Edexcel GCSE Physics

Your notes

Particle Model & Pressure

Contents

Kinetic Theory

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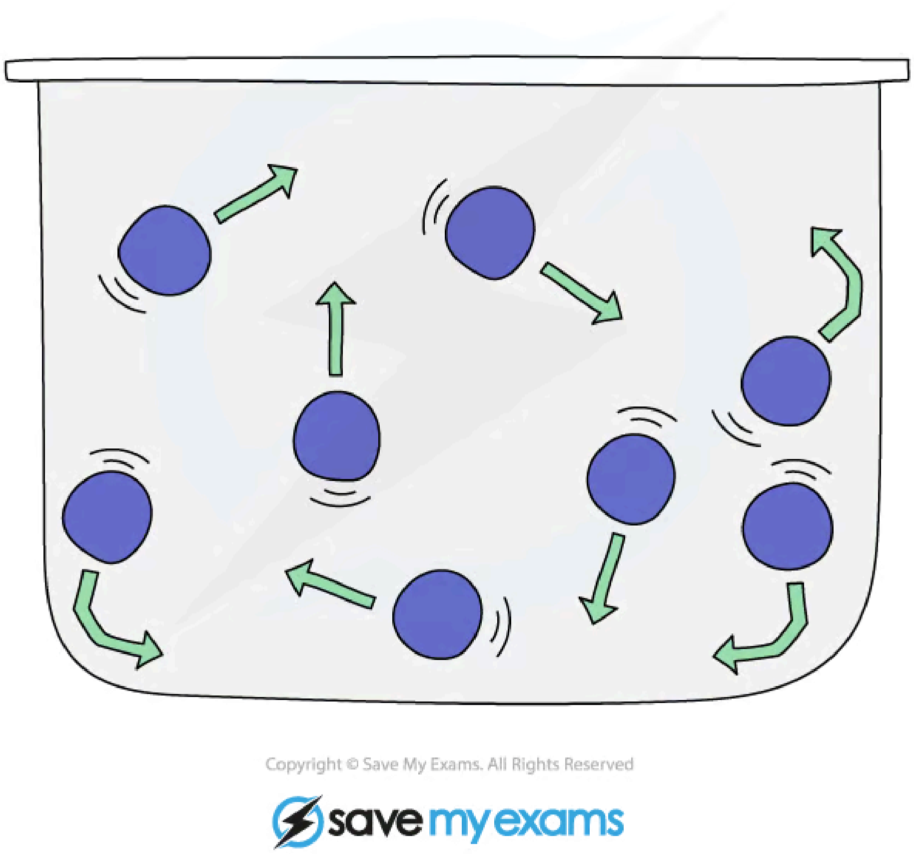
The Pressure of a Gas

Motion of Particles in a Gas

- Molecules in a gas are in constant **random** motion at high speeds
- Random motion means that the molecules are travelling in no specific path and undergo sudden changes in their motion if they collide:
  - With the walls of its container
  - With other molecules
- The random motion of tiny particles in a fluid is known as **Brownian motion**



Random motion of gas molecules in a container

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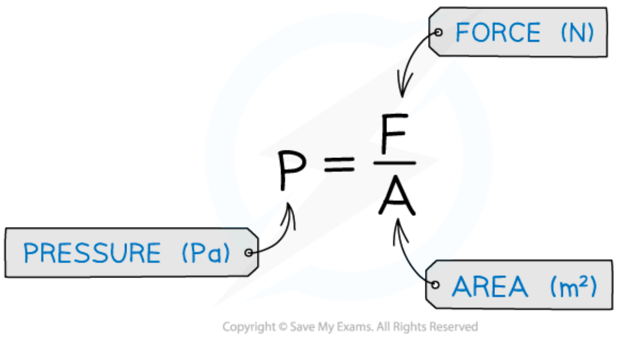
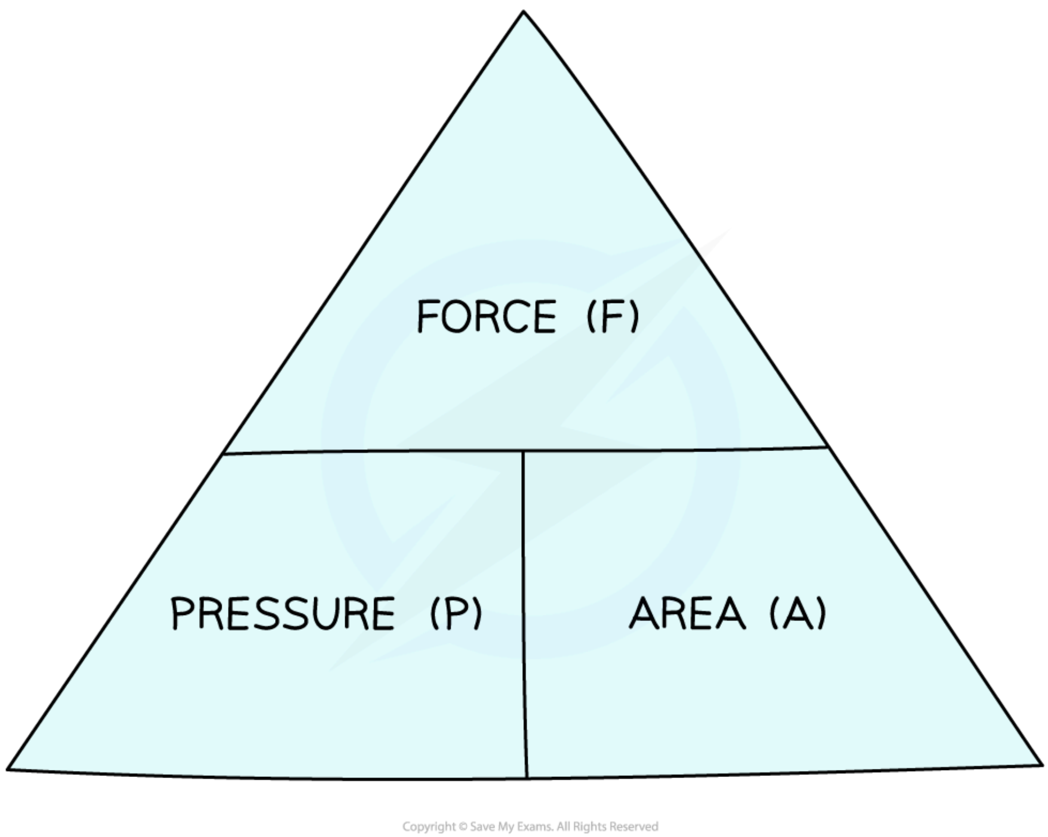
Pressure

- Molecules of gas in a container will collide with the container walls
- Pressure is defined as the **force exerted per unit area**



- Pressure is measured in the units **Pascals (Pa)**
- The area should always be the **cross-sectional area** of the object
  - This means the area where the force is at right angles to it
- This equation can be rearranged with the help of a formula triangle:



Pressure, force, area formula triangle

- Imagine molecules of gas that are free to move around in a box
- The molecules in the gas move around randomly at high speeds, colliding with surfaces and exerting pressure upon them
- The **temperature** of a gas is related to the **average speed** of the molecules:
  - The **hotter** the gas, the **faster** the molecules move and vice versa
  - Hence, the molecules collide with the surface of the walls **more frequently** and with more **force**
  - This increases the **pressure**

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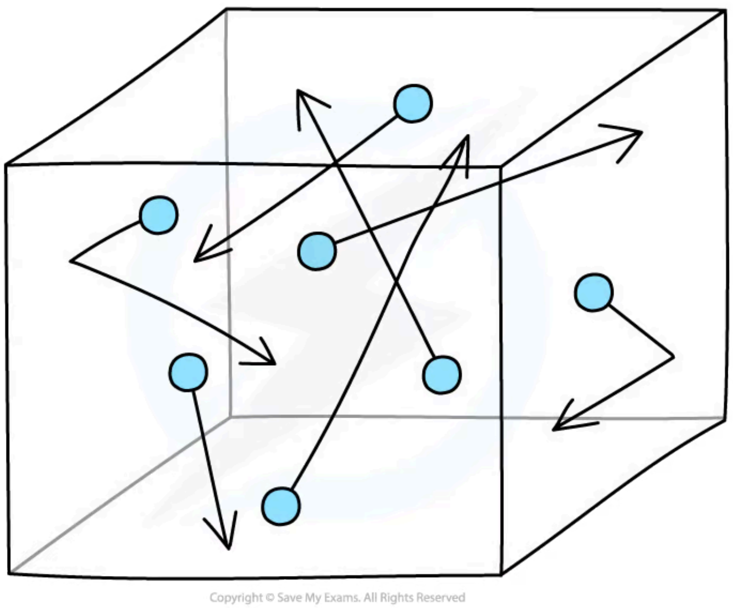
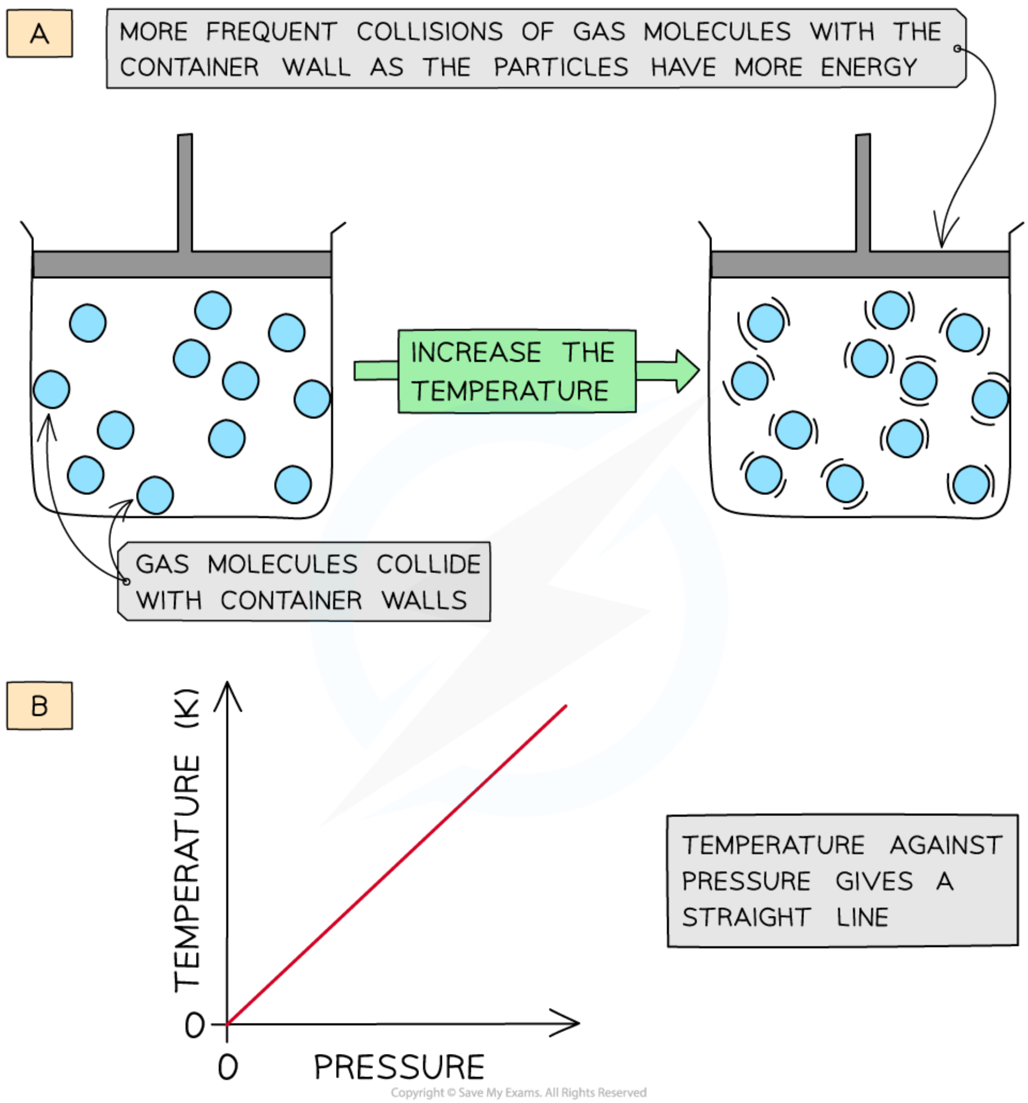


Gas molecules hit the sides of the container which creates pressure

Temperature & Pressure

- The motion of molecules in a gas changes according to the **temperature**
- As the temperature of a gas increases, the average **speed** of the molecules also **increases**
- Since the average kinetic energy depends on their speed, the kinetic energy of the molecules also increases if its volume remains constant
  - The **hotter** the gas, the **higher** the average kinetic energy
  - The **cooler** the gas, the **lower** the average kinetic energy
- If the gas is heated up, the molecules will travel at a higher **speed**
  - This means they will collide with the walls **more often**
  - This creates an increase in **pressure**
- Therefore, at a constant volume, an increase in temperature increases the pressure of a gas and vice versa
- Diagram A shows molecules in the same volume collide with the walls of the container more with an increase in temperature

- Diagram B shows that since the temperature is proportional to the pressure, the graph against each is a straight line



At constant volume, an increase in the temperature of the gas increases the pressure due to more collisions on the container walls

Examiner Tips and Tricks

You are required to be able to describe the link between temperature and pressure **qualitatively**. This means that the correct use of terms such as 'collision', 'kinetic energy' and 'frequency', will be

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really important.

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Absolute Zero

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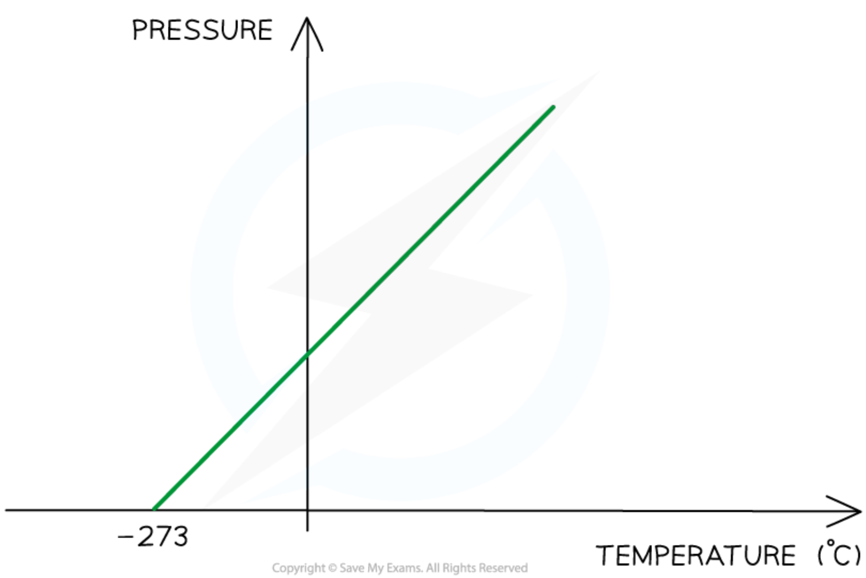
Absolute Zero

- The amount of pressure that a gas exerts on its container is dependent on the temperature of the gas
  - This is because particles move with more energy as their temperature increases
- As the temperature of the gas decreases, the pressure on the container also decreases
- In 1848, Mathematician and Physicist, Lord Kelvin, recognised that there must be a temperature at which the particles in a gas exert no pressure
  - At this temperature they must **no longer be moving**, and hence not colliding with their container
- This temperature is called **absolute zero** and is equal to -273 °C



At absolute zero, or -273 °C, particles will have no net movement. It is therefore not possible to have a lower temperature

- Absolute zero is defined as:

  The temperature at which the molecules in a substance have zero kinetic energy

- This means for a system at absolute zero, it is not possible to remove any more energy from it
- Even in space, the temperature is roughly 2.7 °C above absolute zero

The Kelvin Temperature Scale

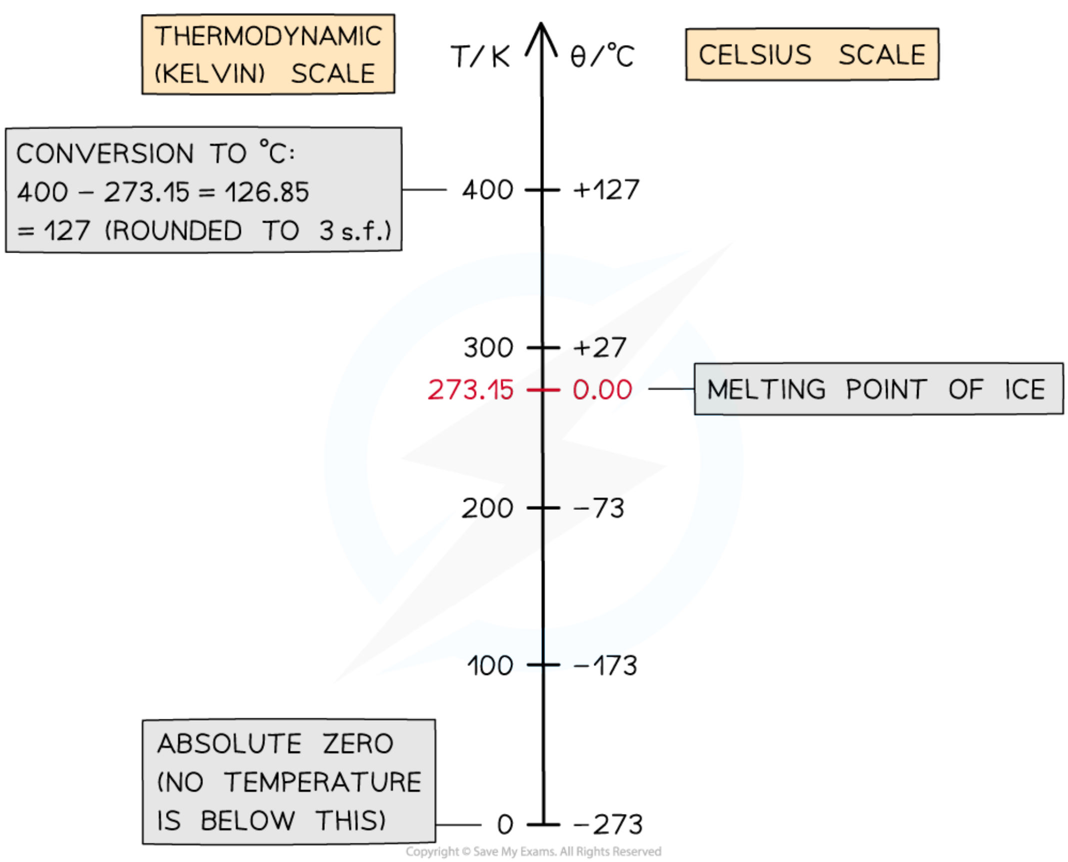
- The **Kelvin temperature scale** begins at absolute zero
  - **0 K is equal to -273 °C**
  - An increase of 1 K is the same change as an increase of 1 °C
- It is not possible to have a temperature lower than 0 K
- This means a temperature in Kelvin will **never** be a negative value

Using the Kelvin Scale

- To convert between temperatures θ in the Celsius scale, and T in the Kelvin scale, use the following conversion:

$$\theta / ^{\circ}C = T / K - 273$$

$$T / K = \theta / ^{\circ}C + 273$$



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Conversion chart relating the temperature on the Kelvin and Celsius scales

- The divisions on both scales are equal. This means:

A change in a temperature of 1 K is equal to a change in temperature of 1 °C

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Worked Example

The temperature in a room is 300 K. What is this temperature in Celsius?

Answer:

Step 1: Kelvin to Celsius equation

$$\theta\ /\ ^{\circ}\mathrm{C} = \mathrm{T}\ /\ \mathrm{K} - 273$$

Step 2: Substitute in value of 300 K

$$300\ \mathrm{K} - 273 = 27\ ^{\circ}\mathrm{C}$$

Examiner Tips and Tricks

If you forget in the exam whether it's +273 or −273, just remember that $0\ ^{\circ}\mathrm{C} = 273\ \mathrm{K}$. This way, when you know that you need to +273 to a temperature in degrees to get a temperature in Kelvin. For example: $0\ ^{\circ}\mathrm{C} + 273 = 273\ \mathrm{K}$.

Pressure & Volume

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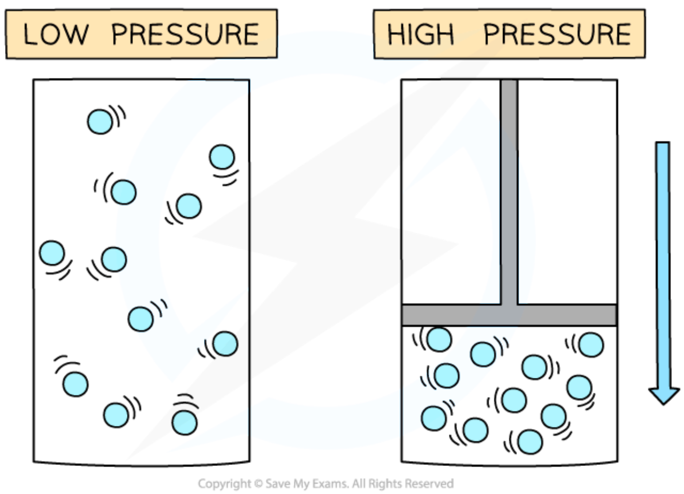
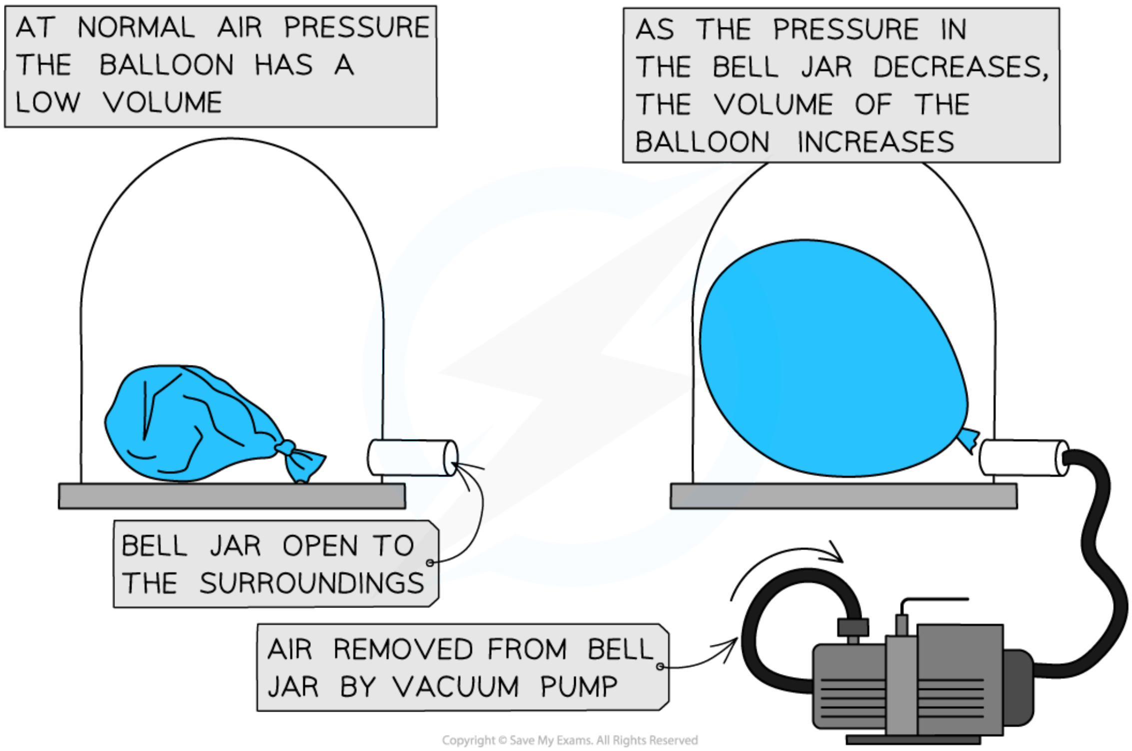
Pressure Changes in a Gas

- If the temperature of a gas remains **constant**, the pressure of the gas changes when it is:
  - **Compressed** – decreases the volume which **increases** the pressure
  - **Expanded** – increases the volume which **decreases** the pressure



Pressure increases when a gas is compressed

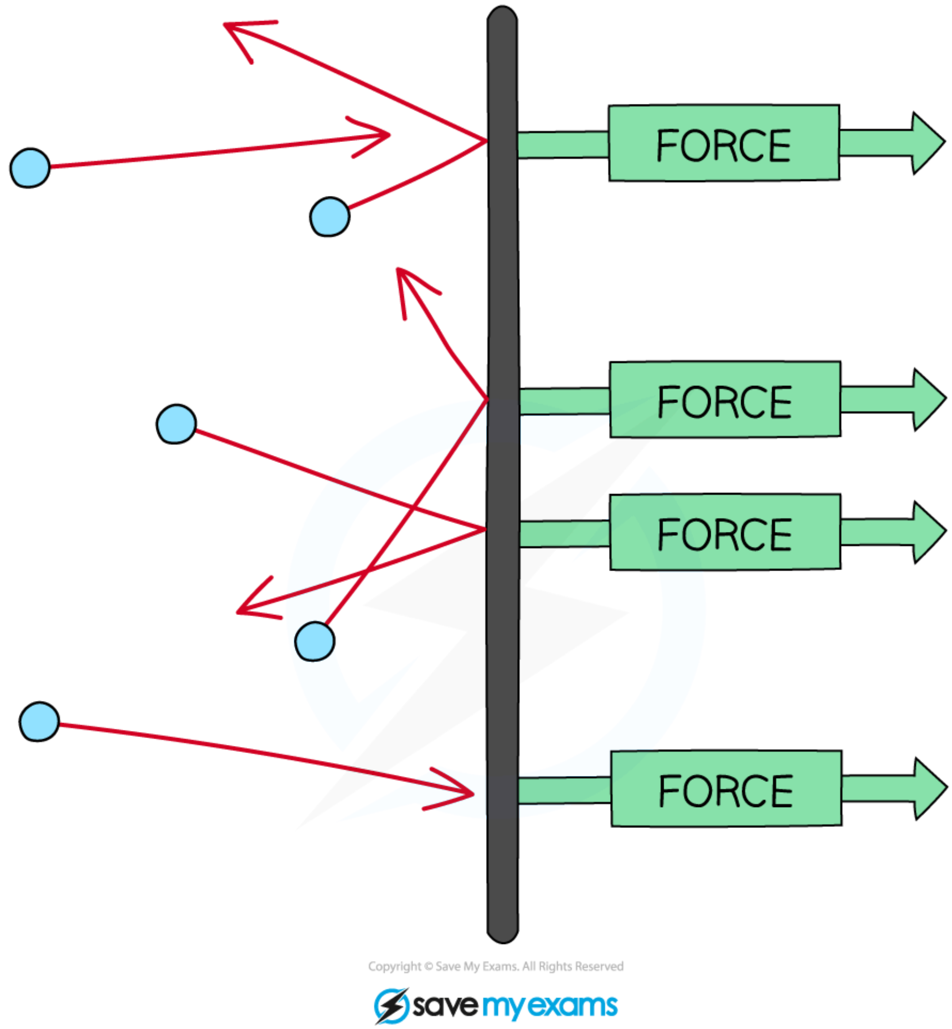
- Similarly, a change in pressure can cause a change in volume
- A **vacuum pump** can be used to remove the air from a sealed container
- The diagram below shows the change in volume to a tied up balloon when the pressure of the air around it decreases:



- Therefore, if the gas is compressed, the molecules will hit the walls of the container **more frequently**
- This creates a larger overall **net force** on the walls which increases the pressure

Pressure on Surfaces

- As the gas particles move about randomly they collide with the walls of their containers
- These collisions produce a **net force** at **right angles** to the wall of the gas container (or any surface)
- Therefore, a gas at **high** pressure has **more frequent collisions** with the container walls and a greater force
    - Hence the higher the pressure, the higher the **force** exerted per unit area



Gas molecules bouncing off the walls of a container

- It is possible for someone to experience this force by closing their mouth and forcing air into their cheeks
- The strain on the cheeks is due to the force of the gas particles pushing at right angles to the cheeks

Pressure and Volume

- In a gas, the molecules are widely spread
- This makes the gas easy to **expand** and **compress**

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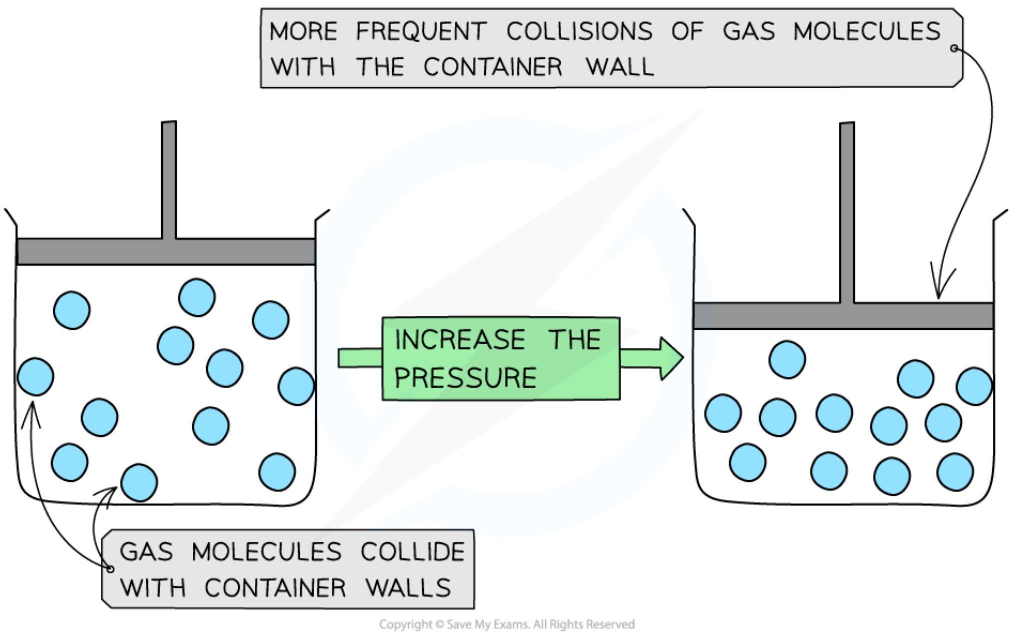
- Changing the pressure acting on the gas will compress it or allow it to expand if the temperature is kept constant
- When a gas is compressed, the volume is **decreased**
  - The density of the gas increases, since the size of the container has decreased but the number of molecules has remained the **same**
  - This allows more **frequent** collisions of the molecules on the container wall
  - This means they hit the walls with a greater **force** and therefore **increases** the **pressure**
- When a gas **expands**, the volume is **increased**
  - This causes a **decrease** in pressure



Decreasing the volume increases the pressure of molecules at the same temperature

- Therefore, in summary:
  - When the volume **decreases** (compression), the pressure **increases**
  - When the volume **increases** (expansion), the pressure **decreases**
- The key assumption is that the **temperature** and the **mass** (and number) of the particles remains the same

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Worked Example

A deodorant can contains a highly pressurised fluid that pushes the deodorant out as a fine mist.

Which of the following is not a true statement about this situation?

A. The total number of particles remains constant throughout

B. The temperature of the deodorant remains constant throughout

C. The pressure of the deodorant decreases as it leaves the can

D. The total volume of the deodorant increases as it leaves the can

Answer: B

- A is **true** because the particles only spread about, but there is no chemical change
- C is **true** because the particles have a larger volume, which means the collide less frequently with any surfaces
  - the pressure therefore decreases
- D is **true** because the deodorant is able to spread out as it leaves the can

- B is **not true** because as gases expand their temperatures decrease

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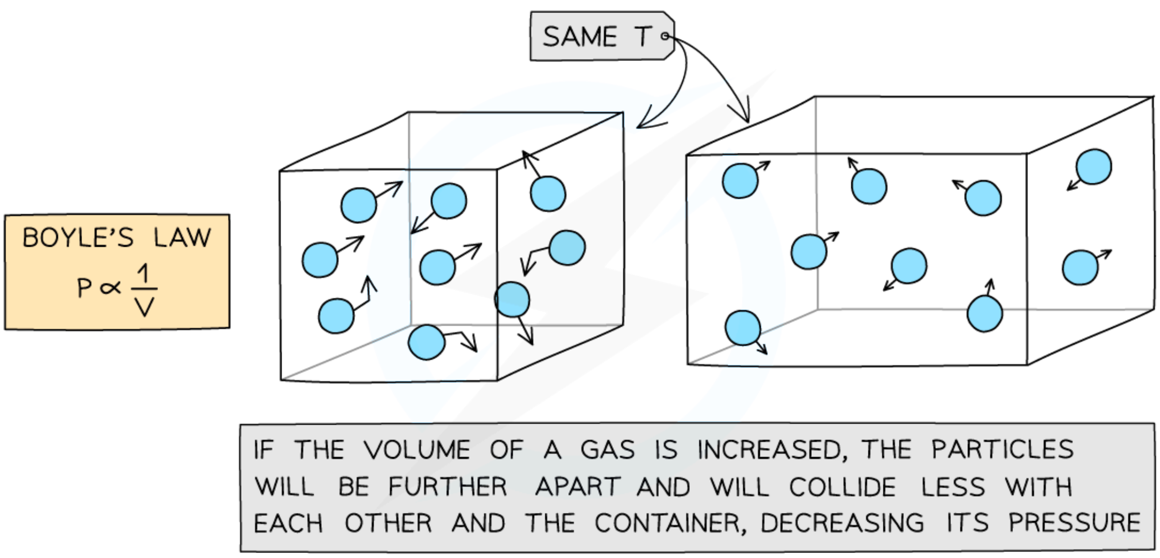
Boyle's Law

Calculating Change in Pressure & Volume

- For a fixed mass of a gas held at a constant temperature:

$$pV = \text{constant}$$

- Where:
  - p = pressure in pascals (Pa)
  - V = volume in metres cubed (m^3)
- This means that the pressure and volume are inversely proportional to each other
  - When the volume **decreases** (compression), the pressure **increases**
  - When the volume **increases** (expansion), the pressure **decreases**
- This is because when the volume decreases, the same number of particles collide with the walls of a container but **more frequently** as there is **less space**
  - However, the particles still collide with the same amount of **force** meaning greater force per unit area (pressure)
- The key assumption is that the **temperature** and the **mass** (and number) of the particles remains the same

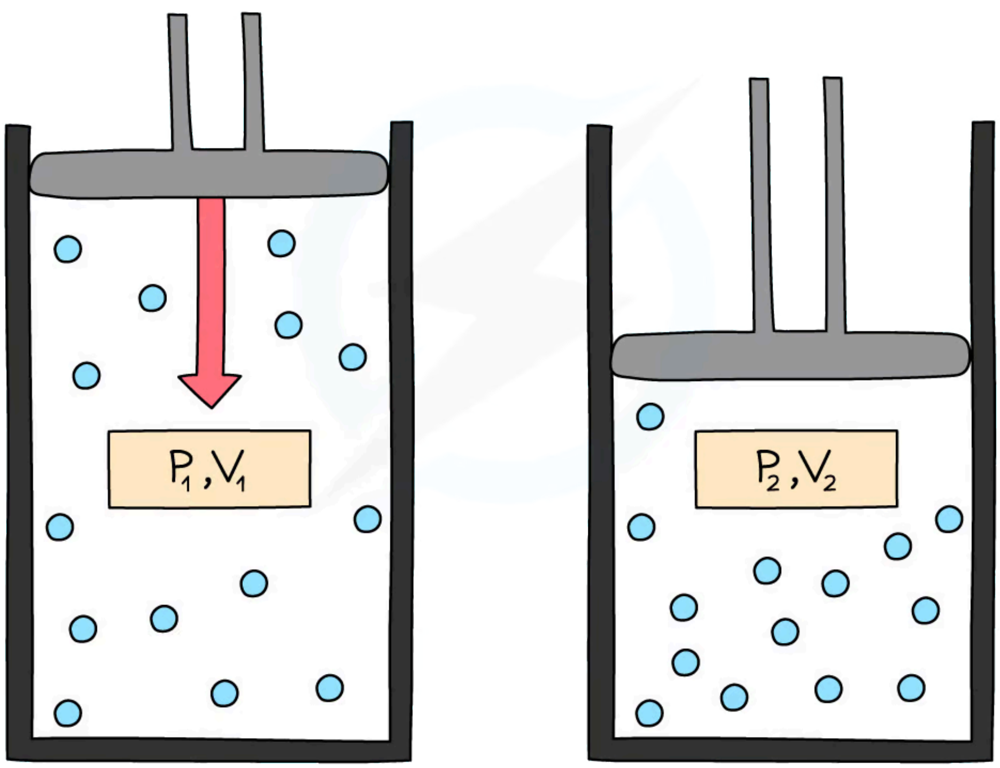


Increasing the volume of a gas decreases its pressure

- This equation can also be rewritten for comparing the pressure and volume before and after a change in a gas:

$$P_1V_1 = P_2V_2$$

- Where:
  - P_1 = initial pressure in pascals (Pa)
  - V_1 = initial volume in metres cubed (m^3)
  - P_2 = final pressure in pascals (Pa)
  - V_2 = final volume in metres cubed (m^3)
- This equation is sometimes referred to as **Boyle's Law**



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Initial pressure and volume, P_1 and V_1, and final pressure and volume, P_2 and V_2

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Worked Example

A gas occupies a volume of 0.70 m³ at a pressure of 200 Pa. Calculate the pressure exerted by the gas if it is compressed to a volume of 0.15 m³.Assume that the temperature and mass of the gas stay the same.

Answer:

Step 1: List the known quantities

- Initial volume, V_1 = 0.70 m³
- Initial pressure, P_1 = 200 Pa
- Final volume = V_2 = 0.15 m³

Step 2: Write the relevant equation

$$P_1V_1 = P_2V_2$$

Step 3: Rearrange for the final pressure, P_2

$$P_2 = \frac{P_1V_1}{V_2}$$

Step 4: Substitute in the values

$$P_2 = \frac{200 \times 0.70}{0.15} = 930 \text{ Pa (2 s.f)}$$

Examiner Tips and Tricks

Always check whether your final answer makes sense. If the gas has been **compressed,** the final pressure is expected to be **more** than the initial pressure (like in the worked example).If this is not the case, double-check the rearranging of any formulae and the values put into your calculator. One pascal is a very small amount of pressure, and you will typically meet pressures in the order of kilopascals. The pressure on you at the moment because of the air around you is equal to 100 kPa, so use this as reference when considering if your answer makes sense.

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Doing Work on a Gas

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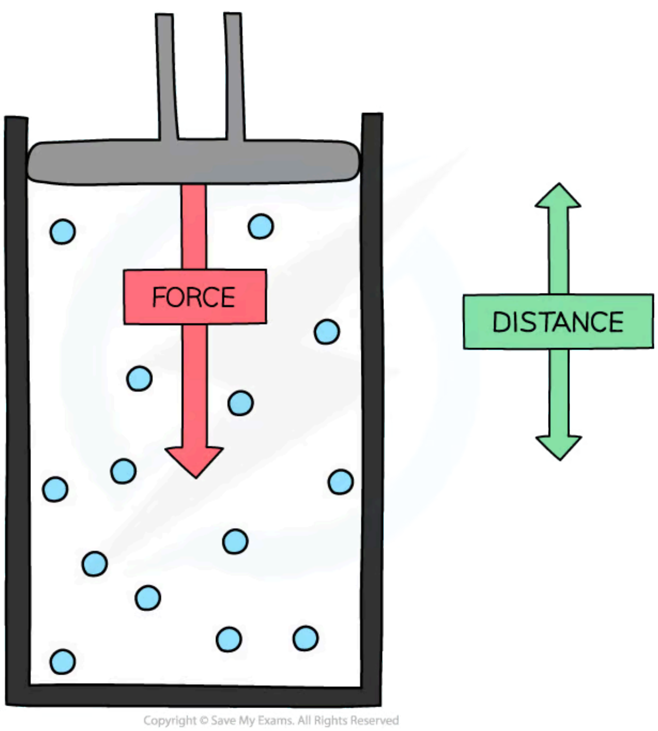
Doing Work on a Gas

Higher Tier Only

- Work is the **transfer of energy** by a **force**
- Doing work on a gas involves a transfer of energy
  - This **increases** its **internal energy** and can also cause an increase in the **temperature**
- Work can be done on a gas by **compression**
  - A **force** is used to push a piston by a certain distance
  - This **decreases** the volume of the gas
  - The molecules move around **faster** and therefore have a higher **kinetic energy**
  - This increase in kinetic energy increases its **temperature**

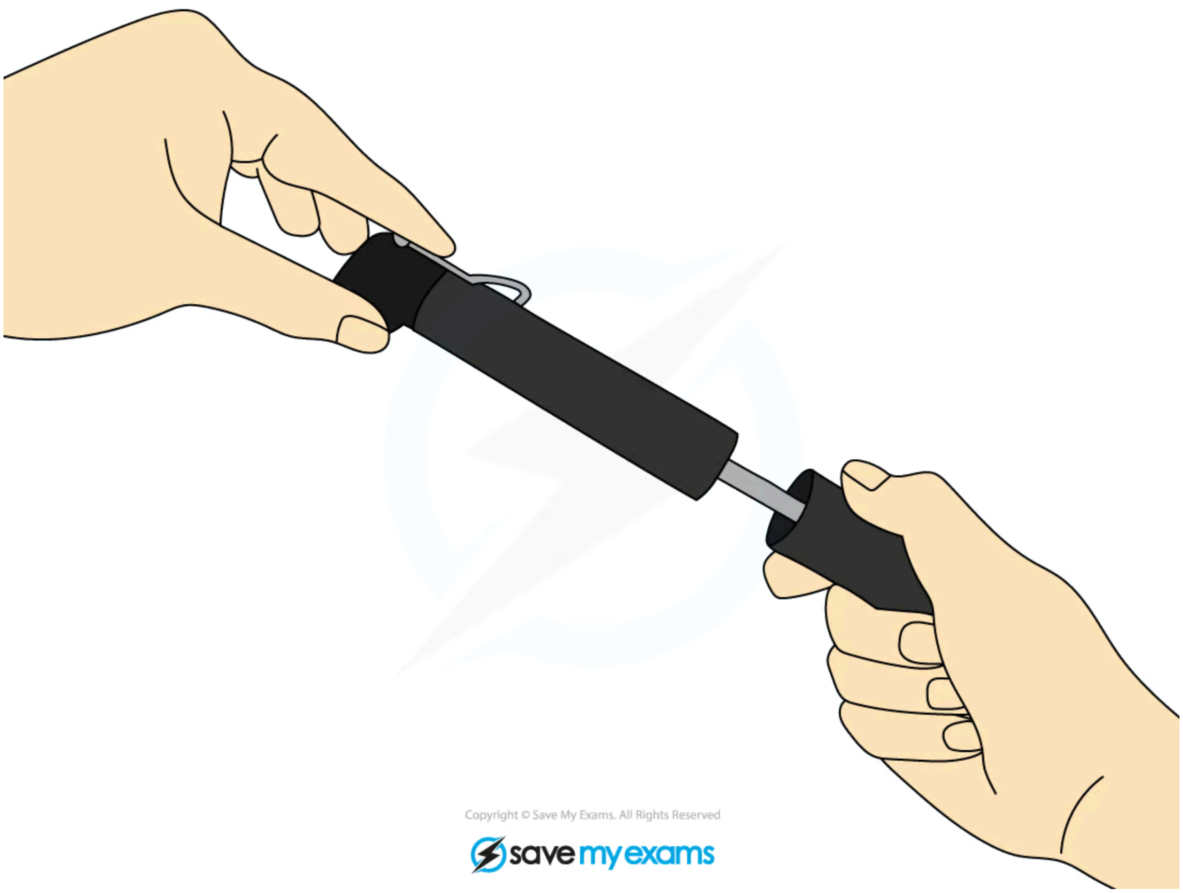


To compress the above gas, a force must be used to move the piston a certain distance. This involves doing work

- If a gas is allowed to **expand,** the gas will do work instead
  - This causes the gas to **lose** energy, which results in a **decrease** in temperature

Example 1: Increasing Temperature

- An example of doing work on an enclosed gas that leads to an increase in its temperature is a **bicycle pump**
- If a thumb is placed on the end of a bicycle pump and it is quickly compressed several times, it will be able to feel the pump getting very warm
  - This is because **work is done** on the gas, causing its temperature to **rise**



Holding your thumb over the end of a pump whilst pushing the handle causes it to feel warmer

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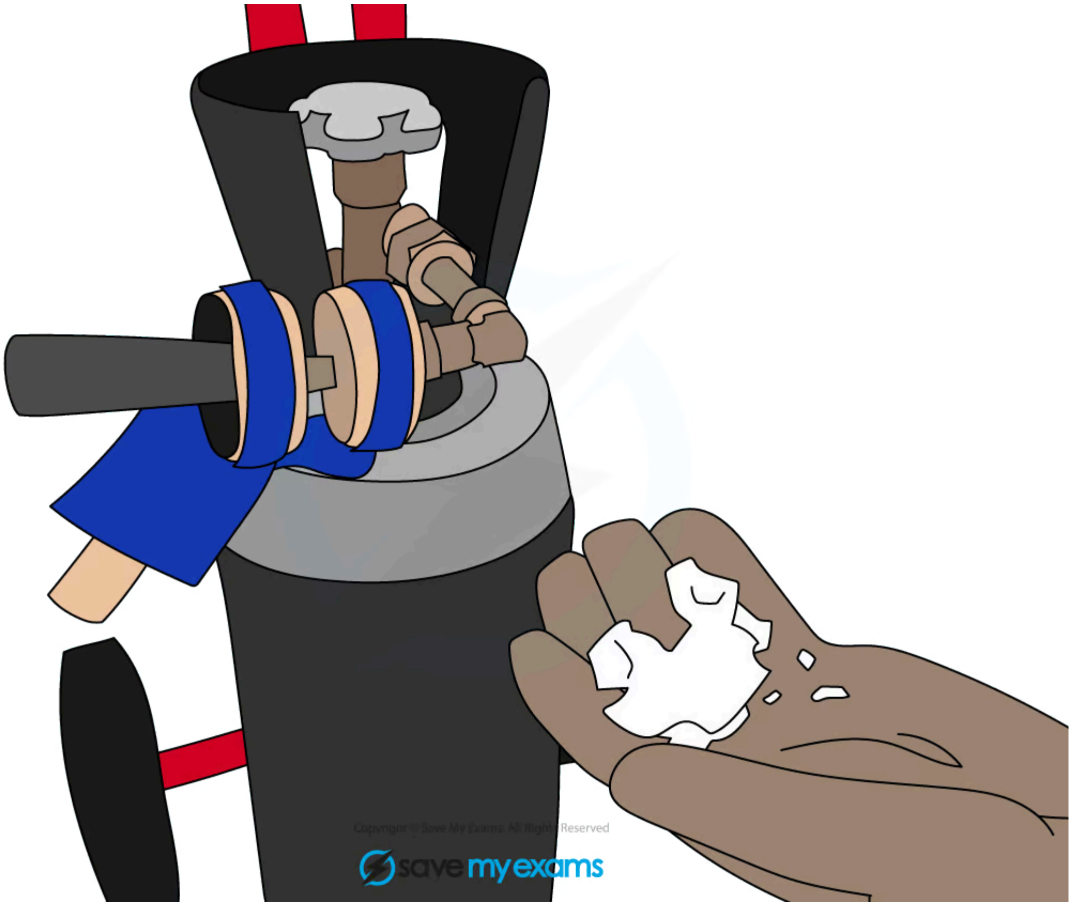
- The engines in diesel-powered vehicles work in a similar way
- A mixture of gas and fuel is compressed very suddenly
  - This causes the gas to **heat up** and **ignites** the fuel

Example 2: Decreasing Temperature

- When pressurised carbon dioxide is **released** from a high-pressure cylinder, the gas does work, which means it **loses** energy
  - This can cause the carbon dioxide to **freeze**, forming dry ice



The sudden expansion of carbon dioxide from a cylinder can rapidly cool it, forming dry ice (solid CO_2)

Examiner Tips and Tricks

It is important to remember whether the work is done **on** the gas or **by** the gas:

- When work is done **on** the gas (i.e. it is compressed), the temperature **rises**
- When the work is done **by** the gas (i.e it expands), the temperature **falls**

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