Topic 3: Particle model of matter

AQA GCSE Physics 8463 · spec 4.3 · sheets 3.1–3.6

Particle model of matter: density, heating and gases

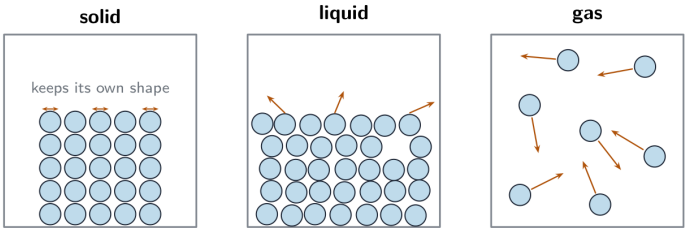
- calculate density, and measure it for regular and irregular objects and for liquids;
- explain changes of state and **internal energy** with the particle model;
- calculate the energy needed to change temperature and to change state, and read heating graphs;
- explain gas **pressure**, and (physics only) use $pV =$ constant and explain why doing work on a gas warms it.

Density of materials

- Regular solid: measure its length, width and height with a ruler (or vernier callipers for small objects), multiply to find the volume, and measure its mass on a balance.
- Irregular solid: fill a displacement (eureka) can until water runs out of the spout, and wait for it to stop. Lower the object in on a thin thread. Collect the water that overflows in a measuring cylinder; its volume equals the object's volume.
- Liquid: measure the mass of an empty measuring cylinder, pour in a known volume of liquid, and measure the mass again. The difference is the mass of the liquid.

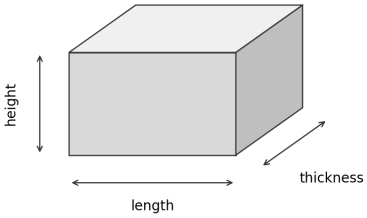
$$\rho = \frac{m}{V}$$

Figure: Density of materials

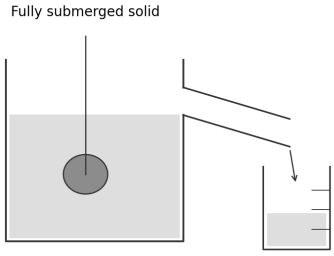


- Particles in a solid, a liquid and a gas.
- Match each part of the diagram to the text.

Figure: Density of materials (2)



Volume = length × height × thickness
Mass from a balance



Collect displaced water
Measure its volume in the cylinder

- Required practical 5: measure a regular block with a ruler; find the volume of an irregular object by displacement.
- Match each part of the diagram to the text.

Changes of state and internal energy

- Mass is conserved: when a substance changes state, the number of particles stays the same.
- Changes of state are **physical changes** : if you reverse the change, the material gets back its original properties. No new substance is made.

Specific heat capacity and temperature changes

- When the temperature of a substance changes, the energy transferred is:
- The **specific heat capacity** c is the energy needed to raise the temperature of 1 kg of the substance by 1 °C, in J/kg °C.
- Required practical 1, which measures it, is in topic 1.
- **Worked example 4.** 0.030 kg of olive oil ($c = 1800$ J/kg °C) is heated from 21 °C to 96 °C.

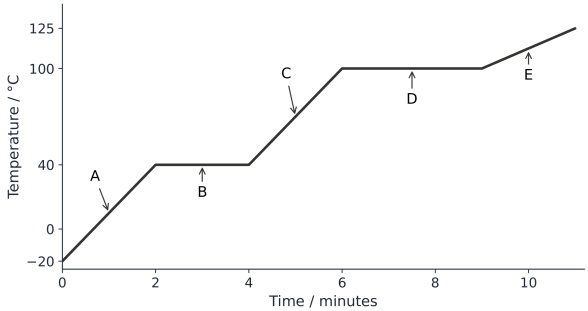
$$\Delta E = m\,c\,\Delta\theta$$

Specific latent heat and heating graphs

- The **specific latent heat** of **fusion** is for changing from solid to liquid.
- The specific latent heat of **vaporisation** is for changing from liquid to vapour.
- on the sloping parts, its temperature rises and the particles gain kinetic energy ($\Delta E = mc\Delta\theta$);
- on the flat parts, it is changing state and the particles gain potential energy ($E = mL$).

$$E = mL$$

Figure: Specific latent heat and heating graphs

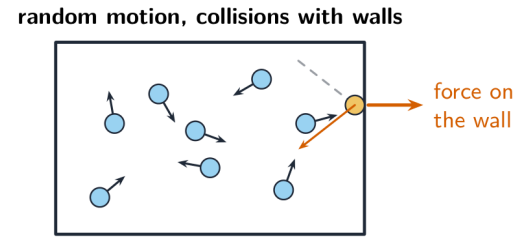


- A heating graph: the substance warms in sections A, C and E, melts in B and boils in D.
- Read the axes and units first.

Particle motion in gases

- The particles of a gas are in constant random motion.
- The temperature of a gas is related to the average kinetic energy of its particles: the hotter the gas, the faster they move.
- **Pressure** in a gas is caused by its particles colliding with the walls of the container.
- Each collision exerts a force at right angles to the wall, and **pressure** is the total force on each square metre.

Figure: Particle motion in gases



- Particles hitting the walls exert forces at right angles to them; compressing the gas makes the collisions more frequent.
- Match each part of the diagram to the text.

Pressure in gases (physics only)

- For a fixed mass of gas at a constant temperature:
- p is **pressure** in pascals (Pa) and V is volume in m^3.
- If the volume increases, the particles travel further between collisions with the walls, so they hit each square metre of wall less often, and the pressure decreases.
- If the volume decreases, the pressure increases.

$$pV = \text{constant} \qquad \text{or} \qquad p_1 V_1 = p_2 V_2$$

Sources for this lesson

- AQA, *GCSE Physics (8463) specification*, section 4.3 Particle model of matter, and the *Required practical handbook* (practical 5).
- J. Black, *Lectures on the Elements of Chemistry*, ed. J. Robison (Edinburgh, 1803), the account of **latent heat** first given in Glasgow in April 1762.
- AQA, *GCSE Physics* Paper 1 Higher, June 2022, June 2024 and June 2025 (ring, turbine, boiling water and nitrogen questions, adapted).

Common errors

- Forgetting to convert $\mathrm{g/cm^3}$ to $\mathrm{kg/m^3}$, or $\mathrm{cm^3}$ to $\mathrm{m^3}$.
- Saying the temperature rises while a substance melts or boils.
- Using $\Delta E = mc\Delta\theta$ for a change of state; use $E = mL$.

Common errors (2)

- Mixing up **fusion** (melting) and **vaporisation** (boiling).
- Saying gas particles get bigger when heated; they move faster.
- Explaining gas **pressure** by particles hitting each other; it comes from collisions with the walls.
- Using $pV =$ constant when the temperature changes.

Key terms

- **Density**: mass per unit volume.
- **Internal energy**: the total kinetic and potential energy of the particles in a system.
- **Specific heat capacity**: the energy to raise 1 kg of a substance by 1 °C.

Key terms (2)

- **Specific latent heat**: the energy to change the state of 1 kg of a substance with no temperature change.
- **Gas pressure**: the force per unit area caused by particles hitting the walls of a container.

Check yourself

- 1.
- A 2.0 kg block has a volume of 0.00025 m^3.
- Calculate its density. 2.
- Describe how to find the volume of a small stone. 3.