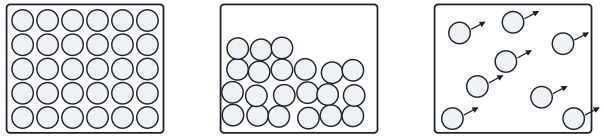
4.3 Particle model of matter

STATES OF MATTER



Solid
close together, regular pattern, vibrate about fixed positions

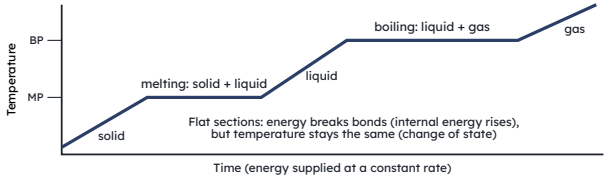
Liquid
close together, random arrangement, move past each other

Gas
far apart, random, move quickly in all directions

DENSITY

- ρ = m ÷ V. Units: kg/m³ (1 g/cm³ = 1000 kg/m³).
- Solids and liquids are dense because the particles are close together; gases are much less dense.
- Changes of state are **physical** changes: the material recovers its properties if the change is reversed, and **mass is conserved**.

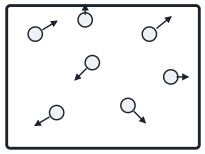
HEATING AND COOLING CURVES



INTERNAL ENERGY AND LATENT HEAT

- **Internal energy** is the total kinetic energy and potential energy of all the particles in a system.
- Heating increases internal energy: either the temperature rises or the state changes.
- **Specific heat capacity:** energy to raise 1 kg by 1 °C.
- **Specific latent heat:** energy to change the state of 1 kg with no change in temperature. Fusion: solid ↔ liquid. Vaporisation: liquid ↔ gas.

GAS PRESSURE



Particles collide with the walls, xerting a force at right angles: pressure

Higher temperature → particles move faster → hit the walls more often and harder → higher pressure

Smaller volume (constant temperature) → particles hit the walls more often → higher pressure: pV = constant (Physics only)

PARTICLE MOTION IN GASES

- Gas molecules are in constant random motion.
- The temperature of a gas is related to the **average kinetic energy** of its molecules.
- Increasing the temperature at constant volume increases the pressure.
- (PO) Increasing the volume at constant temperature decreases the pressure.
- (PO, Higher) Doing work on a gas (e.g. a bike pump) increases its internal energy and can increase its temperature.

EXAM TIPS

- Flat section on a heating curve = change of state: temperature constant, internal energy increasing.
- Temperature ≠ internal energy.
- Evaporation and boiling both turn liquid into gas; sublimation: solid → gas.

MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Explain why a gas exerts more pressure when it is heated in a sealed container.

Heating increases the kinetic energy of the particles, so they move faster. They collide with the walls more often and with more force, so the total force on each unit of area (pressure) increases.

Explain why sweating cools you down.

Sweat evaporates from the skin, which needs energy (latent heat of vaporisation) taken from the skin, so the skin cools. The fastest-moving particles with the most energy escape, so the average kinetic energy of the particles left behind falls.

Explain why pumping up a bike tyre makes the pump warm. (Physics only, Higher)

Pushing the piston does work on the gas. This transfers energy to the gas. The internal energy of the gas increases, so the particles move faster and the temperature rises.

PRACTICAL LANGUAGE

Accurate: close to the true value. **Precise:** measurements close to each other. **Repeatable:** same person, same method, similar results. **Reproducible:** similar results by another person or method. **Resolution:** smallest change an instrument can show. **Random error:** unpredictable scatter; reduce by repeating and averaging. **Systematic error:** every reading out by the same amount, e.g. a **zero error**.

SIX-MARK ANSWERS

- Plan: jot 6 key points first.
- Write in a logical order, using AQA key words.
- Methods: equipment, what you change, what you measure, what you keep the same, repeats, safety.
- Explanations: link each step with "so" or "because".

MATHS SKILLS

- Standard form: $3.2 \times 10^4 = 32\,000$; $5 \times 10^{-3} = 0.005$.
- Give answers to the same number of significant figures as the data (usually 2 or 3).
- Rearrange before substituting; show every step.
- Mean = total ÷ number of readings (leave out anomalies).

4.3 Particle model of matter

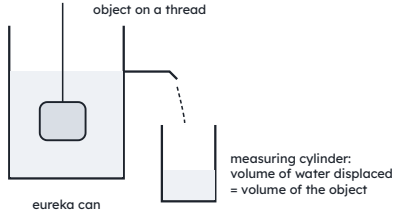
KEY EQUATIONS (ALL ON THE PHYSICS EQUATIONS SHEET)

Equation	Quantities (units)	Watch out
ρ = m ÷ V	density (kg/m³), mass (kg), volume (m³)	1 g/cm³ = 1000 kg/m³
ΔE = m c Δθ	change in thermal energy (J), mass (kg), specific heat capacity (J/kg °C), temperature change (°C)	Used when the temperature changes
E = m L	energy for a change of state (J), mass (kg), specific latent heat (J/kg)	Used when the state changes (no temperature change)
p V = constant	pressure (Pa), volume (m³); fixed mass of gas at constant temperature (Physics only)	$p_1V_1 = p_2V_2$

KEY WORDS

Density: mass per unit volume (ρ = m ÷ V).
Internal energy: the total kinetic energy and potential energy of all the particles that make up a system.
Specific latent heat: the amount of energy required to change the state of 1 kg of a substance with no change in temperature.
Latent heat of fusion: solid ↔ liquid. Latent heat of vaporisation: liquid ↔ gas.
Physical change: the material recovers its original properties if the change is reversed; mass is conserved.
Gas pressure: particles colliding with the walls exert a net force at right angles to the surface.
Temperature of a gas: related to the average kinetic energy of its molecules.

RP5: DENSITY



Aim: Determine the density of regular and irregular solids and of a liquid.

Change	Object or material
Measure	Mass and volume
Control	Balance and measuring equipment used

Must include:

- Measure mass with a balance
- Measure volume correctly for regular and irregular objects
- Use a eureka can for irregular objects
- Calculate ρ = m ÷ V with units
- Read the meniscus at eye level

Common mistake: Forgetting units, or mixing g with m³.

MISCONCEPTIONS

× **Particles expand when heated.**	✓ Particles move faster and further apart; they don't get bigger.
× **Temperature rises while ice melts.**	✓ Temperature stays constant during a change of state.
× **Mass changes when a substance melts.**	✓ Mass is conserved in a change of state.

AIM FOR GRADE 7+

- Heating then melting: add mcΔθ and mL for the total energy.
- Explain flat sections of heating curves using internal energy (potential, not kinetic, increases).
- (PO) pV = constant: compressing a gas at constant temperature increases its pressure.

COMMAND WORDS

State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

QUICK-FIRE QUIZ: COVER THE ANSWERS

Unit of specific latent heat?	**J/kg**
Water's density?	**1000 kg/m³**
Solid → gas directly?	**Sublimation**
Flat section on a heating curve?	**Change of state**
What increases in a gas when it's heated?	**Particles' kinetic energy**
Is a change of state physical or chemical?	**Physical**

UNITS AND PREFIXES

giga (G)	× 10^9
mega (M)	× 10^6
kilo (k)	× 10^3
centi (c)	× 10^{-2}
milli (m)	× 10^{-3}
micro (μ)	× 10^{-6}
nano (n)	× 10^{-9}

Convert to the base unit (m, kg, s, J, W) before you calculate.