Pressure in gases

4.3.3.2 · Particle model of matter · revision notes

What happens to the pressure of a gas when its volume changes at constant temperature. You need to explain this with the particle model and use pV = constant (on the equation sheet). This subtopic is in GCSE Physics only, not in Combined Science. Expect particle explanations and 2 to 4 mark calculations, sometimes from a table of results.

Key facts

- pV = constant (fixed mass of gas at constant temperature; on the equation sheet)
- $p_1V_1 = p_2V_2$
- Bigger volume → molecules collide with the walls less often → lower pressure
- Grade 7+ only p against V: a curve (inverse proportion). p against 1/V: a straight line through the origin
- p in Pa, V in m^3; 1 kPa = 1000 Pa
- Volume up → pressure down (at constant temperature)
- Gas pressure produces a net force at right angles to any surface

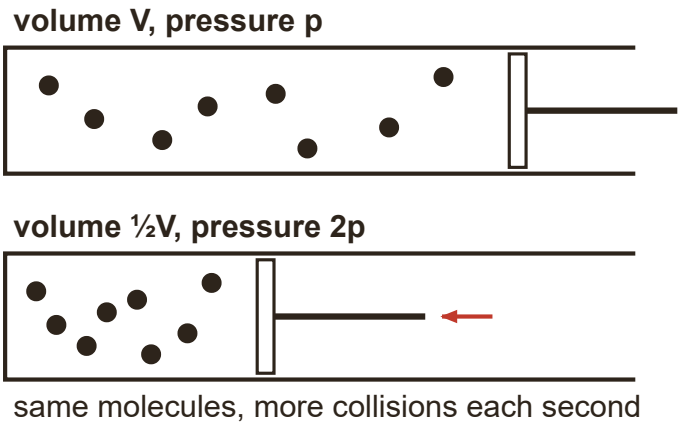
Notes

Gas pressure and force

- A gas can be **compressed** (squashed into a smaller volume) or **expanded** by changes in pressure.
- The pressure of a gas produces a **net force at right angles** to the wall of its container, or to any surface the gas touches.
- That is why the air in a balloon pushes outwards on every part of the rubber.

Changing the volume at constant temperature

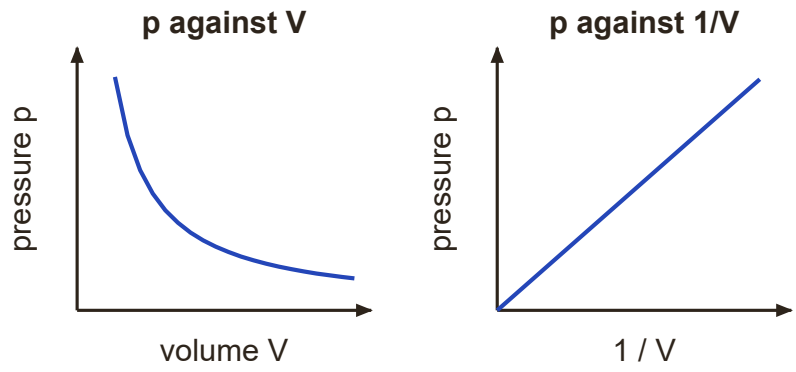
- For a **fixed mass** of gas at a **constant temperature**, increasing the volume decreases the pressure.
- Why: the molecules have more space, so they travel further between collisions with the walls. They collide with the walls **less often**, so there is a smaller force on each unit area: the pressure is lower.
- The temperature is constant, so the average kinetic energy (and speed) of the molecules does not change. It is the frequency of the collisions that changes.
- Decreasing the volume does the opposite: the molecules collide with the walls more often, so the pressure increases.



Constant temperature: smaller volume, more frequent collisions, higher pressure.

pV = constant

- For a fixed mass of gas at constant temperature: pressure × volume = constant, **pV = constant** (on the equation sheet). p in pascals (Pa), V in m^3.
- To compare two situations use $\mathbf{p_1V_1 = p_2V_2}$. Any units work, as long as both pressures are in the same unit and both volumes are in the same unit.
- Pressure and volume are **inversely proportional**: halve the volume and the pressure doubles; triple the volume and the pressure falls to a third.
- A graph of p against V is a curve that gets closer to both axes without touching them. A graph of p against 1/V is a straight line through the origin. Grade 7+ only



pV = constant: p against V is a curve; p against 1/V is a straight line through the origin.

Grade 7+ only

- pV = constant only applies if the mass and the temperature of the gas stay the same. That is why, in experiments, the gas is compressed slowly: then its temperature stays constant. Grade 8+ only

How to answer each type of question

Recall: the force from a gas and the effect of volume 1 mark each **Grade 5**

1. The force from gas pressure is always at right angles (perpendicular) to the surface.
2. At constant temperature, pressure × volume stays the same: if one doubles, the other halves.

Example. A fixed mass of gas is held in a closed container.
(a) Describe the direction of the force that the gas exerts on the walls of the container.
(b) The volume of the container is doubled and the temperature of the gas does not change. What happens to the pressure of the gas?

Model answer.

(a) At right angles (perpendicular) to the walls (1)
(b) The pressure halves (1)

Explain the effect of changing the volume, using particles

3 marks | Grade 5

1. Say that the molecules have more space (or less space) to move in.
2. Say that they collide with the walls less often (or more often).
3. Conclude with the force on each unit area and the pressure.

Example. Explain, in terms of particles, why increasing the volume of a fixed mass of gas at constant temperature decreases its pressure.

Model answer. The molecules have more space, so they travel further between collisions with the walls (1). So they collide with the walls less frequently (1). The force on each unit area of the walls is smaller, so the pressure decreases (1).

Calculate a new pressure or volume with pV = constant

2 to 3 marks | Grade 5

1. Check that the mass and temperature are constant, then write $p_1V_1 = p_2V_2$.
2. Put both pressures in the same unit and both volumes in the same unit.
3. Substitute, rearrange for the unknown and give the unit.

Example. A sealed syringe contains 50 cm^3 of air at a pressure of 120 kPa. The plunger is pushed in slowly, so the temperature of the air stays constant, until the volume of the air is 30 cm^3.
Calculate the new pressure of the air.

Model answer.

$120 \times 50 = p \times 30$ (1)

$p = 6000 \div 30$ (1)

$p = 200$ kPa (1)

Use a table of results to test or apply pV = constant 4 to 6 marks **Grade 7**

1. Multiply p × V for each row. If the products are all the same (within experimental error), the data fit pV = constant.
2. Use the constant to predict a missing value: p = constant ÷ V, or V = constant ÷ p.
3. Remember the conditions: fixed mass of gas and constant temperature.

Example. A student slowly compresses the air in a sealed syringe and records the pressure at three volumes.

Volume in cm^3	Pressure in kPa
40	105
30	140
20	210

(a) Show that these results agree with pV = constant. (2 marks)

(b) Predict the pressure when the volume is 15 cm^3. (2 marks)

(c) Name two things that must stay the same for pV = constant to apply. (2 marks)

Model answer.

(a) 40 × 105 = 4200, 30 × 140 = 4200 and 20 × 210 = 4200 (1). pV is the same for every result, so pV = constant (1).

(b) p = 4200 ÷ 15 (1) = 280 kPa (1)

(c) The temperature of the air (1). The mass of air (no air leaks in or out) (1).

Don’t lose marks

- Using pV = constant when the temperature changes. It needs a fixed mass of gas at constant temperature.
- Mixing units, e.g. one pressure in kPa and the other in Pa.
- Saying the molecules hit the walls 'with less force' when the volume increases. At constant temperature their speed is unchanged; they hit the walls less often.
- Rearranging the wrong way up: $p_2 = p_1V_1 \div V_2$, not $p_1V_2 \div V_1$. Use the sense check.
- Saying gas pressure acts 'downwards' or 'along' a wall. It acts at right angles to the surface.

More tips

Memory tricks

- Squash a gas and its pressure goes up: halve V, double p.
- Units shortcut: for $p_1V_1 = p_2V_2$ you don't need Pa and m^3; just use the same units on both sides.
- Sense check: if the volume got smaller, the new pressure must be bigger (and the other way round).
- To test data, multiply p × V for every row: the products should all be about the same.

Exam technique

- pV = constant is on the equation sheet. Write $p_1V_1 = p_2V_2$ with the numbers substituted to earn the first mark.
- In particle explanations for a volume change at constant temperature, the key phrase is 'collide with the walls less (or more) frequently'.
- If a question says a gas was compressed or expanded slowly, that tells you its temperature stayed constant.
- Give the unit of your answer: it is the unit you used for that quantity (e.g. kPa or cm^3).

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4 — **State the direction of gas pressure forces**
The pressure of a gas produces a net force at right angles to the wall of its container (or any surface).

Grade 5 — **Describe how volume affects gas pressure**
At constant temperature, increasing the volume of a gas decreases its pressure, and decreasing the volume increases it.

Grade 5 — **Explain the volume–pressure link using particles**
In a bigger volume, the molecules collide with the walls less often, so the pressure is lower.

Grade 5 — **Use pV = constant for a fixed mass**
Use $p_1V_1 = p_2V_2$ to find a new pressure or volume.

Grade 7 — **Test data against pV = constant**
Multiply p × V for each result: if the products are the same, the data fit pV = constant.

Grade 7 — **Interpret graphs of pressure against volume**
p against V is a curve (inverse proportion); p against 1/V is a straight line through the origin.

Grade 8 — **Explain when pV = constant does not apply**
It only works for a fixed mass of gas at constant temperature; if the gas heats up or leaks, the prediction is wrong.

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