The Gas Laws

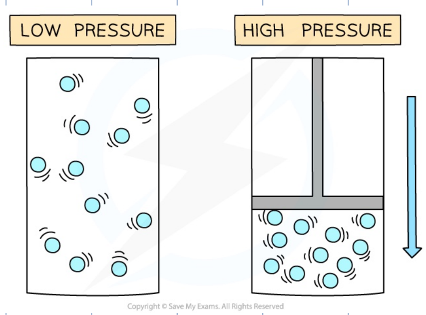
gases inside a container behave, when the surrounding pressure changes, the volume of the container changes, or the temperature changes.

Pressure & Volume

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

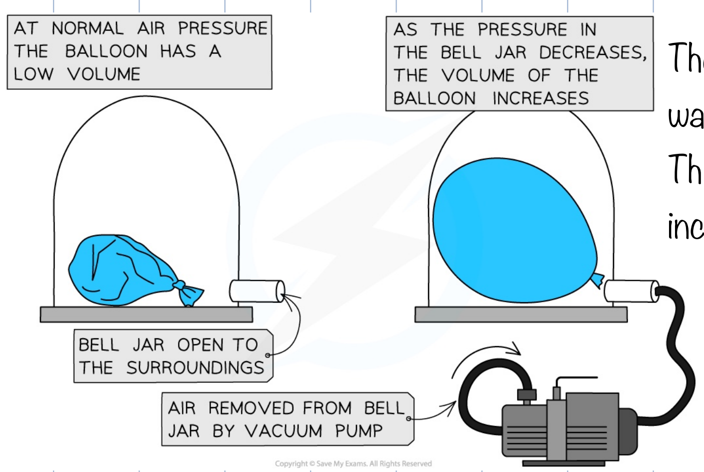
Expanded – increases the volume which decreases the pressure



Similarly, a change in pressure can cause a change in volume

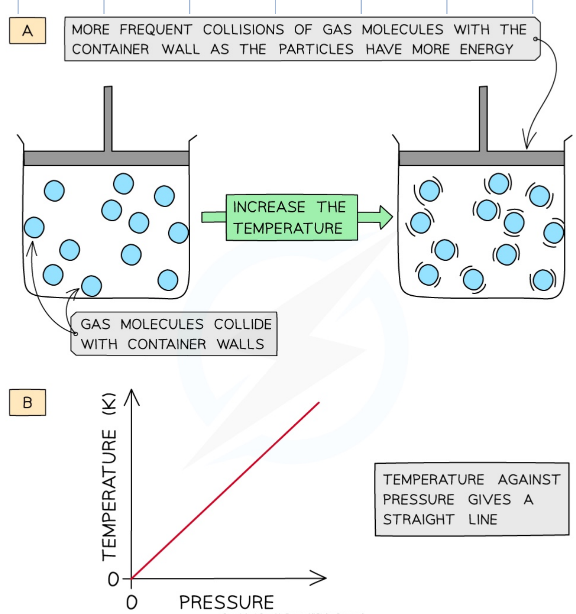
A vacuum pump can be used to remove the air from a sealed container

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 & Temperature

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

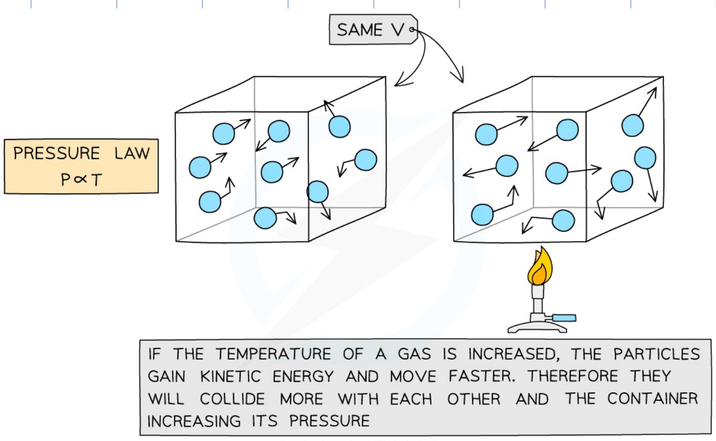
Diagram B shows that since the temperature is proportional to the pressure, the graph against each is a straight line

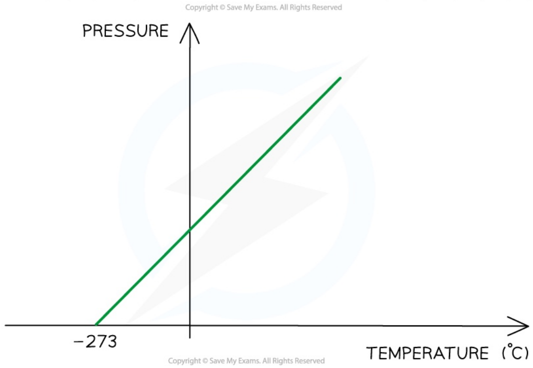
The Pressure Law

If the volume V of an ideal gas is constant, the pressure law is given by:

$$P \propto T$$

if the temperature decreases, the pressure inside the container will decrease. From this we say that the pressure inside a gas container is directly proportional to the temperature at constant volume.





The relationship between the pressure and (Kelvin) temperature for a fixed mass of gas at constant volume can also be written as:

Pressure Law

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Where:

P1 = initial pressure (Pa)

P2 = final pressure (Pa)

T1 = initial temperature (K)

T2 = final temperature (K)

The pressure inside a bicycle tyre is 5.10 × 105 Pa when the temperature is 279 K. After the bicycle has been ridden, the temperature of the air in the tyre is 299 K.Calculate the new pressure in the tyre, assuming the volume is unchanged.

Step 1: Choose which ideal gas law to use

Since the volume is constant, the pressure law must be used

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Step 2: Write down the known quantities

P, = 5.10 × 105 Pa

P=?

T+= 279 K

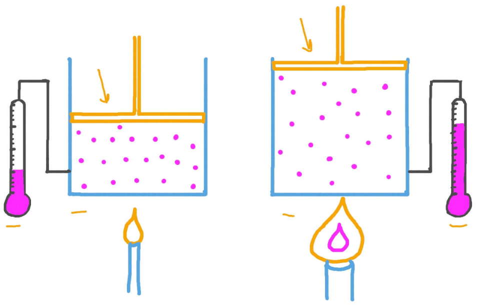
Ta = 299 K

Step 3: Substitute values into pressure low equation

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{(5.10 \times 10^5) \times 299}{279} = 5.47 \times 10^5 \text{ Pa}$$

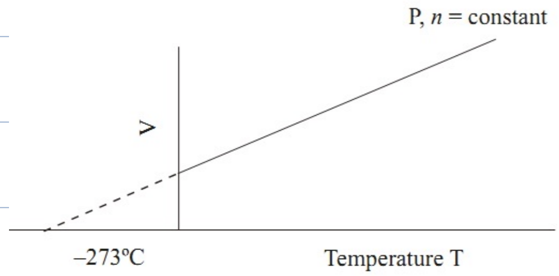
Charles' Law

If the temperature of a gas inside a container increases while the pressure is kept constant, the volume of the container will increase.



the volume of a fixed mass of gas is directly proportional to its temperature providing the pressure remains constant.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$



Example

A mass of gas has a volume of 400 cm° at 27 °C. What will be the volume of this gas at 327 °C providing that the pressure remains constant?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{400}{(27+273)} = \frac{V_2}{(327+273)}$$

$$V_2 \quad \frac{400 \times 600}{300}$$

$$_2 \quad 800 cm^3$$

Boyle's Law

The volume of a fixed mass of gas is inversely proportional to its pressure providing the temperature is kept constant.

pV = constant

Where:

p = pressure in pascals (Pa)

V = volume in metres cubed (m3)

This means that the pressure and volume are inversely proportional to each other

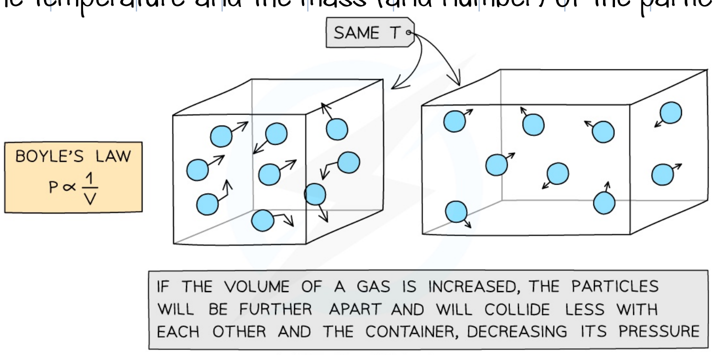
When the volume decreases (compression), the pressure increases

When the volume increases (expansion), the pressure decreases

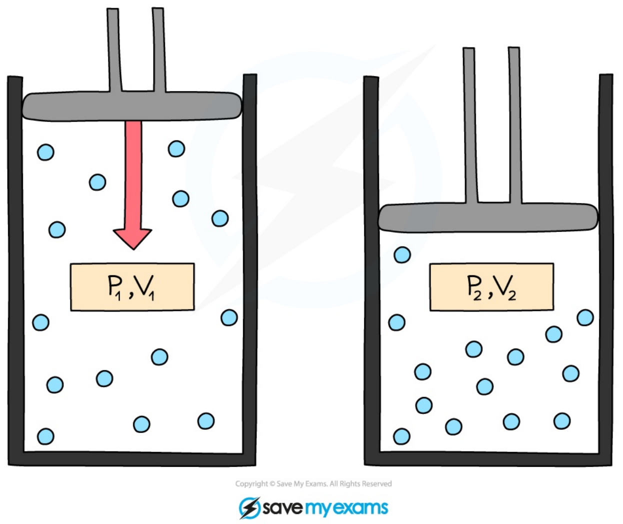
This is because when the volume decreases, the same number of particles collide with the walls of a container but more frequently as there is less space

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



$$P_1V_1 = P_2V_2$$



P1, V1
P2, V2
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