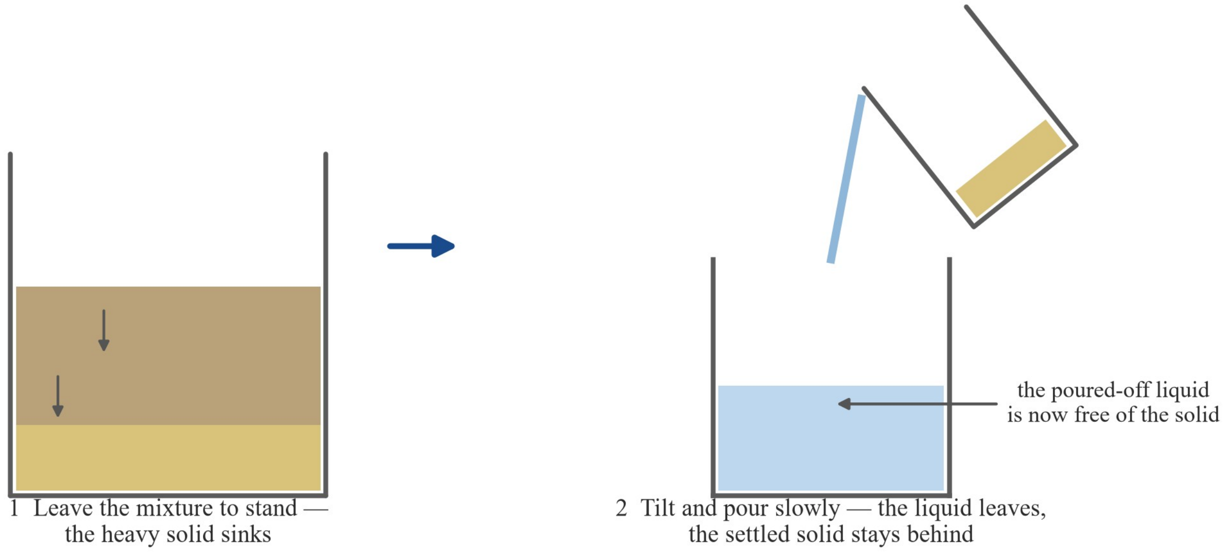
Filtration apparatus: a beaker of sand and water pouring down a glass rod into a funnel lined with filter paper above a collecting beaker; the sand sits on the paper as the residue and clear drops fall into the filtrate below

Filtration works on particle size. It cannot separate salt from salt water — the dissolved salt passes straight through the paper with the water, because dissolved particles are far too small to be caught. For dissolved solids we need the boiling-point handle instead.

Decantation — settle, then pour off

Decantation separates a solid from a liquid by letting the solid settle to the bottom and then carefully pouring the liquid off. It uses density: the solid is denser than the liquid, so given time it sinks, and the liquid above it can be tipped away without dragging the solid with it.

Decantation — let the solid settle, then pour the liquid off



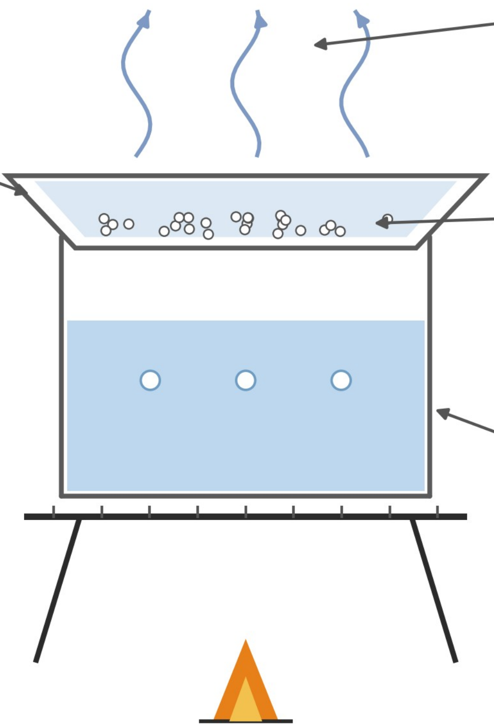
Two frames: first, a beaker of muddy water left to stand with arrows showing the heavy solid sinking to the bottom; second, the beaker tilted so the clear liquid pours into a second beaker while the settled solid stays behind

Decantation is quick and needs no paper, but it is less complete than filtration — a little cloudy liquid always stays with the solid. It is the technique you have used at home many times: pouring the water off boiled potatoes is decantation.

Evaporation — drive the liquid off, keep the solid

Evaporation, as a separating technique, means heating a solution so the liquid boils away as vapour and the dissolved solid is left behind. It uses volatility: the water is volatile and leaves; the salt is not volatile and stays. A water bath (the dish sits over simmering water rather than straight in the flame) gives gentle, even heating so the solution does not spit as it dries.

Evaporation — boil off the liquid and the dissolved solid stays behind



Evaporation apparatus: an evaporating dish of salt water sitting on a beaker of simmering water over a tripod and flame; water vapour rises from the dish and salt grains are left behind in it

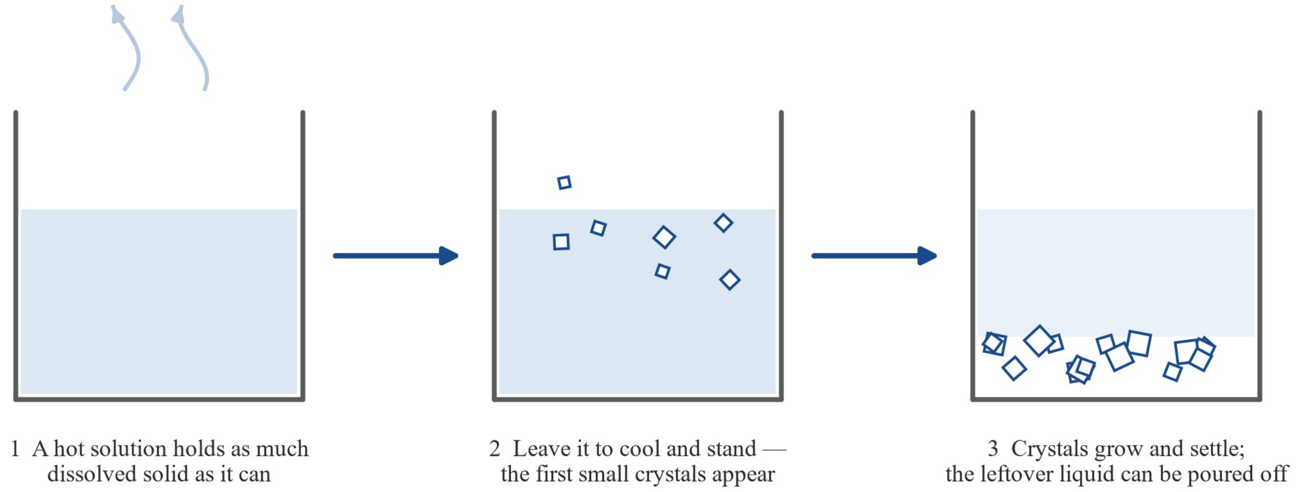
Choose evaporation when the part you want is the **solid** and you do not mind losing the liquid — the water vapour goes into the air and is not recovered. Salt is made from sea water exactly this way, at the size of whole shallow ponds: solar salt fields let the sun do the evaporating.

Crystallisation — evaporation, done slowly

Crystallisation gets the solid back slowly, as **crystals**. A hot solution holds as much dissolved solid as it can; as it cools, or as the liquid slowly leaves, the solid can no longer stay dissolved and comes back — first as tiny crystals, then bigger ones as they grow and settle.

Crystallisation — the solid comes back slowly, as crystals

the slower the liquid leaves or cools, the bigger the crystals grow



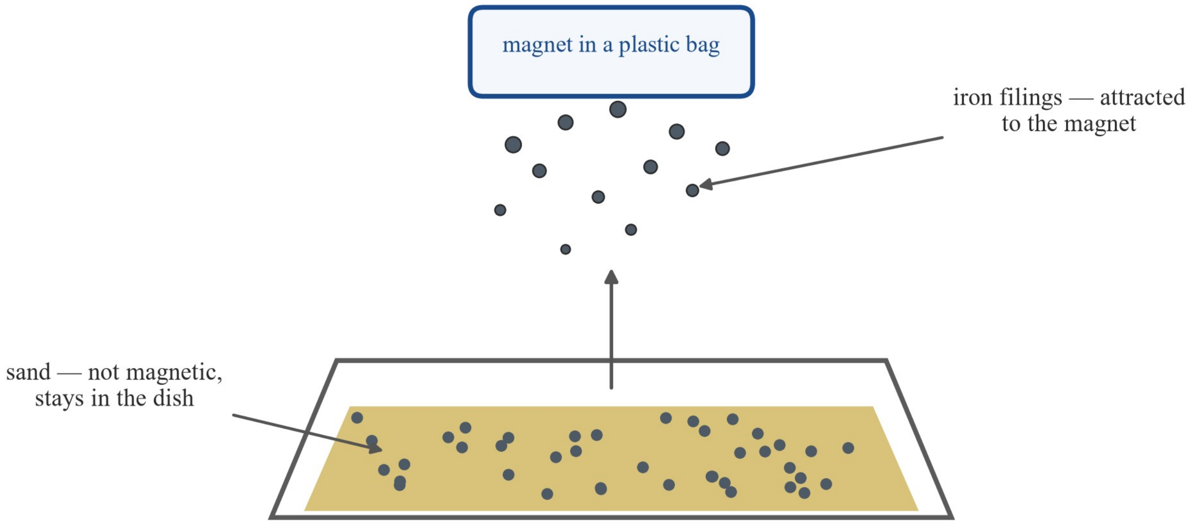
Three frames: a jar of hot solution holding as much dissolved solid as it can; the same jar cooling with the first small crystals appearing; the jar with a layer of crystals settled at the bottom under clearer liquid

The fine point that separates the two techniques: **the slower the liquid leaves or cools, the bigger the crystals grow.** Fast evaporation over a flame gives a powder of tiny grains; slow cooling over days gives big, well-shaped crystals. Rock candy — sugar crystallised slowly on a string — is the tasty proof.

Magnetic separation — the magnet takes only its own

If one part of a solid mixture is magnetic (iron, steel) and the rest is not, a magnet lifts the magnetic part straight out. Wrapping the magnet in a plastic bag means the filings stick to the bag instead of the magnet, so they can be wiped off cleanly afterwards.

Magnetic separation — the magnet takes only the magnetic part



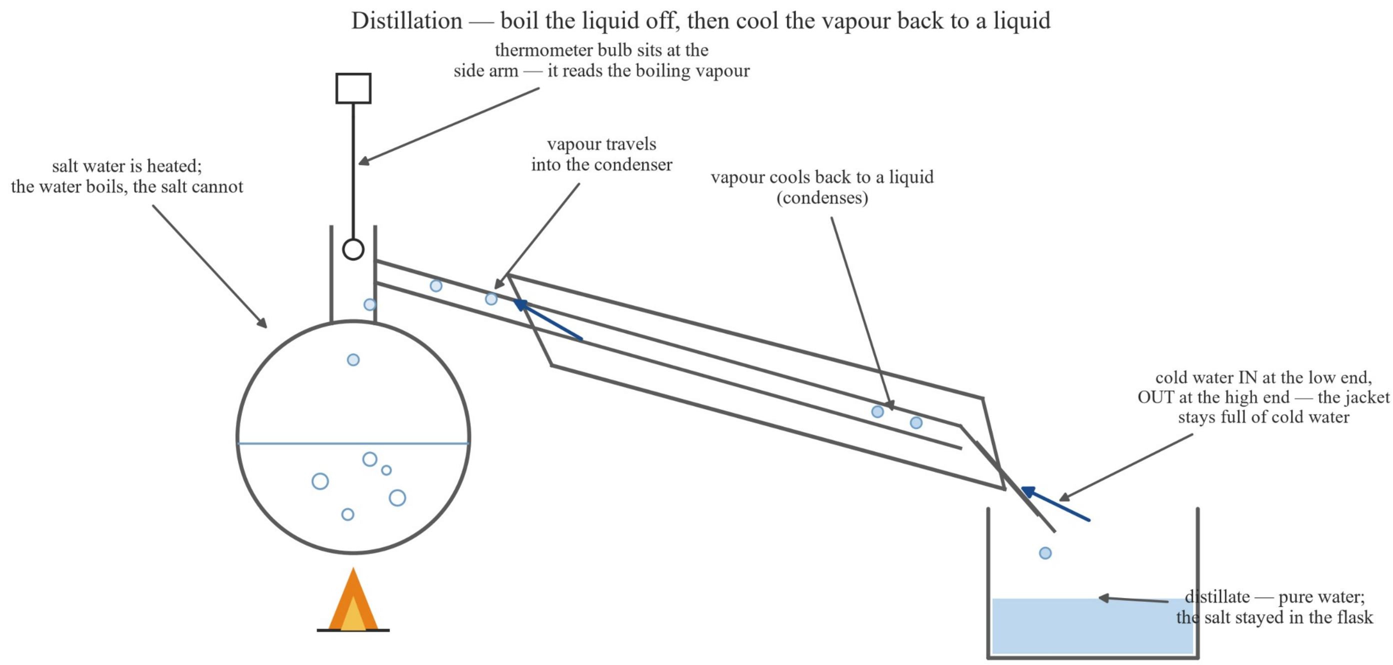
wipe the magnet clean away from the dish — the bag keeps the filings off the magnet

A dish of sand dotted with iron filings, and above it a bar magnet in a plastic bag with iron filings climbing towards it while the sand stays in the dish

Magnetic separation needs no dissolving, no heating and no paper — it is the cheapest handle there is, which is why industry loves it (see the recycling conveyor below).

Distillation — keep the liquid as well as the solid

Distillation is evaporation with a second step bolted on: the vapour is cooled and turned back to liquid so it can be collected. Simple distillation of salt water gives **both** products — pure water in the collection beaker, and salt left in the flask.



Simple distillation apparatus: a round-bottomed flask of salt water over a flame with a thermometer at the top, joined by a sloping tube to a cooled condenser jacket with cold water entering at the low end and leaving at the high end, and a delivery tube dripping pure water into a collection beaker

Follow the water through the apparatus:

- In the flask, the water boils (at about 100 °C) and turns to vapour; the salt cannot boil away, so it stays.
- The thermometer bulb sits level with the side arm, so it reads the temperature of the vapour — steady at the boiling point of the water while the water lasts.
- In the **condenser**, the vapour passes through a cooled tube. Cold water runs the other way around the tube — in at the low end, out at the high end — so the jacket stays full of cold water and the vapour condenses back to liquid.
- The liquid drips into the collection beaker as pure water, with no salt in it.

Risk: distillation uses a flame, boiling liquid and hot glass, and in most schools it is a teacher demonstration. Follow the risk-management guidance from Science ASSIST (see Sources): safety glasses for everyone in the room, the flask clamped tight, never let the flask boil dry, and treat all glass as hot — hot glass looks exactly like cold glass.

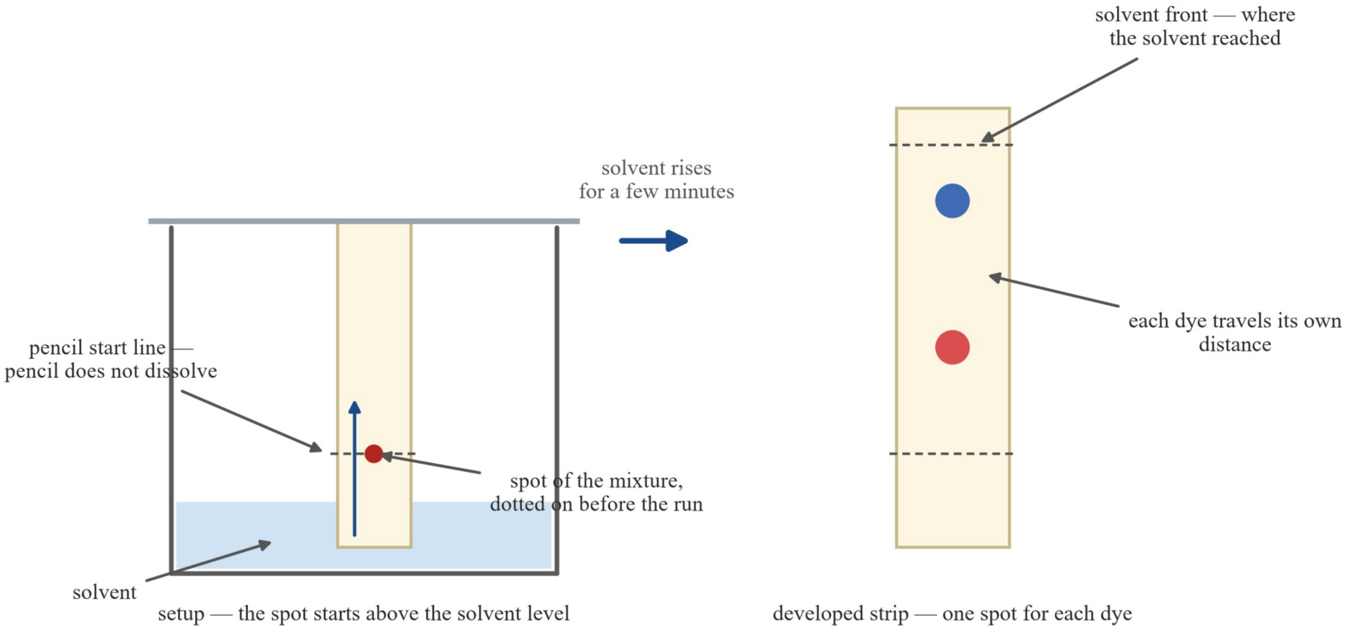
Choose by what you want to keep:

- want the **solid** only → evaporation
- want the **liquid** too → distillation

Paper chromatography — the solvent carries the parts along

Chromatography separates dissolved substances — the dyes in an ink or a food colouring — by letting a solvent carry them along a paper. Different dyes travel at different rates, so a single spot of ink splits into its separate dyes.

Paper chromatography — a solvent carries the dissolved parts along



Two panels: left, a beaker with a shallow layer of solvent and a paper strip hanging from a glass rod across the rim, with a pencil start line and a spot of ink above the solvent level; right, the developed strip showing the start line, two separated dye spots, and the solvent front near the top

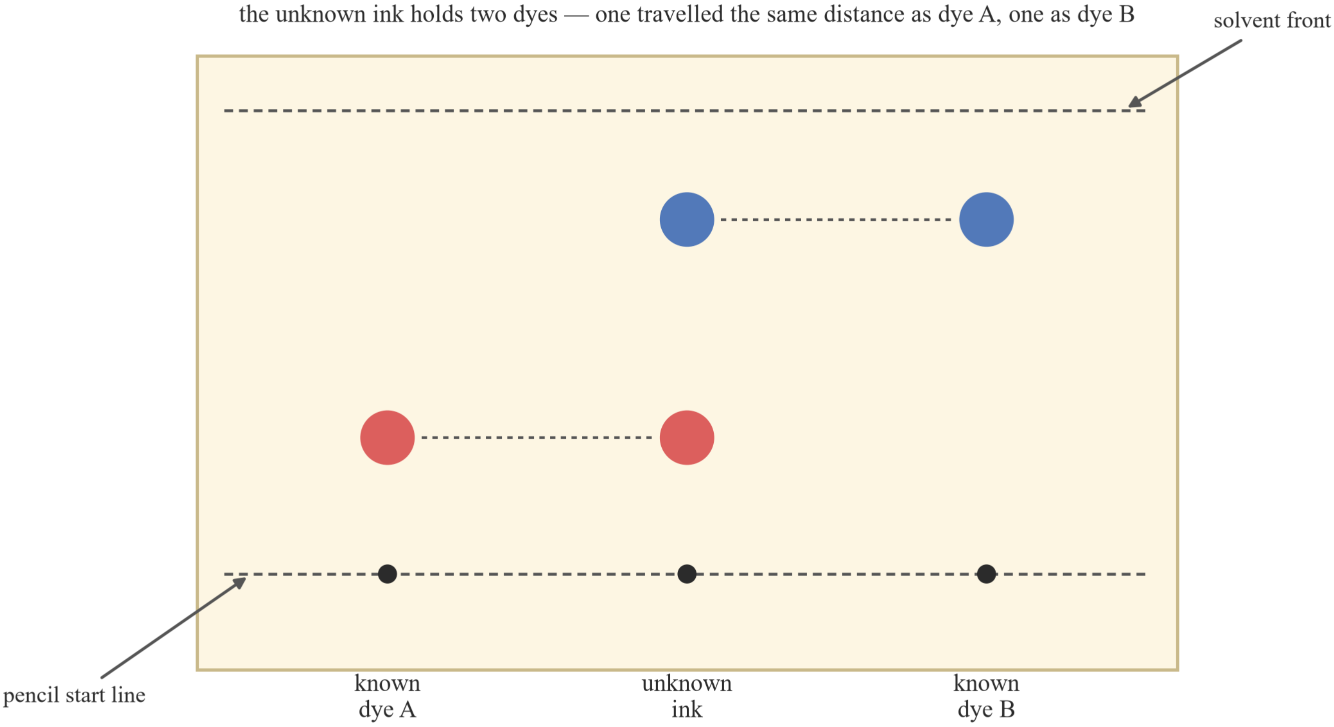
Three rules make the run work (this is the ink-and-dye run of `VC2S8U06.E04`):

- **Draw the start line in pencil**, not pen — pencil (graphite) does not dissolve, so the line stays put; a pen line would dissolve and run its own dyes up the paper.
- **The spot starts above the solvent level**, so the dyes dissolve into the rising solvent instead of washing straight off into the beaker.
- **Stop the run before the solvent reaches the top**, and mark how far it got — the **solvent front**.

Reading the result is matching, not measuring: a dye is identified by travelling the **same distance** as a known dye run beside it. Here we compare distances by eye; no ratio is computed at this level (D11).

Reading a chromatogram — match the spots to identify the dyes

the unknown ink holds two dyes — one travelled the same distance as dye A, one as dye B



A developed chromatogram with three lanes from a pencil start line: known dye A (one red spot), the unknown ink (a red spot and a blue spot), and known dye B (one blue spot); dashed lines match the unknown's red spot to dye A and its blue spot to dye B, under a solvent front line

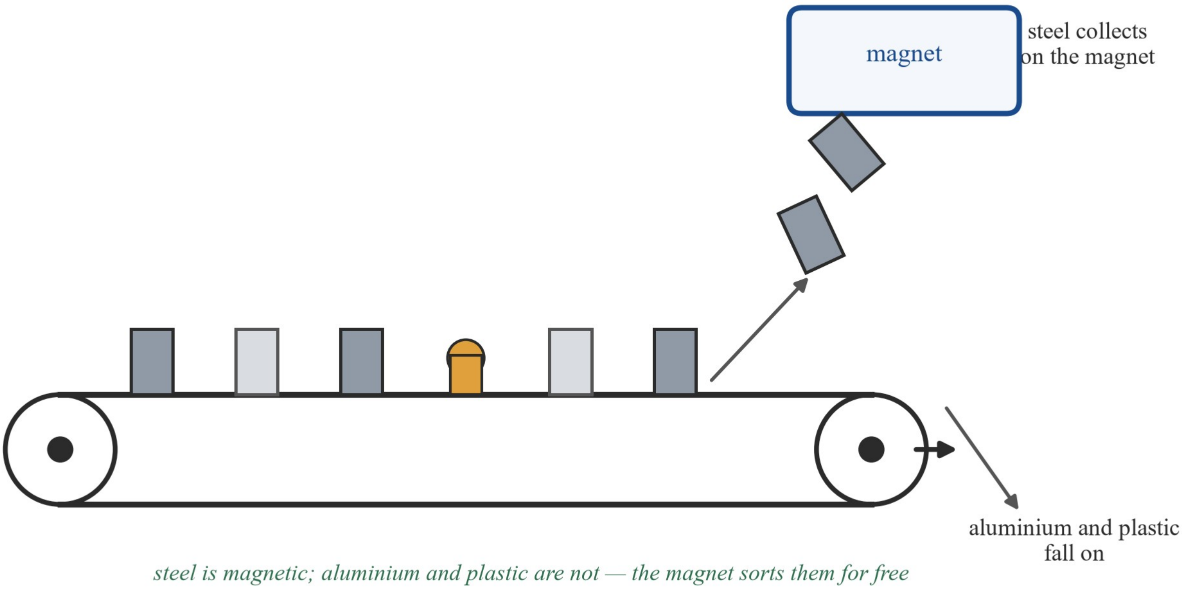
In this run the unknown ink holds **two** dyes: one travelled the same distance as dye A and one travelled the same distance as dye B — the ink is a mixture of the two.

Separation at work — homes, recycling, water (E07)

The same seven techniques run through everyday life and industry; only the size changes.

- **At home:** a colander draining pasta is filtration by particle size; pouring water off boiled potatoes is decantation; a tea strainer is filtration; leaving muddy dam water to settle and pouring off the clear water is decantation again.
- **In recycling:** an overband magnet hung over a conveyor lifts steel cans out of mixed recycling, while aluminium and plastic — not magnetic — fall on. Magnetism does the sorting for free, at the speed of the belt.

Magnetic separation at work — steel pulled from mixed recycling

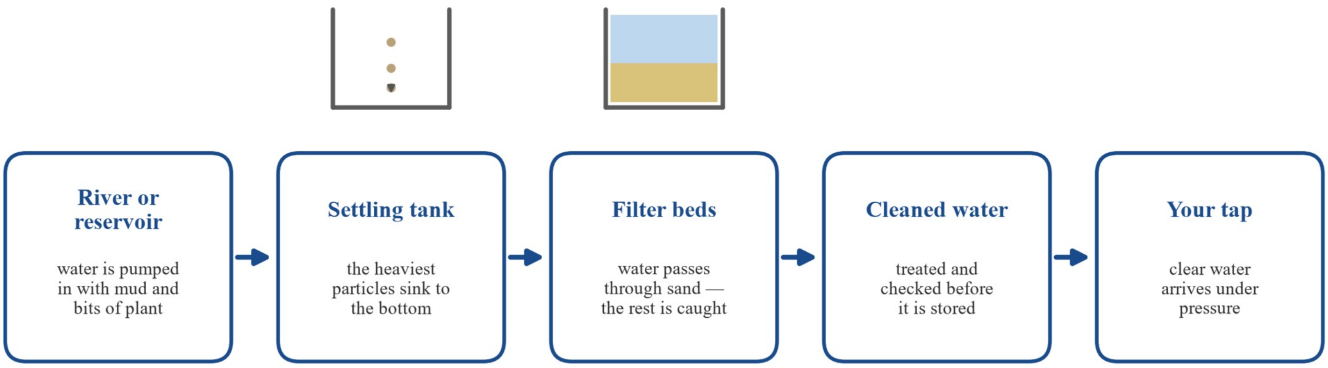


steel is magnetic; aluminium and plastic are not — the magnet sorts them for free

A conveyor belt carrying steel cans, aluminium cans and a plastic bottle under an overband magnet; steel cans lift off the belt towards the magnet while aluminium and plastic fall on, labelled as two output streams

- **In purifying water:** a town cleans its drinking water with the same two ideas at town size — a settling tank (the density handle of decantation) and filter beds of sand (filtration).

Separation at work — one way a town cleans its drinking water



settling is decantation's idea; the filter beds are filtration — the same two techniques, at town size

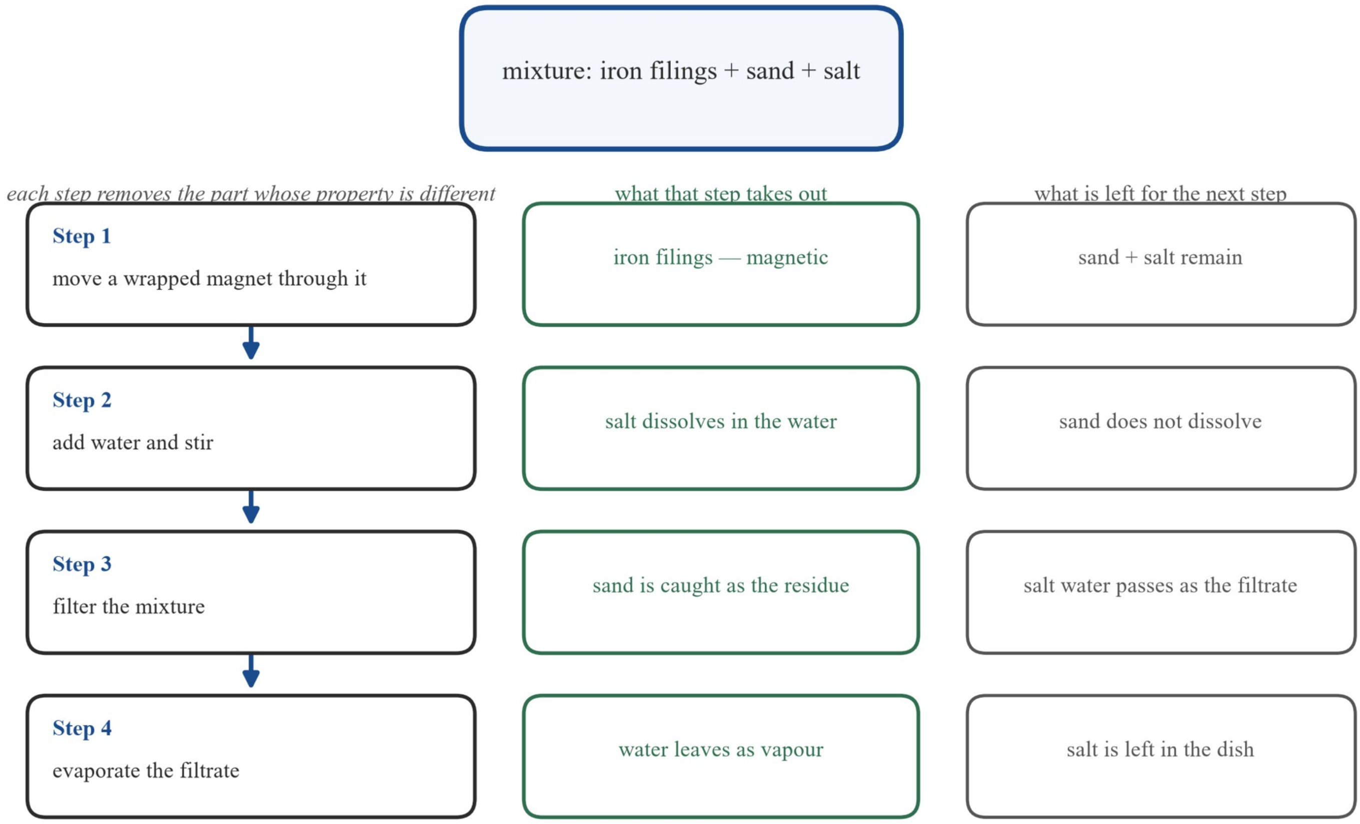
A five-box flow chart of a town water supply: river or reservoir, settling tank, filter beds, cleaned water, your tap; small icons above the settling tank show particles sinking and above the filter beds a sand layer under clear water; a caption notes that settling is decantation's idea and the filter beds are filtration

- **In industry:** crude oil is a mixture of many liquids with different boiling points, and it is separated by distillation on a large scale — worth watching a simulation or video of a distillation column to see the school apparatus scaled up (this is one of the `VC2S8U06.E07` contexts).

Design task — build a 'separating machine' (E06)

The elaboration `VC2S8U06.E06` asks you to design, make, test and refine a machine that separates a mixture. A good test mixture is **iron filings + sand + salt**, because it needs three different handles — and the order of the steps is the design problem.

Designing a separation — iron filings, sand and salt, split one property at a time



A four-step flow chart separating iron filings, sand and salt: step 1 a wrapped magnet removes the iron filings (magnetism), step 2 water is added and stirred so the salt dissolves (solubility), step 3 the mixture is filtered so the sand is caught as residue and salt water passes as filtrate (particle size), step 4 the filtrate is evaporated so the water leaves and the salt remains (volatility)

Run the design the way the inquiry subtopics teach:

- **Plan (subtopic 3A):** write the steps in order before touching anything — each step removes the part whose property is different, and what is left moves on to the next step.
- **Risk (subtopic 3B):** this version is low risk (magnet, sand, salt, water, filter paper) — still wear safety glasses as for any lab work, wipe spills, and if you evaporate with heat, treat the dish and tripod as hot.
- **Test and refine (subtopic 5A):** try the machine on the mixture, then evaluate — did the magnet take all the iron? Was the filtrate clear? If the filtrate is cloudy, the paper has a tear: refine that step and re-test.

A good design question to argue about: *could the steps run in a different order?* Adding water first would still let the magnet take the iron (wet iron is still magnetic) — but drying the wet iron afterwards is extra work, so magnet-first is the tidier machine. Evaluating choices like that is the refining in "design, make, test and refine".

Words to know in 10D

Word	What it means here
filtration	separating an insoluble solid from a liquid by passing the mixture through filter paper
residue	the solid caught on the filter paper
filtrate	the liquid that passes through the filter paper

Word	What it means here
decantation	letting a solid settle, then pouring the liquid off
evaporation	heating a solution so the liquid boils off and the dissolved solid is left behind
crystallisation	getting a dissolved solid back slowly, as crystals, by slow cooling or slow evaporation
magnetic separation	using a magnet to lift a magnetic part out of a mixture
distillation	boiling a liquid off and then cooling the vapour back to a liquid so it can be collected
volatile	(of a liquid) evaporating and boiling easily
chromatography	separating dissolved substances by letting a solvent carry them along a paper at different rates
solvent front	the furthest point the solvent reached on the paper

Worked examples

Example 1 — scaffolded

For each mixture, name the property the parts differ in and the technique you would use: (a) sand and water, where you want the water clear; (b) salt water, where you want the salt.

Working	Comment
(a) Sand is an insoluble solid — the parts differ in **particle size**. → **Filtration**: the water passes, the sand is caught as residue.	Filtration is the particle-size handle; the sand is too big for the paper's holes.
(b) Salt is dissolved — the parts differ in **volatility**. → **Evaporation**: the water boils off, the salt stays.	A dissolved solid passes through filter paper, so filtration cannot help; the boiling-point handle must.

Example 2 — scaffolded

Use the chromatogram figure to read the unknown ink.

Working	Comment
1. The unknown ink shows two spots: one red, one blue.	Each separated dye gives one spot.
2. The red spot travelled the same distance as known dye A; the blue spot travelled the same distance as known dye B.	Dyes are matched by equal travel distance from the same start line.
3. ∴ the unknown ink is a mixture of dye A and dye B.	Matching distances identifies the dyes — no measuring needed at this level.

Example 3 — unscaffolded

A student has salt water and wants **pure water** from it. Explain why evaporation alone will not do, and name and explain the technique that will.

Evaporation boils the water off as vapour and lets it escape into the air — the salt is kept but the water is lost, so it cannot give the student the water. Distillation adds a condenser: the vapour is cooled back to liquid and collected. ∴ to keep the liquid as well as leave the solid behind, the technique is distillation — the water boils at about 100 °C and the salt does not boil away, so what condenses and collects is pure water.

Example 4 — unscaffolded

A dish holds a mixture of iron filings, sand and salt. Design a procedure that ends with three separate piles, and state the property each step uses.

Step 1: pass a wrapped magnet through the mixture — it lifts out the iron filings (magnetism). Step 2: add water and stir — the salt dissolves, the sand does not (solubility). Step 3: filter — the sand is caught as the residue and the salt water passes as the filtrate (particle size). Step 4: evaporate the filtrate — the water leaves as vapour and the salt is left in the dish (volatility). ∴ three properties — magnetism, solubility, particle size, then volatility — give three clean piles: iron, sand, salt. This is exactly the separating-machine chain of the design task figure.

Practice questions

Scaffolded

Q1. Name the technique that separates an insoluble solid from a liquid using filter paper in a funnel.

Q2. Filtering sand and water, name (a) the solid caught on the paper, (b) the liquid that passes through.

Q3. Muddy water is left to stand until the mud sinks, and the clear water is poured off. Name the technique.

Q4. Salt water is heated in an evaporating dish until dry. State what is left in the dish and what has left it, and name the technique.

Q5. State the property that makes magnetic separation work, and one mixture it could separate.

Q6. Complete the explanation: "The start line in chromatography is drawn in pencil because pencil …, and the spot of ink is placed above the solvent level so the dyes …"

Unscaffolded

Q7. Iron filings are mixed with sand. Describe how to separate them and state the property your method uses.

Q8. A student has salt water and wants pure water. Name the technique and explain what the condenser does in it.

Q9. A mixture is sand and salt. Describe, step by step, how to get the salt out, and say what happens to the sand.

Q10. A chromatogram of an unknown ink shows a single spot, and it travelled the same distance as known dye B. What can you conclude about the ink?

Q11. Two dishes hold the same salt solution. One is heated fast until dry; the other is left to cool and stand for a week. Compare what you would see in the two dishes and explain the difference.

Q12. At a recycling plant, a magnet hangs over a conveyor carrying steel cans, aluminium cans and plastic bottles. Explain what the magnet removes and why the rest fall on.

Q13. In the town water flow chart, name the separation idea at work in (a) the settling tank, (b) the filter beds.

Q14. A student draws the chromatography start line in pen instead of pencil. Explain why the run is ruined.

Answers

Q1. Filtration. **Q2.** (a) The residue (sand). (b) The filtrate (water). **Q3.** Decantation. **Q4.** Salt is left in the dish; the water has left as vapour. The technique is evaporation. **Q5.** Magnetism — one part is attracted to a magnet and the rest is not; for example iron filings and sand. **Q6.** …does not dissolve, so the line stays put; …dissolve into the rising solvent instead of washing off into the beaker. **Q7.** Pass a (wrapped) magnet through the mixture; the iron filings stick to it and the sand stays. The property is magnetism — iron is magnetic, sand is not. **Q8.** Distillation. The condenser cools the water vapour back to a liquid so it can be collected. **Q9.** Add water and stir (the salt dissolves; the sand does not); filter (the sand is caught as the residue); evaporate the filtrate (the water leaves and the salt is left). **Q10.** The ink contains dye B (one spot matching dye B's distance); there is no sign of a second dye, so the ink appears to be a single dye, or at least to contain dye B. **Q11.** The fast-heated dish shows a fine powder of tiny grains; the slow dish shows bigger, shaped crystals. The slower the liquid leaves or cools, the bigger the crystals grow. **Q12.** The magnet lifts the steel cans off the belt (steel is magnetic); aluminium and plastic are not magnetic, so they are not attracted and fall on. **Q13.** (a) Decantation's idea — the densest particles settle and the liquid is moved on. (b) Filtration — the water passes through sand and the remaining solids are caught. **Q14.** Pen ink dissolves in the solvent, so the pen line itself runs up the paper and adds its own dye spots to the run — the result no longer shows only the ink being tested.

Fully-worked solutions

Q1. The technique is **filtration** *(1 mark)*.

Q2. (a) The caught solid is the **residue** (the sand) *(1 mark)*. (b) The liquid that passes through is the **filtrate** (the water) *(1 mark)*.

Q3. The technique is **decantation** — settle, then pour off *(1 mark)*.

Q4. Salt is left in the dish *(1 mark)*; the **water has left as vapour** *(1 mark)*. The technique is **evaporation** *(1 mark)*.

Q5. The property is **magnetism** — one part is attracted to a magnet and the rest is not *(1 mark)*; for example **iron filings and sand** *(1 mark)*.

Q6. Pencil **does not dissolve**, so the start line stays put *(1 mark)*; the spot sits above the solvent level so the dyes **dissolve into the rising solvent instead of washing off into the beaker** *(1 mark)*.

Q7. Pass a wrapped magnet through the mixture *(1 mark)*; the iron filings stick to the magnet and the sand stays in the dish *(1 mark)*. The property used is **magnetism** — iron is magnetic, sand is not *(1 mark)*.

Q8. The technique is **distillation** *(1 mark)*. The condenser **cools the water vapour back to a liquid** (condenses it) so it can be collected *(1 mark)*.

Q9. Add water and stir — the salt dissolves, the sand does not *(1 mark)*; filter — the sand is caught as the residue and salt water passes as the filtrate *(1 mark)*; evaporate the filtrate — the water leaves as vapour and the salt is left in the dish *(1 mark)*.

Q10. The ink's single spot travelled the same distance as dye B, so **the ink contains dye B** *(1 mark)*; with no second spot, **there is no evidence of any other dye** in the ink *(1 mark)*.

Q11. The fast-heated dish holds a **fine powder of tiny grains**; the slow dish holds **bigger, shaped crystals** *(1 mark)*. The difference is speed: **the slower the liquid leaves or cools, the bigger the crystals grow** — fast evaporation gives grains, slow cooling gives crystals *(1 mark)*.

Q12. The magnet **lifts the steel cans off the belt**, because steel is magnetic *(1 mark)*; **aluminium and plastic are not magnetic**, so no force pulls them and they fall on *(1 mark)*.

Q13. (a) The settling tank is **decantation's idea** — the densest particles sink and the liquid moves on *(1 mark)*. (b) The filter beds are **filtration** — water passes through the sand and the remaining solids are caught *(1 mark)*.

Q14. Pen ink **dissolves in the solvent** *(1 mark)*, so the pen line **runs up the paper and adds its own dye spots**, and the chromatogram no longer shows only the ink under test *(1 mark)*.

Sources

Web sources below were retrieved 2026-08-21.

- Science ASSIST (Australian Science Teachers' Association), "Risk management", n.d. asta.edu.au

The boiling point quoted for water (about 100 °C) is the standard table value, given for practice; no simulated data tables are used in this subtopic — the chromatograms and flow charts are qualitative by design (D11).

Elaboration contexts used: `VC2S8U06.E03` (analysing how the physical properties of substances in mixtures determine the separation technique used), `VC2S8U06.E04` (paper chromatography of coloured inks and food dyes), `VC2S8U06.E06` (designing, making, testing and refining a separating machine) and `VC2S8U06.E07` (separation at home, in recycling industries and in purifying water, and crude oil distillation viewed in simulation).

Teacher-facing note — reserved elaboration (not student text). `VC2S8U06.E05`, the elaboration that places these separation techniques in Aboriginal and Torres Strait Islander contexts, is reserved under the ICIP decision (D10; CONTENT_POLICY rule 1): no Aboriginal or Torres Strait Islander content is delivered in this book. The techniques it names (hand-picking, sieving, winnowing, filtering, pressing, distilling) appear here only in general contexts — home, recycling and water treatment — per `VC2S8U06.E07`.