

# Particle model of matter

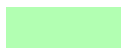
Specification 8464 · AQA

## Free edition

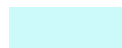
**Revision notes for one topic, free to download.**

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

## Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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### Define Density

- the mass per unit volume of a material.

### Define Change of state

- a physical change between solid, liquid and gas (melting, freezing, boiling, evaporating, condensing, subliming).

### Define Internal energy

- the total kinetic energy and potential energy of all the particles (atoms and molecules) that make up a system.

### Define Latent heat

- the energy needed for a substance to change state.

### Define Specific latent heat of fusion

- specific latent heat for the change of state from solid to liquid.

### Define Particle model

- a model in which matter is made of small particles whose arrangement and motion explain the properties of solids, liquids and gases.

### Define Physical change

- a change in which no new substance is made, so the material recovers its original properties if the change is reversed.

### Define Specific heat capacity

- the amount of energy required to raise the temperature of one kilogram of a substance by one degree Celsius.

### Define Specific latent heat

- the amount of energy required to change the state of one kilogram of a substance with no change in temperature.

### Define Specific latent heat of vaporisation

- specific latent heat for the change of state from liquid to vapour.

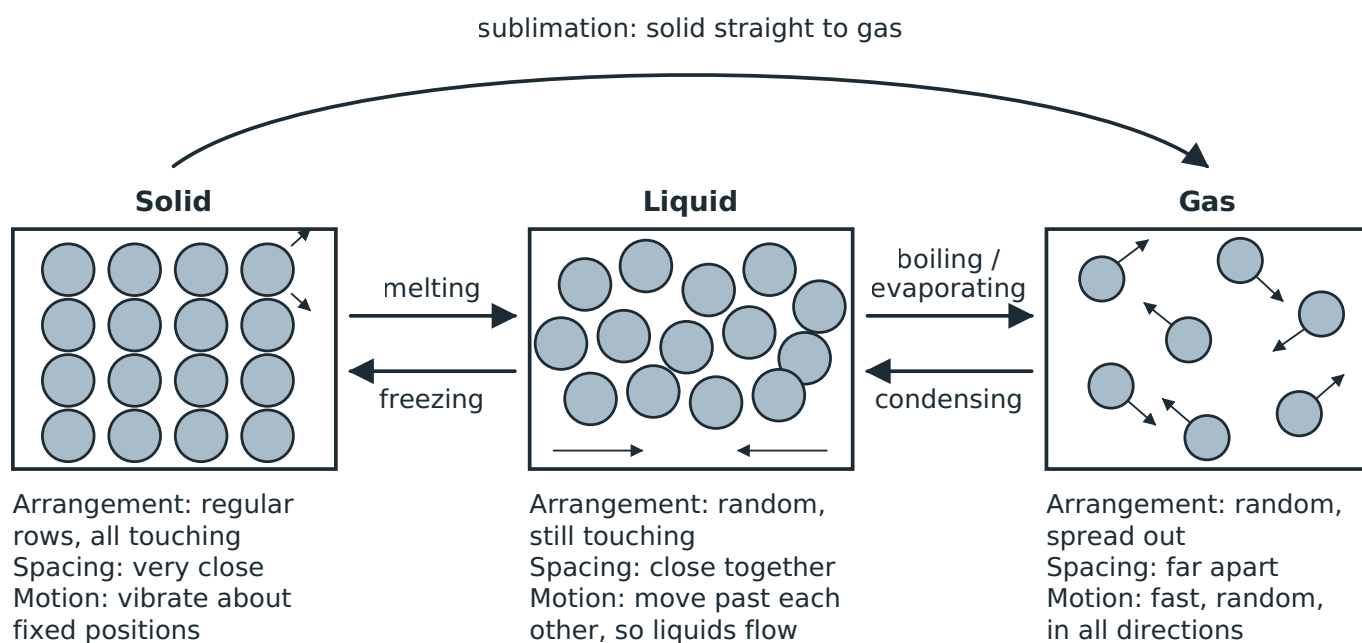
## 20.1 Changes of state and the particle model

### 20.1.1 Density of materials

| State         | Arrangement                             | Movement                                     | Density                  | Shape / volume                        |
|---------------|-----------------------------------------|----------------------------------------------|--------------------------|---------------------------------------|
| <b>Solid</b>  | Regular, touching, tightly packed       | Vibrate about fixed positions                | Highest                  | Fixed shape and volume                |
| <b>Liquid</b> | Close together and touching, but random | Move around each other                       | Slightly below the solid | Takes container's shape, fixed volume |
| <b>Gas</b>    | Far apart, random, mostly empty space   | Constant random motion, fast, all directions | Very much lower          | Fills its container                   |

- You should be able to **draw or recognise simple diagrams** of these three arrangements.
- **Explaining the density difference:** in a solid or liquid the particles are touching, so a given volume holds a very large number of particles — high density. In a gas they are far apart, so the same volume holds far fewer — much lower density. A solid is usually slightly denser than its liquid because its particles are packed in a regular, more efficient pattern.

## The particle model of solids, liquids and gases



A change of state is a physical change, not a chemical change — no new substance is made.  
Mass is conserved: they are the same particles, just arranged and spaced differently.  
Reverse the change and the material recovers its original properties.  
The spacing changes, so the states have very different densities — a gas is least dense.

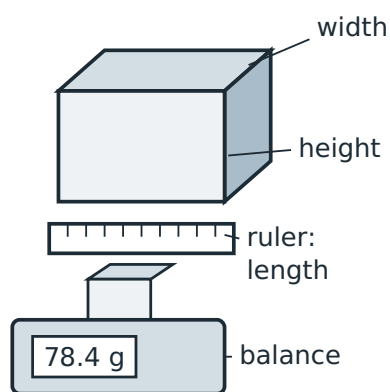
### WATCH OUT

Particles do **not** get bigger, smaller or heavier when a substance is heated or changes state. Only their **spacing, arrangement and speed** change. Density changes because the **volume** changes, not the mass.

**Required practical 17 — density = mass ÷ volume,  $\rho = m / V$**

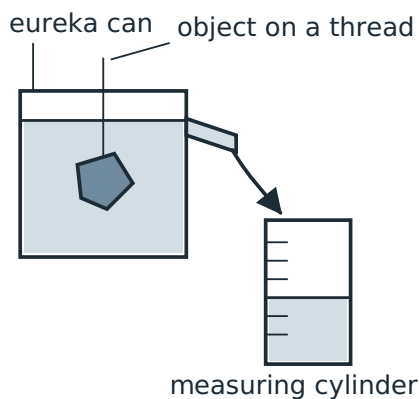
$\rho$  in  $\text{kg/m}^3$  (or  $\text{g/cm}^3$ ) ·  $m$  in kg (or g) ·  $V$  in  $\text{m}^3$  (or  $\text{cm}^3$ ) ·  $1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$

**A Regular solid**



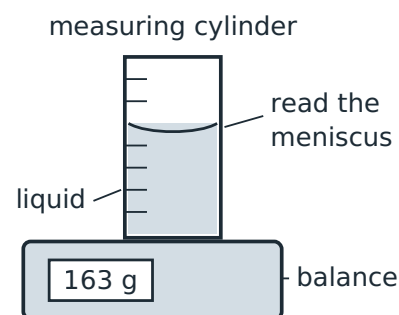
- find the mass on a balance
- measure the length, width and height with a ruler or callipers
- volume =  $l \times w \times h$
- density = mass ÷ volume

**B Irregular solid**



- find the mass on a balance
- fill the can up to the spout, then lower the object in gently
- the water pushed out is collected in a measuring cylinder: it equals the volume of the object

**C Liquid**



- find the mass of the empty measuring cylinder
- pour in the liquid, find the new mass
- mass of liquid = new mass – empty mass
- read the volume in  $\text{cm}^3$  at the bottom of the meniscus, at eye level

**20.1.2 Changes of state**

- When substances melt, freeze, boil, evaporate, condense or sublime, the number of particles does not change, so **mass is conserved**.
- Changes of state are **physical changes**, which differ from **chemical changes** because the material recovers its original properties if the change is reversed. No new substance is made.

**20.2 Internal energy and energy transfers**

### 20.2.1 Internal energy

- Energy is stored inside a system by the **particles (atoms and molecules)** that make it up: this is **internal energy**.
- Internal energy is the total kinetic energy and potential energy of all the particles in the system. The kinetic part depends on how fast particles move or vibrate; the potential part depends on their separation.
- Heating changes the energy stored within the system by increasing the energy of the particles. This either **raises the temperature** (kinetic energy rises) **or produces a change of state** (potential energy rises, temperature constant).

#### ANALOGY

Internal energy is the total money held by a crowd. Kinetic energy is the cash in their pockets; potential energy is money tied up in savings. Temperature only reports the *average cash per pocket* — so you can pour energy into melting ice, filling up the "savings", while the temperature reading does not move.

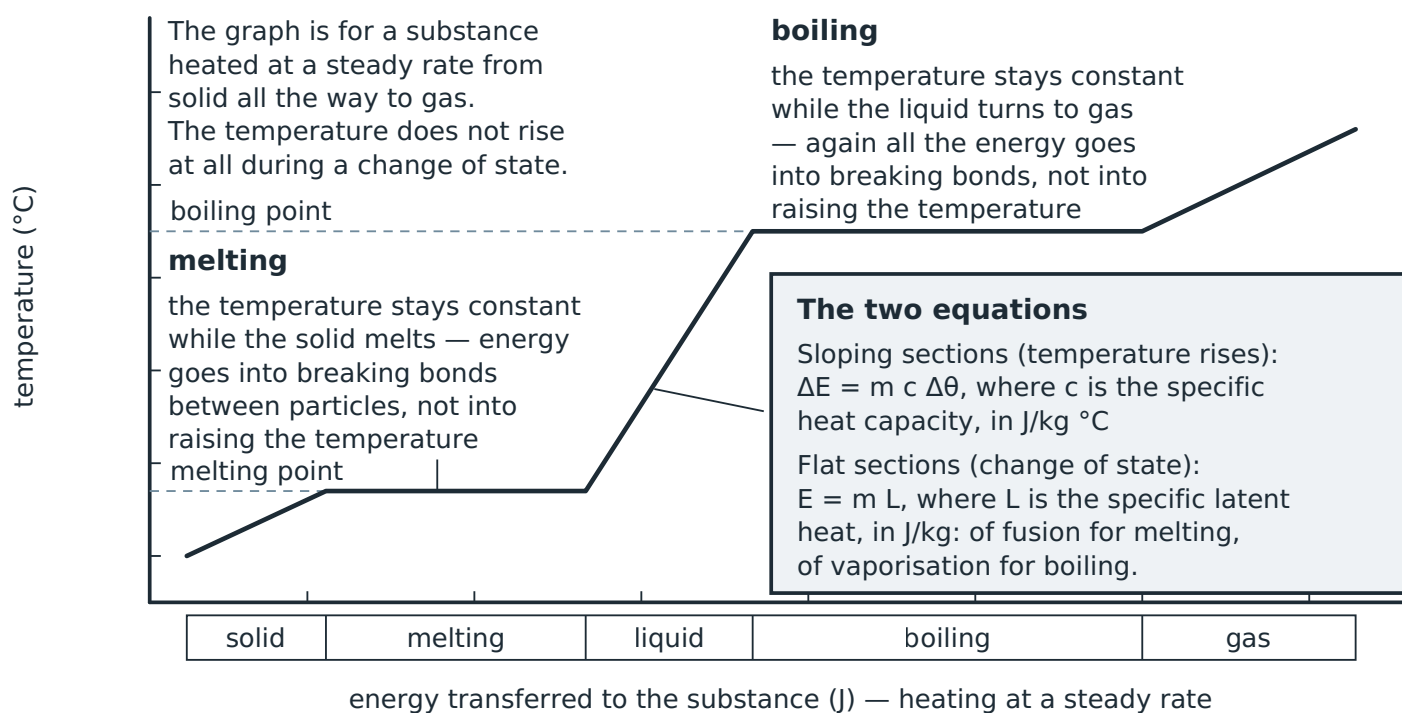
### 20.2.3 Changes of state and specific latent heat

- The energy needed for a substance to change state is **latent heat**. During a change of state the energy supplied changes the internal energy but not the temperature.
- **Specific latent heat of fusion** — solid to liquid. **Specific latent heat of vaporisation** — liquid to vapour.

### 20.2.2 Temperature changes in a system and specific heat capacity

- The temperature rise depends on the **mass** heated, the **type of material** and the **energy input**.
- **Specific heat capacity** = the energy required to raise the temperature of **one kilogram** of a substance by **one degree Celsius**. A high value (water, 4200 J/kg °C) means a lot of energy for a small temperature rise, and slow cooling.

### A heating curve and the changes of state



#### ANALOGY

Latent heat is the queue at the door of a concert. While people are queuing, energy is being spent but nobody moves further inside — the "temperature" reading is flat. Only once everyone is through does the crowd move on again. The energy is not lost; it is stored as potential energy in pulling particles apart.

|                       | Specific heat capacity, $c$                             | Specific latent heat, $L$     |
|-----------------------|---------------------------------------------------------|-------------------------------|
| What changes          | The <b>temperature</b>                                  | The <b>state</b>              |
| Energy per kg to...   | raise the temperature by $1\text{ }^{\circ}\text{C}$    | change the state completely   |
| Temperature during it | Rises or falls                                          | Stays <b>constant</b>         |
| Energy store          | Kinetic energy of particles                             | Potential energy of particles |
| Equation / unit       | $\Delta E = m c \Delta\theta$ / J/kg $^{\circ}\text{C}$ | $E = m L$ / J/kg              |

**Reading a heating or cooling graph** (temperature against time or energy):

- **Sloping sections** — one state, **temperature changing**; use  $\Delta E = m c \Delta\theta$ . A steeper slope means a smaller specific heat capacity for the same heating power.
- **Flat sections** — a **change of state**. Energy is still supplied but is **breaking the forces between particles**, so the temperature does not change; use  $E = m L$ .
- The **first flat** is at the **melting point**, the **second** at the **boiling point**. The second is **longer** because separating particles completely needs far more energy.
- On a **cooling** graph the flat sections are freezing and condensing, with energy given out.

#### WATCH OUT

Boiling water does not get hotter the longer you boil it. Once at  $100\text{ }^{\circ}\text{C}$  all further energy goes into latent heat of vaporisation, so the temperature stays at  $100\text{ }^{\circ}\text{C}$  until all the water has turned to steam.

## 20.3 Particle model and pressure

### 20.3.1 Particle motion in gases

- The molecules of a gas are in **constant random motion**, in all directions and at a range of speeds.
- The temperature of the gas is related to the average kinetic energy of the molecules — hotter means faster on average.
- Molecules **collide with the walls** of the container; each collision exerts a tiny force, and the total effect of billions per second is the **pressure**.
- Changing the temperature of a gas held at constant volume changes the pressure: hotter  $\rightarrow$  faster molecules  $\rightarrow$  collisions are **harder and more frequent**  $\rightarrow$  **higher pressure**. Cooler  $\rightarrow$  **lower pressure**.

#### ANALOGY

Gas pressure is hail on an umbrella. Each hailstone gives a tiny push; what you feel is the average of thousands of impacts. Heat the gas and the hailstones travel faster and arrive more often, so the push is bigger.