Particles and states of matter

Teacher review edition. Ask your teacher if anything is unclear.

Why can ice, water and steam behave so differently?

What you will learn

- Describe the particles in a solid, liquid and gas.
- Explain melting, freezing, boiling and evaporation.
- Use melting and boiling points to identify a state.
- Explain why mass is conserved.

Matter is made of particles

> **Particle model**
> An explanation of matter using tiny moving particles.

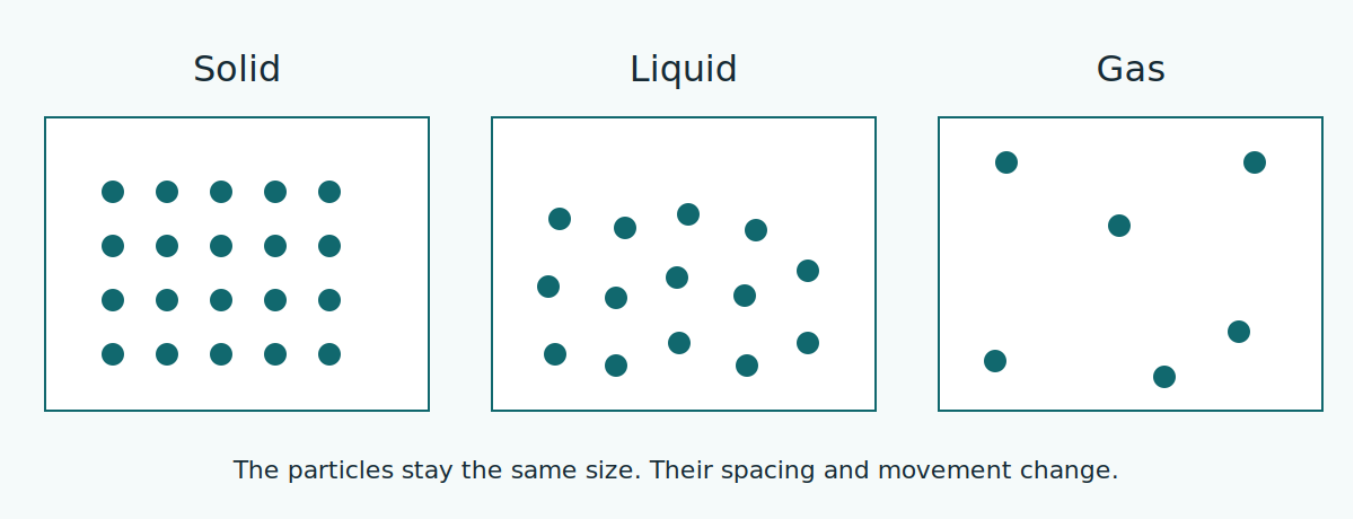
Matter is anything that has mass and takes up space. Air, water and everyday objects are all matter.

- Matter is made of tiny particles, too small to see with your eyes.
- The particle model explains matter using particles that move and have spaces between them.
- Their arrangement and movement explain the properties of solids, liquids and gases.

Solids, liquids and gases

> **Solid**
> A state of matter with a fixed shape and volume.
>
> **Liquid**
> A state of matter with a fixed volume but no fixed shape.
>
> **Gas**
> A state of matter with no fixed shape or volume.

State	What the particles do	What we observe
Solid	Stay close together and vibrate about fixed positions.	Has a fixed shape and volume.
Liquid	Stay close together but move past one another.	Has a fixed volume and takes the shape of its container.
Gas	Are far apart and move freely in all directions.	Spreads out to fill its container.



Particles are close together in solids and liquids, but much further apart in a gas. The particles do not grow when a substance changes state.

Why is a gas easy to compress?

Compressing means squeezing something into a smaller space.

- Gases: large spaces between particles allow the particles to be pushed closer together.
- Solids and liquids: particles are already close together, so these states are difficult to compress.

Changing state

> **Physical change**
> A change in which no new substance is made.

Heating transfers energy to a substance. Its particles do not grow or shrink when it changes state.

- As a solid warms, its particles vibrate more. During melting, they leave their fixed positions and move past one another.
- Melting: solid → liquid.
- Freezing: liquid → solid.
- Boiling or evaporation: liquid → gas.
- Condensation: gas → liquid.

Evaporation and boiling

Both evaporation and boiling change a liquid into a gas.

- Evaporation happens at the surface and can occur below the boiling point. It dries a wet jumper.
- Boiling happens throughout the liquid at its boiling point. Bubbles form inside the liquid.
- Pure water boils at about 100 °C at normal air pressure.

Melting and boiling points

Different substances have different melting and boiling points. The table uses normal air pressure.

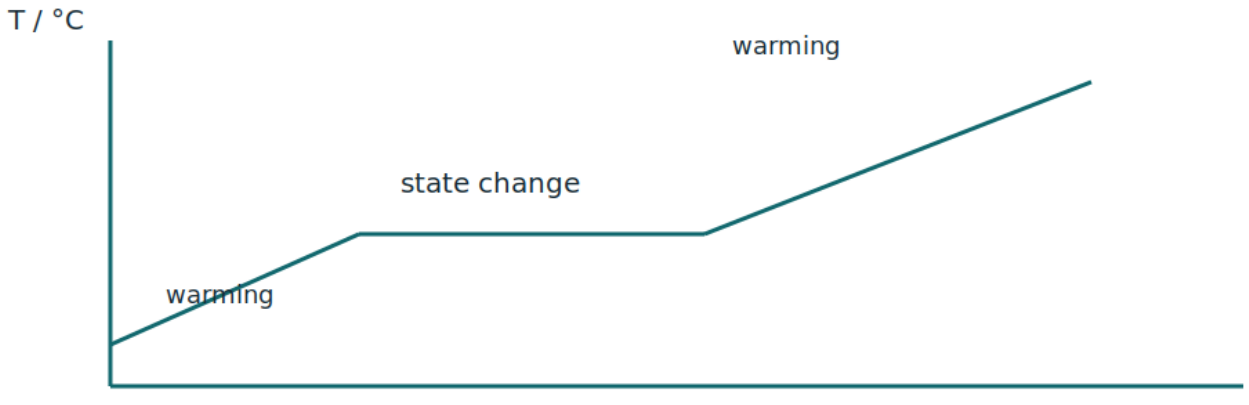
- Below the melting point: solid.
- Between the melting and boiling points: liquid.
- Above the boiling point: gas.

Substance	Melting point	Boiling point
Water	0 °C	100 °C
Ethanol	-114 °C	78 °C
Aluminium	660 °C	2519 °C

What happens on a heating curve?

A heating curve shows temperature as a substance is heated.

- Sloping sections: temperature rises.
- Flat sections can show melting or boiling.
- During a change of state, energy changes particle arrangement or separation.
- For a pure substance at constant pressure, temperature stays constant until the change of state is complete.



Temperature stays constant while a pure substance melts.

For a pure substance at constant pressure, flat sections show melting or boiling while energy is still being transferred in.

Matter does not disappear

> **Closed system**
> A system that matter cannot enter or leave.

Conservation of mass means that total mass stays the same when no matter enters or leaves.

- Physical change: no new substance forms. Melting ice is still water.
- Chemical change: new substances form, but atoms are still present.
- If gas escapes from an open container, the measured mass falls because matter has left.

Worked examples

A container and its contents have a total mass of 146.2 g. A change takes place inside it, but no matter enters or leaves. What is the total mass afterwards?

Work through it

1. The mass before the change is 146.2 g.
2. All the particles stay inside, including any gas produced.
3. The total mass afterwards is therefore 146.2 g.

Another example

1. Ethanol melts at −114 °C and boils at 78 °C at normal air pressure.
2. 20 °C lies between these two temperatures.
3. Ethanol is therefore a liquid at 20 °C.

Common mistakes

Common mistake: Particles get bigger when a substance is heated.

Remember: The particles themselves do not get bigger. Their movement and separation can change.

Common mistake: Evaporation happens only at the boiling point.

Remember: Evaporation happens at the liquid surface and can occur below its boiling point.

Answering questions

- For a particle explanation, describe arrangement, spacing and movement – not just what the substance looks like.
- To identify a state from data, compare the stated temperature with both the melting and boiling points.

Try an investigation

Observe ice melting and record its temperature at regular intervals. Plot temperature against time. For a conservation-of-mass reaction, use teacher-supplied data or approved gas-collection equipment. Never seal a gas-producing reaction in a rigid container.

Plan, record and review

- Question and prediction: What are you testing, and what do you think will happen? Give a reason.
- Change, measure, keep the same: What will you deliberately change? What will you measure, and in what units? What stays the same to make it a fair test? For an observation, say what you will record consistently instead.
- Record and look for a pattern: Use a table with headings and units. Look for a pattern or a result that does not fit.
- Conclude from evidence: Answer your question using a result or observation. Say if the evidence is unclear.
- Improve the investigation: What would you repeat or change, and how would that make the evidence better?

Do practical work with your teacher and follow the laboratory safety instructions.