3.5 Particle motion in gases

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

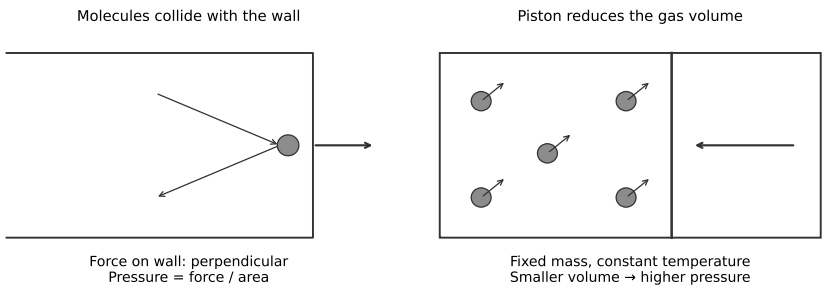
KEY WORDS density

Objective

Explain gas pressure from molecular motion, relate temperature to average kinetic energy, and reason about constant-volume pressure changes. Original questions for spec statement 4.3.3.1.

1 Key knowledge and worked examples

Gas molecules are in **constant random motion**. The temperature of a gas is related to the **average kinetic energy** of its molecules – hotter means faster on average (individual molecules keep colliding and changing speed; only the average is fixed by the temperature).



Each collision pushes at right angles to the wall.

A complete particle-model explanation of gas pressure:

1. the molecules move constantly and randomly, so they **collide with the container walls**;
2. each collision exerts a **force at right angles** to the wall;
3. the pressure is the **total force from many collisions per unit area** of wall.

Temperature up at constant volume → pressure up. Faster molecules (higher average kinetic energy) hit the walls **more often** and **harder**, so the force per unit area rises. Reverse the reasoning for cooling.

Number sense: doubling the **kelvin** temperature doubles the average kinetic energy – but at GCSE you only need the qualitative link; the equation work (pV, work on a gas) is on sheet 3.6.

Worked example (explanation). A sealed can of air is warmed in the sun. Explain why the pressure rises.

- The air is a fixed mass in a fixed volume (sealed, rigid can).
- Warming raises the average kinetic energy of the molecules: they move faster on average.
- Faster molecules collide with the walls more frequently and exert a larger force in each collision.
- The total force per unit area – the pressure – therefore increases.

2 Practice

2.1 Describe the motion of gas molecules, in two phrases the scheme credits. [2]

2.2 What does the temperature of a gas tell you about its molecules? [1]

2.3 A car tyre's air warms after motorway driving. State and explain the change in tyre pressure, at constant volume. [3]

3 Exam-style questions

3.1 A sealed syringe of air is held at fixed volume in a water bath.

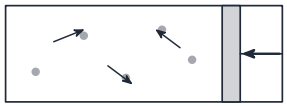
(a) The bath's temperature is increased. Explain why the pressure in the syringe increases. [3]

(b) The syringe is then allowed to expand instead (constant temperature, larger volume). Explain what happens to the pressure. [2]

3.2 A student compresses air quickly in a bicycle pump and the pump becomes warm.

(a) Explain why the air's temperature rises, in terms of what the compression does to the molecules. [3]

(b) The student then compresses the same pump very slowly, and the pump stays near room temperature. Explain the difference. [2]



air sealed in the pump

3.3 The table shows the pressure of a fixed mass of gas at constant volume as its temperature changes.

Temperature in °C	**20**	**40**	**60**	**80**
Pressure in kPa	101	108	115	122

(a) Describe the relationship shown. [2]

(b) The gas is cooled to 0 °C at the same volume. Estimate the pressure. [2]

(c) Explain the relationship using the particle model. [3]

(d) A second gas has molecules of smaller mass at the same temperature. Compare the average kinetic energies and explain whether the average molecular speeds are the same. [2]

Solutions

2.1 The molecules are in constant random motion.

2.2 The temperature is related to the **average kinetic energy** of the molecules – a higher temperature means faster molecules on average.

2.3 The pressure increases: the warmer air's molecules move faster on average, so they collide with the tyre walls more often and harder, raising the force per unit area.

3.1 (a) The fixed volume keeps the wall area unchanged (implicit). Warming increases the molecules' average kinetic energy, so they move faster; faster molecules collide with the walls more frequently and each collision transfers a larger force, so the pressure increases. (b) At constant temperature the average molecular speed is unchanged; in the larger volume there are fewer wall collisions per unit area per second, so pressure decreases. The piston area need not change.

3.2 (a) Compressing does **work** on the gas – the piston forces the molecules closer and speeds them up as it moves in; the gas's internal energy increases, seen as greater average kinetic energy; the average kinetic energy sets the temperature, so the temperature rises. (b) In slow compression, energy has time to transfer out to the surroundings through the pump's walls; the internal energy – and temperature – stays near room temperature while the work done is carried away.

3.3 (a) Pressure increases **linearly** (equal steps of 7 kPa per 20 °C) with temperature at constant volume. (b) Continuing the pattern: 3.5 kPa per 10 °C below 20 °C gives $101 - 7 = \mathbf{94}$ kPa. (c) Higher temperature means greater average kinetic energy of the molecules; they hit the walls more often and harder; at constant volume the wall area is fixed, so force per unit area – pressure – rises in step with temperature. (d) The gases have the same average molecular kinetic energy at the same temperature. The lighter molecules move **faster** on average: $E_k = \frac{1}{2}mv^2$, so the same kinetic energy with smaller molecular mass requires greater mean-square speed. No pressure comparison follows from temperature and molecular mass alone.