

Gas pressure, volume and the kelvin scale

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: Gas pressure is caused by particles colliding with the walls of their container. For a fixed mass of gas at constant temperature, pressure $\times$ volume stays constant (Boyle's law). Temperature in kelvin equals $^{\circ}\text{C}$ plus 273, and absolute zero, 0 K or -273°C , is the lowest possible temperature.

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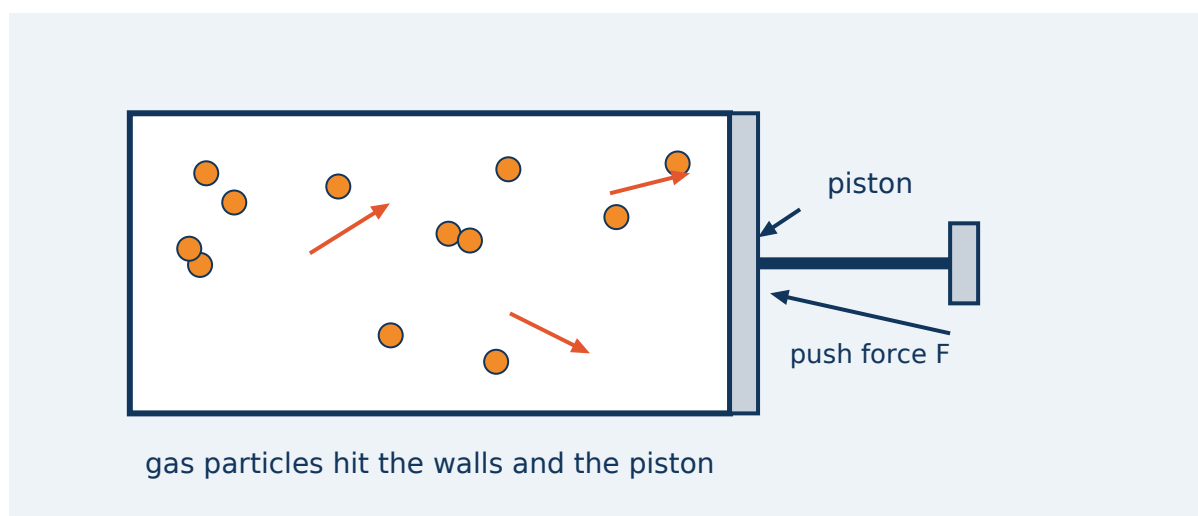
How does the kinetic theory explain a gas?

The air in a bicycle tyre looks perfectly still, yet its molecules are racing around at several hundred metres per second. The **kinetic theory** pictures every gas as a huge number of tiny particles in constant, random motion. They are far apart compared with their own size, they travel in straight lines until they collide, and they exert almost no forces on each other between collisions.

Definition

Gas pressure is the force the gas particles exert on a surface per unit area: $p = F / A$. It is measured in pascals (Pa), where $1 \text{ Pa} = 1 \text{ N/m}^2$, or in kilopascals (kPa).

Each particle that hits a wall bounces back, so the wall feels a tiny push. Billions of these collisions every second add up to a steady force, which is why a sealed gas pushes outwards on its container in every direction equally.



Gas pressure comes from countless collisions of fast particles with the walls.

What changes the pressure of a gas?

Three things control how hard and how often the particles hit the walls:

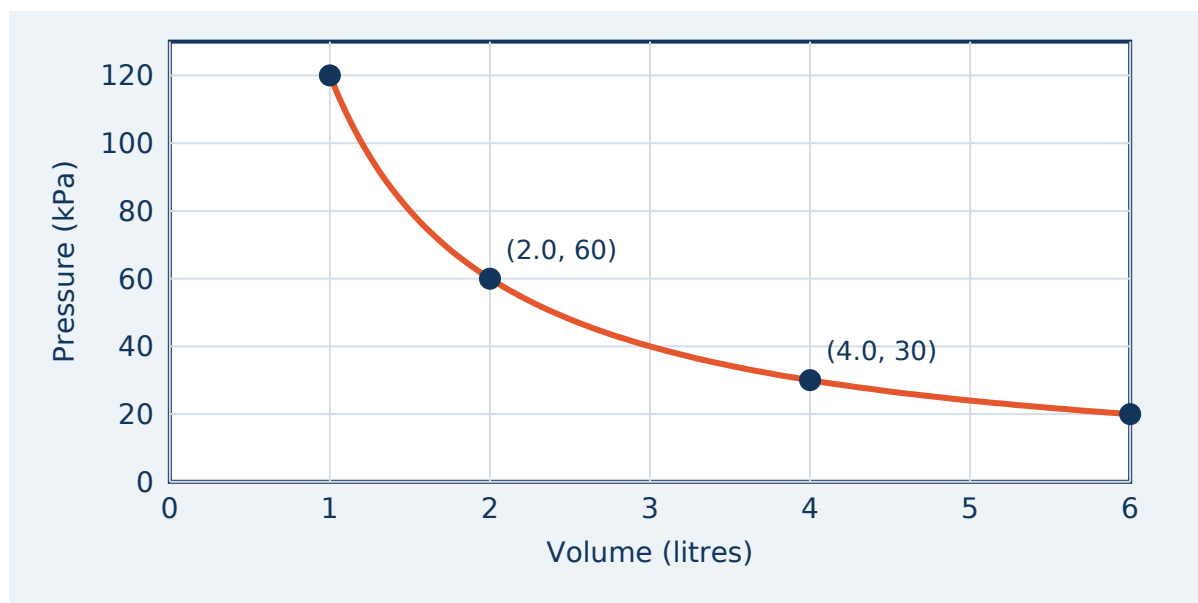
- **Temperature:** a hotter gas has faster particles. They hit harder and more often, so pressure rises if the volume stays the same.
- **Volume:** squeezing the same particles into a smaller space means they reach a wall sooner, so there are more collisions each second.
- **Number of particles:** pumping more air into a tyre increases the collisions per second.

The average kinetic energy of the particles is proportional to the temperature measured from absolute zero. That is why the kelvin scale matters.

What is the relationship between pressure and volume?

Key law (Boyle's law)

For a fixed mass of gas at constant temperature, pressure $\times$ volume is constant: $pV = \text{constant}$, or $p_1V_1 = p_2V_2$. Pressure is inversely proportional to volume.



For a fixed mass of gas at constant temperature, halving the volume doubles the pressure.

Worked example 1

Mei in Singapore traps 60 cm³ of air at 100 kPa in a syringe and pushes the plunger until the volume is 24 cm³. The temperature does not change.

$$p_2 = p_1 V_1 / V_2 = 100 \times 60 / 24 = 250$$

Answer: **250 kPa**. Both pressures must use the same unit, and both volumes too.

What is absolute zero and how do you use kelvin?

If you cool a gas, its particles slow down. At $-273\text{ }^{\circ}\text{C}$ they would have the lowest possible energy. This temperature is **absolute zero**, and the kelvin scale starts there: 0 K. A one-kelvin

step is the same size as a one-degree Celsius step.



The two scales have the same size of degree; only the zero is different.

Formula

$$T = \theta + 273$$

T = temperature in kelvin (K) · θ = temperature in degrees Celsius ($^{\circ}C$). To go back: $\theta = T - 273$.

For a fixed mass of gas in a rigid container, the pressure is directly proportional to the kelvin temperature: $p_1 / T_1 = p_2 / T_2$.

Worked example 2

A sealed rigid flask has air at 100 kPa and 27 $^{\circ}C$. It is heated to 87 $^{\circ}C$.

$$T_1 = 27 + 273 = 300 \text{ K}, T_2 = 87 + 273 = 360 \text{ K}$$

$$p_2 = 100 \times 360 / 300 = 120$$

Answer: **120 kPa**.

Quantity kept constant	What changes	Relationship
Temperature and mass	p and V	$p_1 V_1 = p_2 V_2$
Volume and mass	p and T	$p_1 / T_1 = p_2 / T_2$ (T in K)
Nothing is kept constant	Number of particles	More particles, more pressure

Common mistake

Never put a Celsius temperature into p / T . Doubling 20 $^{\circ}C$ to 40 $^{\circ}C$ does not double the pressure. Convert to kelvin first: 293 K to 313 K is a rise of only about 7 %.

Lina's tip

Write the gas law you are using, circle the quantity that stays constant, and convert every temperature to kelvin before you substitute. Then ask: should pressure go up or down? If your answer disagrees, check again.

Key points to remember

- Gas particles move randomly; pressure = force / area, from collisions with the walls
- $pV = \text{constant}$ at constant temperature: $p_1V_1 = p_2V_2$
- $T \text{ (K)} = \theta \text{ (}^\circ\text{C)} + 273$; absolute zero = $0 \text{ K} = -273 \text{ }^\circ\text{C}$
- At constant volume $p / T = \text{constant}$, with T in kelvin
- Higher temperature means faster particles, so more frequent and harder collisions

Gas pressure, volume and the kelvin scale: frequently asked questions

Why does a gas exert pressure?

Its particles move randomly and collide with the container walls. Each collision gives the wall a small push, and billions of them per second add up to a steady force on each unit of area.

Why must I use kelvin in gas calculations?

The pressure of a gas is proportional to the temperature measured from absolute zero, not from $0 \text{ }^\circ\text{C}$. Using Celsius gives wrong ratios, such as $40 \text{ }^\circ\text{C}$ seeming twice as hot as $20 \text{ }^\circ\text{C}$.

What is absolute zero?

Absolute zero is 0 K , which equals $-273 \text{ }^\circ\text{C}$. At this temperature the particles have the minimum possible energy, so no object can be colder.

Does Boyle's law work if the temperature changes?

No. Boyle's law needs a fixed mass of gas at constant temperature. If the gas is compressed quickly it warms up, so the law holds only for slow changes.

Why does a heated sealed can of gas risk exploding?

The volume cannot increase, so a higher temperature makes the particles hit the walls harder and more often. The pressure rises until the can may split.