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QUANTUM BRAIN TUTORING LTD.

"TURNING BRAINS QUANTUM"

GUIDED EXPLANATION

AQA GCSE Physics | Spec Ref: 4.3.3

HIGHER TIER

Particle Model and Pressure

Key Learning Objectives

1. Explain how temperature is related to the average kinetic energy of particles
2. Explain how the motion of particles in a gas creates pressure
3. Describe the relationship between pressure and volume for a fixed mass of gas at constant temperature (Boyle's law)
4. Use the equation pV = constant for a gas at constant temperature (HT only)
5. Explain how increasing the temperature of a gas held at constant volume increases the pressure (HT only)

Particle Model and Pressure

1. Particle Motion in Gases

In a gas, particles are in constant **random motion**. They move in all directions at a range of speeds. The particles collide with each other and with the walls of their container. These collisions are **elastic**, meaning no kinetic energy is lost overall.

> **Key Definition: Temperature and Kinetic Energy**
>
> The **temperature** of a gas is related to the **average kinetic energy** of its particles. When a gas is heated, the particles gain kinetic energy and move faster. When cooled, they slow down.

At **absolute zero** (0 K or -273 degrees C), particles would have zero kinetic energy and stop moving entirely. This is the lowest possible temperature.

2. Gas Pressure

When gas particles collide with the walls of their container, they exert a **force** on the wall. The total force exerted by all the particle collisions per unit area is what we call **gas pressure**.

> **Key Definition: Gas Pressure (Physics Only)**
>
> **Gas pressure** is caused by the collisions of gas particles with the walls of their container. The more frequent or forceful the collisions, the higher the pressure.

Gas pressure depends on:

- **Number of particles** - more particles means more collisions, so higher pressure.
- **Temperature** - higher temperature means particles move faster, collide more often and with more force.
- **Volume of container** - a smaller container means particles hit the walls more frequently.

3. Pressure and Volume (Boyle's Law) - HT Only

For a **fixed mass of gas** at **constant temperature**, increasing the volume of the container means the particles have further to travel between collisions with the walls. This means they collide with the walls less frequently, so the pressure **decreases**.

> **Key Definition: Boyle's Law**
>
> For a fixed mass of gas at constant temperature, the pressure is **inversely proportional** to the volume. If the volume doubles, the pressure halves (and vice versa).

Key Equation (HT Only)

pressure x volume = constant

pV = constant

Or equivalently: $p_1V_1 = p_2V_2$

p in pascals (Pa), V in metres cubed (m^3)

This equation is given on the Physics equation sheet.

4. Increasing the Temperature at Constant Volume - HT Only

If a gas is heated in a sealed container (so the volume cannot change), the particles gain kinetic energy and move faster. They collide with the walls more frequently and with greater force. This means the **pressure increases**.

This explains why aerosol cans carry warnings not to heat them - the pressure inside could increase enough to cause the can to explode.

5. Doing Work on a Gas

When a gas is compressed (its volume decreases), work is done **on** the gas. This transfers energy to the kinetic energy store of the gas particles, so the **temperature increases**. This is why a bicycle pump gets warm when you pump it.

Conversely, when a gas expands, it does work on its surroundings. Energy is transferred away from the kinetic energy store of the particles, so the temperature decreases.

Worked Examples

Worked Example: Boyle's Law Calculation (HT Only)

Problem: A gas occupies a volume of 0.50 m^3 at a pressure of 100 kPa. The gas is compressed to a volume of 0.25 m^3 at constant temperature. Calculate the new pressure.

Solution:

Step 1: Write the equation: $p_1V_1 = p_2V_2$

Step 2: Substitute: $100 \times 0.50 = p_2 \times 0.25$

Step 3: Rearrange: $p_2 = (100 \times 0.50) / 0.25$

Step 4: Calculate: $p_2 = 50 / 0.25 = 200$ kPa

Answer: $p_2 = 200$ kPa

Worked Example: Boyle's Law - Finding Volume (HT Only)

Problem: A sealed syringe contains 60 cm^3 of gas at a pressure of 1.0×10^5 Pa. The plunger is pushed in until the pressure reaches 3.0×10^5 Pa. Calculate the new volume.

Solution:

Step 1: $p_1V_1 = p_2V_2$

Step 2: $1.0 \times 10^5 \times 60 = 3.0 \times 10^5 \times V_2$

Step 3: $V_2 = (1.0 \times 10^5 \times 60) / (3.0 \times 10^5)$

Step 4: $V_2 = 20\ cm^3$

Answer: $V_2 = 20\ cm^3$

Common Mistakes

Common Mistake

Saying that gas particles 'expand' when heated. The particles themselves do not change size - they move faster and further apart, so the gas as a whole takes up more space.

Common Mistake

Confusing temperature with heat. Temperature is a measure of the average kinetic energy of particles. Heat is the transfer of thermal energy from a hotter to a cooler object.

Common Mistake

Forgetting to keep units consistent in Boyle's law calculations. If you use kPa for p_1, you must use kPa for p_2. The same applies to volume units.

Common Mistake

Stating that particles 'stop' at 0 degrees C. Particles only stop at absolute zero (0 K = -273 degrees C), not at 0 degrees C.

Exam Tips

Exam Tip

When explaining gas pressure, always mention: (1) particles are in random motion, (2) they collide with the walls, (3) these collisions create a force, and (4) pressure = force per unit area.

Exam Tip

For Boyle's law questions, always check that the temperature is constant before applying pV = constant. If the temperature changes, this equation does not apply.

Exam Tip

When asked to 'explain' a pressure change, link your answer to particle speed, collision frequency, and collision force. A description alone won't earn full marks.

Exam Tip

Remember: pV = constant is a Higher Tier equation and is given on the equation sheet. You do not need to memorise it, but you must be able to use and rearrange it.

Summary

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Gas particles are in constant random motion. The temperature of a gas is related to the average kinetic energy of its particles. Gas pressure is caused by particles colliding with the walls of their container. For a fixed mass of gas at constant temperature, pressure is inversely proportional to volume (pV = constant, HT only). Heating a gas at constant volume increases the pressure because particles move faster and collide with the walls more frequently and with more force. Compressing a gas does work on it, increasing its temperature.