Increasing the pressure of a gas

4.3.3.3 · Particle model of matter · revision notes

Why doing work on a gas, for example pushing in the piston of a bicycle pump, makes the gas hotter. You need to link work done on a gas to an increase in its internal energy and temperature. This subtopic is in GCSE Physics only (not Combined Science) and is Higher tier only. Expect 2 to 4 mark explanations, sometimes with a W = F s calculation.

Key facts

- Work = energy transferred by a force
- W = F s (W in J, F in N, s in m); practise using and rearranging it
- Doing work on a gas → internal energy increases → temperature can increase
- Bicycle pump gets warm: work is done on the air
- Quick compression: little time for energy to escape → large temperature rise
- Slow compression: energy transferred to the surroundings → temperature about constant
- Grade 8+ only Quick compression: hotter AND smaller volume → pressure higher than pV = constant predicts

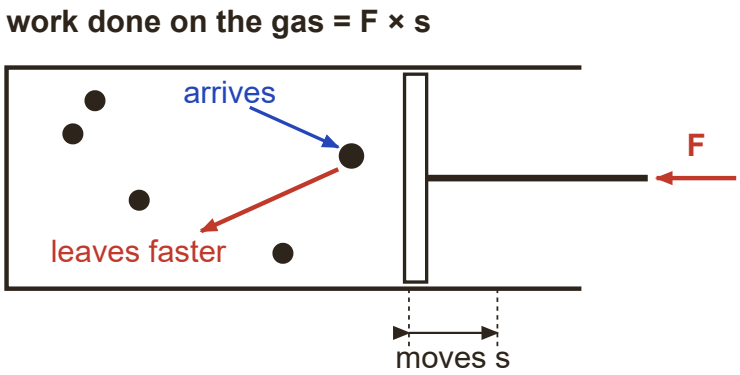
Notes

Doing work on a gas

- **Work** is the transfer of energy by a force. Work done (J) = force (N) × distance moved along the line of action of the force (m): W = F s.
- When you push a piston into a cylinder of gas, you exert a force and the piston moves through a distance, so you **do work on the gas**.
- Doing work on a gas transfers energy to it, so the **internal energy** of the gas increases. This can cause the **temperature** of the gas to increase.

The particle explanation

- Molecules that hit the moving piston bounce off it faster than they arrived.



Pushing the piston in does work on the gas; molecules rebound faster, so the temperature rises.

- So the average kinetic energy of the molecules increases, which means the temperature of the gas rises.
- The pressure rises for two reasons: the volume is smaller, and the gas is hotter, so the molecules hit the walls more often and harder. That is why a quickly compressed gas reaches a higher pressure than pV = constant predicts. Grade 8+ only

Examples, and why speed matters

- **Bicycle pump**: after you pump up a tyre quickly, the barrel of the pump feels warm, because work has been done on the air inside.
- If a gas is compressed **quickly**, there is little time for energy to be transferred to the surroundings by heating, so its temperature rises a lot.
- If it is compressed **slowly**, energy is transferred to the surroundings by heating about as fast as the work transfers it to the gas, so the temperature hardly changes. That is why doing work on a gas *can* raise its temperature, rather than always doing so.
- In a diesel engine, the air is compressed so quickly and so much that it becomes hot enough to ignite the fuel without a spark.
- The reverse also happens: a gas that expands quickly and pushes a piston out does work on the piston, so its internal energy falls and it cools. Grade 8+ only

How to answer each type of question

Explain why a gas gets hotter when work is done on it

3 marks | Grade 7

1. Say that a force moves the piston (or plunger) through a distance, so work is done on the gas.
2. Say that this transfers energy to the gas, so its internal energy increases.
3. Link to the molecules: their average kinetic energy increases, so the temperature rises.

Example. A student seals the end of a syringe full of air and pushes the plunger in very quickly. A sensor inside the syringe shows that the temperature of the air increases.
Explain why.

Model answer. The student exerts a force on the plunger, which moves through a distance, so work is done on the air (1). This transfers energy to the air, so its internal energy increases (1). The average kinetic energy of the air molecules increases, so the temperature rises (1).

Calculate the work done on a gas

2 marks | Grade 6

1. Write W = F s (on the equation sheet).
2. Convert the distance to metres if needed, substitute and give the unit (J).

Example. A girl pushes the handle of a tyre pump with an average force of 150 N. The handle moves 30 cm in one stroke.
Calculate the work done in one stroke.

Model answer.

W = 150 × 0.30 (1)

W = 45 J (1)

Explain why quick compression heats a gas more than slow compression

2 marks | Grade 8

1. Compare the time available for energy to be transferred to the surroundings by heating.
2. Say what happens to the energy transferred by doing work: more of it stays in the gas as internal energy when the compression is quick.

Example. A mechanic inflates a tyre with a hand pump. When she pumps quickly, the pump gets much hotter than when she pumps slowly with the same number of strokes.
Explain why.

Model answer. When she pumps quickly, there is less time for energy to be transferred from the air to the surroundings by heating (1). So more of the energy transferred by doing work stays in the air as internal energy, and its temperature rises more (1).

Explain why the pressure is higher than pV = constant predicts 3 marks **Grade 8**

1. Say that work done on the gas raises its internal energy and temperature.
2. Say that pV = constant only applies at constant temperature.
3. Explain with molecules: they move faster, so they hit the walls more often and with more force than at constant temperature.

Example. The air in a cylinder is compressed very quickly to one tenth of its starting volume. The final pressure is more than ten times the starting pressure.
Explain why.

Model answer. Work is done on the air, so its internal energy and temperature increase (1).
pV = constant only applies when the temperature is constant (1). The molecules move faster, so they collide with the walls more frequently and with more force than at the starting temperature, making the pressure higher than pV = constant predicts (1).

Don’t lose marks

- Putting the warming down to friction between the piston and the barrel. The idea examiners want is that work is done on the gas, increasing its internal energy.
- Saying that energy or heat is 'created'. Energy is transferred to the gas by the force doing work.
- Stopping at 'internal energy increases' without linking it to the kinetic energy of the molecules and the temperature.
- Saying the molecules get bigger or 'get hot'. They move faster on average.
- Using pV = constant for a quick compression. The temperature is not constant, so it underestimates the pressure.

More tips

Memory tricks

- The chain: force moves piston → work done on gas → internal energy up → molecules faster → temperature up. Each link is often a mark.
- Quick means hot, slow means not: a fast compression gives the energy no time to escape.
- Spot the context: 'bicycle pump', 'plunger pushed in quickly' or 'diesel engine' means a work-done-on-a-gas question.

Exam technique

- Use the key terms: work done, force, distance, internal energy, kinetic energy of the molecules, temperature.
- Write the explanation as a chain joined with 'so': force moves the piston, so work is done on the gas, so its internal energy increases, so the molecules move faster, so the temperature rises.
- If a force and a distance are given, calculate the work with W = F s: it is on the equation sheet, so pick it and use it.
- Look for the words 'quickly' or 'slowly' in the question: they tell you whether energy has time to be transferred to the surroundings.

What each grade needs

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

Grade 5 — **Define work as energy transferred by a force**
Work done = force × distance moved along the line of action of the force: W = F s.

Grade 6 — **State how doing work affects a gas**
Doing work on a gas transfers energy to it, increasing its internal energy, which can raise its temperature.

Grade 6 — **Calculate the work done on a gas**
Use W = F s with the force on the piston in N and the distance it moves in m.

Grade 7 — **Explain why a bicycle pump gets warm**
Work done on the air increases its internal energy, so the average kinetic energy of the molecules and the temperature rise.

Grade 8 — **Explain why fast compression heats more**
There is less time for energy to be transferred away by heating, so more of the work done stays in the gas as internal energy.

Grade 8 — **Explain why pressure rises more than pV predicts**
The temperature rises as well, so the molecules hit the walls more often and harder than they would at constant temperature.

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