# The three states of matter

4.2.2.1 · Bonding, structure and the properties of matter · revision notes

Solids, liquids and gases, the changes of state between them, and why different substances melt and boil at different temperatures. You need to predict states from melting and boiling point data, explain changes of state in terms of energy and forces and, on the Higher tier, explain the limitations of the simple particle model.

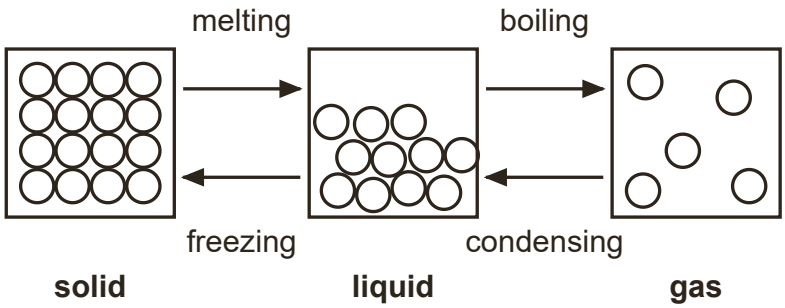
## Key facts

- Solid: close, regular, vibrate about fixed positions
- Gas: far apart, random, move quickly in all directions
- Stronger forces between particles → more energy needed → higher melting and boiling points
- Grade 7+ only Particle model limitations: particles shown as solid spheres with no forces between them
- Liquid: close, random, move around each other
- Melting and freezing at the melting point; boiling and condensing at the boiling point
- Below mp: solid; between mp and bp: liquid; above bp: gas

## Notes

### Solids, liquids and gases

- In the simple particle model, each particle (atom, ion or molecule) is drawn as a small solid sphere.
- **Solid**: particles packed closely in a regular arrangement; they vibrate about fixed positions.
- **Liquid**: particles close together but randomly arranged; they move around each other.
- **Gas**: particles far apart and randomly arranged; they move quickly in all directions.




Solid: regular, touching. Liquid: random, touching. Gas: far apart.

## Changes of state, energy and forces

- **Melting** (solid → liquid) and **freezing** (liquid → solid) happen at the **melting point**. **Boiling** (liquid → gas) and **condensing** (gas → liquid) happen at the **boiling point**.
- To melt or boil a substance, energy must be transferred to it to overcome the forces between its particles. When it freezes or condenses, energy is transferred to the surroundings.
- The **stronger the forces** between the particles, the **more energy** is needed, so the **higher** the melting and boiling points.
- The strength of the forces depends on the type of bonding and structure, e.g. strong ionic bonds in sodium chloride, but only weak forces between the molecules in oxygen.
- To predict the state at a temperature: below the melting point it is a solid; between the melting and boiling points a liquid; above the boiling point a gas.

## Atoms and bulk properties

- Melting point, colour, hardness and conductivity are **bulk properties**: they belong to a large collection of particles, not to a single atom.
- For example, a single copper atom is not orange-brown, and a single water molecule does not have a boiling point.

## Limitations of the particle model Grade 7+ only

- The model shows particles as **solid** spheres. Real atoms are not solid (they are mostly empty space).
- The model shows all particles as **spheres**. Real particles are atoms, ions or molecules, and many molecules are not spherical.
- The model shows **no forces** between the particles. In reality there are forces of attraction, and their strength decides the melting and boiling points.
- So the simple model cannot explain why different substances change state at different temperatures.

## How to answer each type of question

### Predict the state of a substance from data

1 to 3 marks | Grade 5

1. Compare the temperature with the melting point first, then the boiling point.
2. Below the melting point → solid; between the two → liquid; above the boiling point → gas.
3. Take care with negative numbers: −183 °C is colder than −7 °C.

**Example.** The table gives data for three substances.

| Substance | Melting point in °C | Boiling point in °C |
|---|---|---|
| A | −218 | −183 |
| B | −7 | 59 |
| C | 801 | 1413 |

Give the state of each substance at 25 °C.

**Model answer.**

A: gas (1)
B: liquid (1)
C: solid (1)

### Describe what happens to the particles during a change of state

2 to 3 marks | Grade 5

1. Say that energy is transferred to (or from) the particles.
2. Say what happens to the forces between the particles.
3. Describe the new arrangement and movement of the particles.

**Example.** Describe what happens to the particles when a solid is heated until it melts.

**Model answer.** Energy is transferred to the particles, so they vibrate more (1). At the melting point they have enough energy to overcome some of the forces holding them in fixed positions (1). The particles can then move around each other in a random arrangement (1).

**Explain why one substance has a higher boiling point than another** 3 marks **Grade 6**

1. Say which substance has the stronger forces between its particles (name the forces if you know the bonding).
2. Say that more energy is needed to overcome these forces.
3. Link this to the higher boiling point.

**Example.** Substance C boils at 1413 °C and substance B boils at 59 °C.
Explain, in terms of the forces between particles, why substance C has a much higher boiling point than substance B.

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**Model answer.** The forces between the particles in C are much stronger than the forces between the particles in B (1). So much more energy is needed to overcome the forces in C (1). This means C must be heated to a much higher temperature before it boils (1).

**Give limitations of the particle model** 2 marks **Grade 7**

1. Name what the model shows: solid spheres with no forces between them.
2. Say how real particles are different, and what the model therefore cannot explain.

**Example.** In the simple particle model, particles are shown as small solid spheres.
Give two limitations of this model for explaining changes of state.

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**Model answer.**

Any two from:

| | |
|---|---|
| there are no forces between the spheres, but real particles attract each other | (1) |
| real particles are not solid / atoms are mostly empty space | (1) |
| real particles are not all spheres | (1) |
| it cannot explain why different substances melt or boil at different temperatures | (1) |

## Don’t lose marks

- Getting negative temperatures the wrong way round: −183 °C is lower than −7 °C.
- Saying the particles in a solid don't move. They vibrate about fixed positions.
- Saying the particles themselves expand or melt. The particles don't change; their energy, movement and arrangement do.
- Saying that boiling always breaks bonds. For small molecules only the weak forces between the molecules are overcome.
- Writing 'it needs heat' without linking the energy to overcoming the forces between particles.

## More tips

### Memory tricks

- Number line trick: mark the melting point and boiling point on a line, then place the temperature. Left of the mp = solid, between = liquid, right of the bp = gas.
- Stronger forces, higher temperatures: the strength of the forces between particles decides the melting and boiling points.
- Melting and freezing happen at the same temperature, in opposite directions. So do boiling and condensing.

### Exam technique

- In data questions, quote the numbers: 'at 25 °C, B is above its melting point (−7 °C) but below its boiling point (59 °C), so it is a liquid'.
- Always say what is overcome: 'the forces between the particles', or name the actual bonds or forces.
- Higher tier: learn the three limitations of the model: particles shown as solid, as spheres, and with no forces between them.

## What each grade needs

What you need to be able to do, from the first marks up to the top grade.

**Grade 3**

**Name the changes of state**

Melting and freezing happen at the melting point; boiling and condensing happen at the boiling point.

**Grade 4**

**Describe particles in solids, liquids and gases**

Regular and vibrating in solids, close but moving around in liquids, far apart and moving quickly in gases.

**Grade 5**

**Predict states from melting and boiling points**

Below the melting point: solid; between the melting and boiling points: liquid; above the boiling point: gas.

**Grade 6**

**Link melting and boiling points to forces**

The stronger the forces between the particles, the more energy is needed and the higher the melting and boiling points.

**Grade 6**

**Recognise that single atoms lack bulk properties**

One atom does not have properties such as colour, melting point or conductivity; these come from huge numbers of particles.

**Grade 7**

**Give limitations of the particle model**

The model shows particles as solid spheres with no forces between them; real particles are not like this.

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