

Solids, liquids and gases

Pearson Edexcel · International GCSE · Physics

Matter under pressure

The same substance can be solid, liquid or gas, and its molecules never stop moving. This section measures matter: density and pressure, the (P) energy needed to heat or melt things, and the ideal-gas behaviour that links pressure, volume and temperature.

Edexcel International GCSE Physics 4PH1, Section 5 (statements 5.1–5.22). Units include the pascal (Pa), kelvin (K) and (P) J/kg °C.

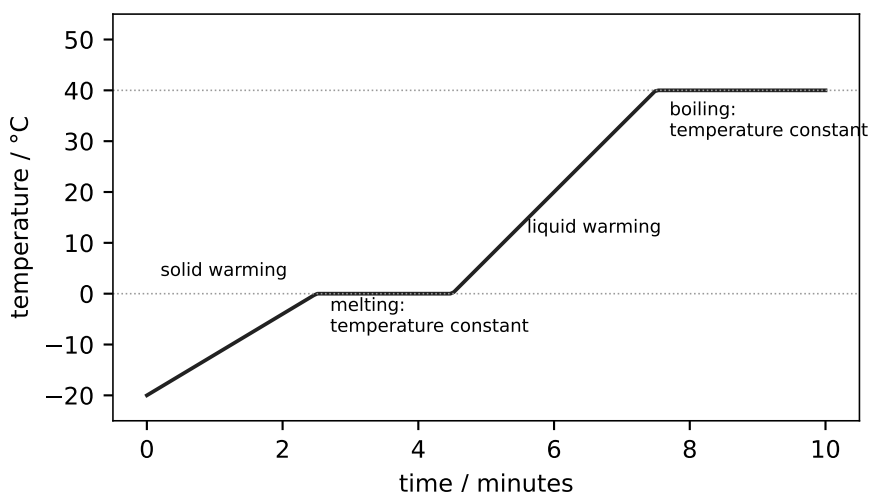
Density and pressure

$$\rho = \frac{m}{V} \quad p = \frac{F}{A} \quad p = h \times \rho \times g$$

Density is measured directly – mass on a balance, volume by displacement (irregular solid) or dimensions (regular shape). Pressure in a fluid at rest acts **equally in all directions**, and the pressure difference between two depths comes from the weight of fluid between them.

Worked check. A diver at 10 m in water ($\rho = 1000 \text{ kg/m}^3$, $g = 10 \text{ N/kg}$): pressure difference = $10 \times 1000 \times 10 = 100\,000 \text{ Pa}$ on top of atmospheric pressure.

Change of state (P)



Heating raises the energy stored in a system – either its temperature rises, or at a **melting point** or **boiling point** the extra energy breaks bonds while the temperature **stays constant**. Particles: solids vibrate about fixed points; liquids move randomly

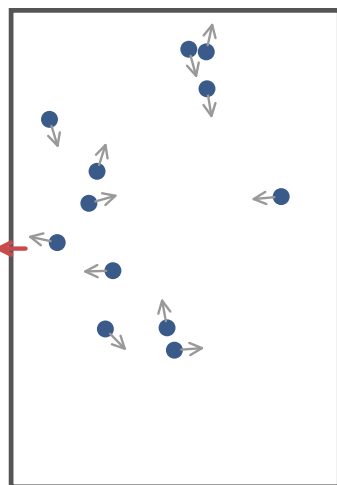
but touch; gases move fast, far apart, in straight lines between collisions. **Specific heat capacity** is the energy needed to raise 1 kg by 1 °C:

$$\Delta Q = m \times c \times \Delta T$$

Worked check. Heating 2 kg of water ($c = 4200 \text{ J/(kg °C)}$) by 30 °C: $\Delta Q = 2 \times 4200 \times 30 = 252\,000 \text{ J}$.

Ideal gas molecules

force on the wall:
pressure



molecules in random motion collide with the walls — each collision exerts a force; pressure is the total force per unit area

Gas molecules move **randomly**, exerting force – and so **pressure** – on the walls at every collision. **Absolute zero** (–273 °C) is the temperature at which molecular kinetic energy is minimum: $\text{K} = \text{°C} + 273$. Higher temperature → faster average molecular speed, and the **Kelvin temperature is proportional to the average kinetic energy** of the molecules.

For a fixed mass of gas: at constant temperature, **pressure × volume is constant** (squeeze it and the molecules hit the walls more often); at constant volume, **pressure/T (K) is constant** (hotter molecules hit harder):

$$\frac{p_1 V_1}{1} = p_2 V_2 \quad \frac{p_1}{T_1} = \frac{p_2}{T_2}$$

Worked check. A gas at 100 kPa and 300 K is heated (constant volume) to 450 K: $p_2 = 100 \times 450/300 = 150 \text{ kPa}$. Squashed from 2 dm³ to 0.5 dm³ at constant temperature: $p_2 = 100 \times 2/0.5 = 400 \text{ kPa}$.

Check yourself

1. A 240 g block has volume 40 cm^3 . Calculate its density in kg/m^3 .
2. State the pressure equation and its unit.
3. Calculate the pressure under a 500 N boot heel of area 0.01 m^2 .
4. (P) What stays constant in a substance's temperature while it melts?
5. (P) Calculate the energy to heat 0.5 kg of aluminium ($c = 900 \text{ J/(kg } ^\circ\text{C)}$) by $40 ^\circ\text{C}$.
6. Convert $27 ^\circ\text{C}$ to kelvin, and 373 K to $^\circ\text{C}$.
7. Why does a gas exert pressure on its container?
8. What happens to average molecular speed as temperature rises?
9. A gas at 120 kPa in 3 dm^3 is compressed to 1 dm^3 at constant temperature. Find the new pressure.
10. State two conditions that make a gas's pressure double.

Answers: 1 $m = 0.24 \text{ kg}$, $V = 4.0 \times 10^{-5} \text{ m}^3$; $\rho = 0.24/4.0 \times 10^{-5} = 6000 \text{ kg/m}^3$; 2 $p = F/A$, in pascals (N/m^2); 3 $p = 500/0.01 = 50\,000 \text{ Pa}$; 4 (P) temperature – the energy goes to breaking intermolecular bonds, not to faster molecules; 5 (P) $\Delta Q = 0.5 \times 900 \times 40 = 18\,000 \text{ J}$; 6 300 K ; $100 ^\circ\text{C}$; 7 its molecules collide with the walls, each collision exerting a force; the total force per unit area is the pressure; 8 it increases; 9 $p_2 = 120 \times 3/1 = 360 \text{ kPa}$; 10 doubling the Kelvin temperature at constant volume, or halving the volume at constant temperature.