States of Matter Notes

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The particle model: a scientific idea used to explain the properties of solids, liquids and gases.

Matter can exist in many different forms. There are four that we see in everyday life, these are solids, liquids, gases and plasma (fire). For the GCSE we only study three states these are **solids**, **liquids** and **gases**.
We need to understand the following about each of the three states of matter:

1. **How the particles are arranged in each state.**
2. **How the particles move in each state.**
3. **What the forces between the particles are like in each state.**
4. **What are the properties of each state.**

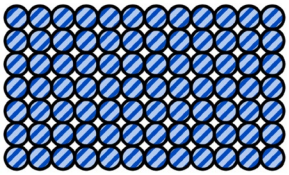
Solids

Particle arrangement: the particles in a solid are closely packed in a fixed regular arrangement.

Particle movement: Particles vibrate about their fixed positions so they don't move freely.

Forces between particles: There are strong forces of attraction holding the particles in place.

Properties: Solids are incompressible which means they cannot be compressed into a smaller space. Solids typically have a high density. Solids have a definite shape which means that they will not flow.



The figure shows the arrangement of particles in a solid.

Solids have the lowest kinetic energy.

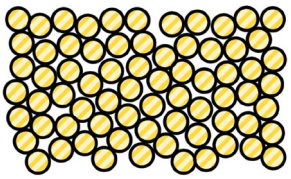
Liquids

Particle arrangement: particles are close together but further apart than they are in solids.

Particle movement: particles are constantly moving **randomly**, sliding past one another. This movement allows liquids to flow.

Forces between particles: there are weak forces holding particles to each other.

Properties: liquids are incompressible. Liquids can flow and take the shape of any container they are placed into.



The diagram shows the arrangement of particles in a liquid.

Liquids have more kinetic energy that solids.

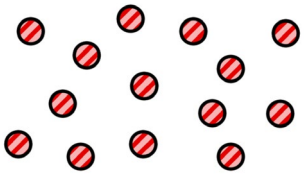
Gases

Particle arrangement: particles are far apart from each other.

Particle movement: particles move rapidly and randomly in all directions.

Forces between particles: there are forces between particles but they are very weak and easy to overcome.

Properties: gases are compressible, this means they can be compressed into a smaller volume.
Gases don't have a definite shape meaning they will take the shape of their container.

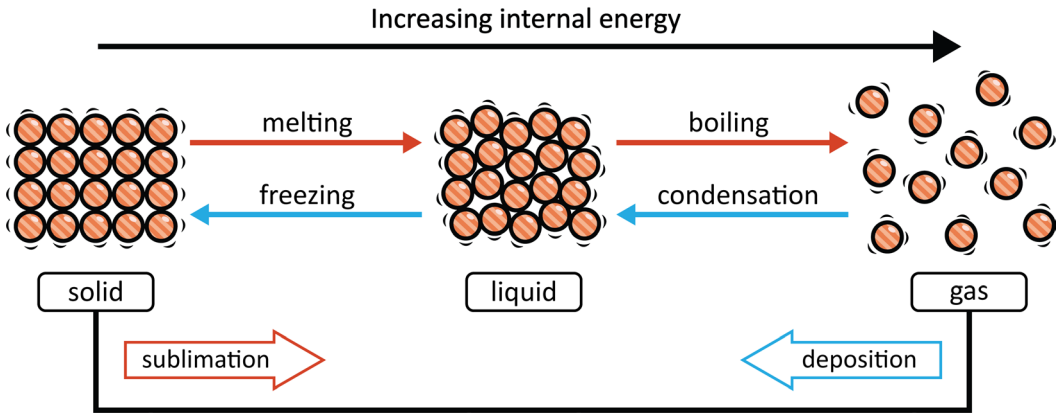


The diagram shows the arrangement of particles in a gas.

Gases have the highest kinetic energy.

Changes of State

Substances can exist as a solid, liquid or gas. Converting from one state to another usually involves heating or cooling. The figure below shows the changes in heat energy and their effect on the state of matter.



Energy (in the form of heat) must be supplied to a substance for it to melt or boil. A liquid can also turn into a gas by evaporating, which happens at the surface and can occur at any temperature.

For example, you need to heat ice to melt it, and you need to heat water to make steam. Heat must be removed from a substance to condense or freeze it. In other words, the substance must be cooled down.

Under certain conditions, some solids turn straight into a gas when heated. This process is called **sublimation**.

Sublimation: the direct change of a solid into a gas. **Deposition**: is the direct change of a gas to a solid.

A good example of sublimation is solid carbon dioxide, also called 'dry ice'. At atmospheric pressure, it turns straight into gaseous carbon dioxide. Liquid carbon dioxide can exist under high pressure, such as in fire extinguishers.

Energy must be removed or lost from a substance for it to condense or freeze. A gas can form a liquid by condensing and a liquid can form a solid by freezing.

State Symbols

In chemical equations, state symbols are written in brackets after a chemical formula to show the physical state of the reactants and products. There are **four state symbols** we need to know for GCSE these are…

(s)	**(l)**	**(g)**	**(aq)**
Solid	**Liquid**	**Gas**	**Aqueous**

Exam note: a common error in exams is mixing up the state symbols (l) and (aq).

Use (**l**) for a pure liquid (like pure H_2O) or a substance that has been melted.

Use (**aq**) only when a substance is dissolved in water like NaCl (aq) which is salt dissolved in water.

Limitations of the Particle Model

The simple particle model which is the drawings of solids, liquids, and gases as little circles, is really very useful for visualising states of matter, but it's not a perfect show of the reality of what the substance actually looks like.

For the exams, we need to know three main limitations of this model:

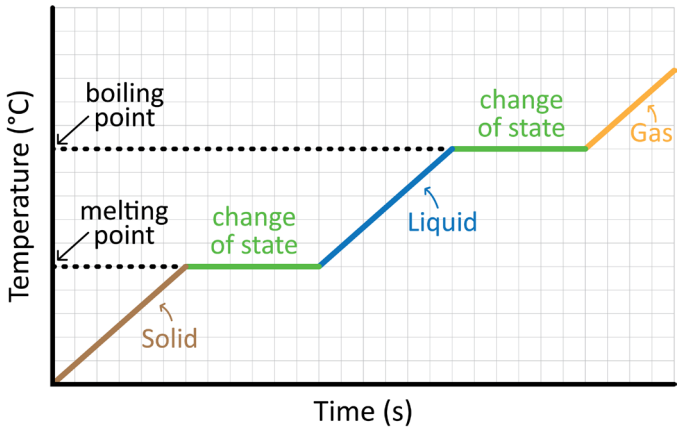
Limitation 1: It assumes particles are solid spheres.

Limitation 2: It does not show the forces between particles.

Limitation 3: It assumes all particles are the exact same size.

Heating and Cooling Curves

A heating or cooling graph is a visual way of showing exactly what happens to the temperature of a substance as we steadily add heat to it, or take heat away from it, over time. The figure below shows a typical heating graph.



The Y-axis always shows the Temperature (usually in °C).

The X-axis shows the Time or sometimes the amount of thermal energy added.

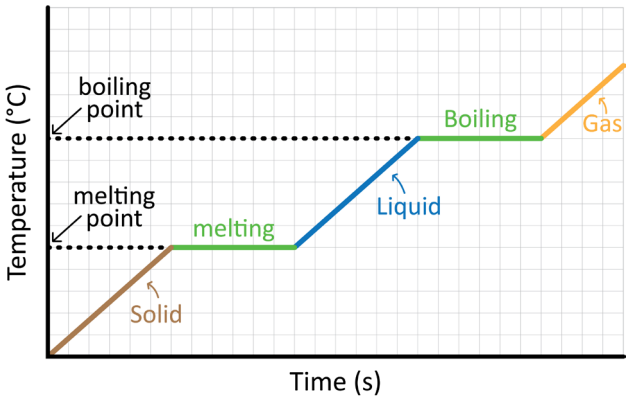
Why does it look a bit like a staircase? Let's explain this with an example, if we heat up a block of ice, we might expect the temperature to just go up in a straight line. **But**… because substances change state (melt and boil), the graph actually forms a "staircase" shape! Let's look at heating curves first 😊

Heating Curves

Heating curves are graphs that show a substance absorbing thermal energy.

As the overall temperature goes up, the substance changes from **solid to liquid to gas**.

What do we need to know? We need to know what the different lines on the graph mean and what is happening at the horizontal lines.



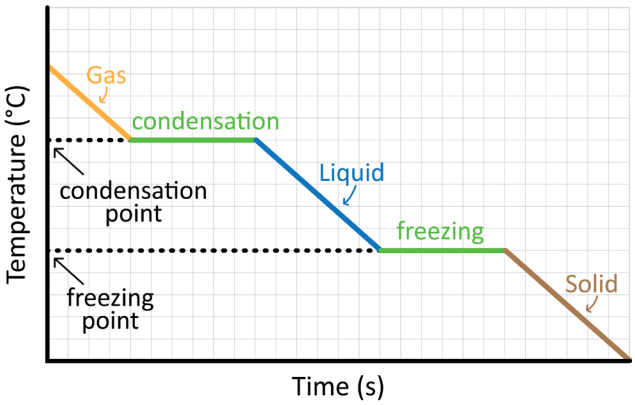
The sloped lines – Heating up: as we add heat, the particles gain kinetic energy and vibrate faster.

The first flat line – Melting: at the melting point, the temperature stops going up.

What happens here? The energy is now being used to break the bonds between particles instead, turning the solid into a liquid.

The second flat line – Boiling: the exact same thing happens here! The temperature stays perfectly steady while the heat energy completely breaks the bonds, turning the liquid into a gas. 😊

Cooling Curves



Cooling curves show a substance losing thermal energy to its surroundings.

As the overall temperature goes down, the substance changes from **gas to liquid to solid**.

The sloped lines – cooling down: as heat is transferred away, the particles lose kinetic energy and slow down.

The first flat line – condensing: The temperature stops dropping. The particles are coming close enough to form bonds, turning the gas into a liquid.

The second flat line – freezing: The temperature stops dropping The particles are coming close enough to form bonds, turning the liquid into a solid