Physics Knowledge Organiser

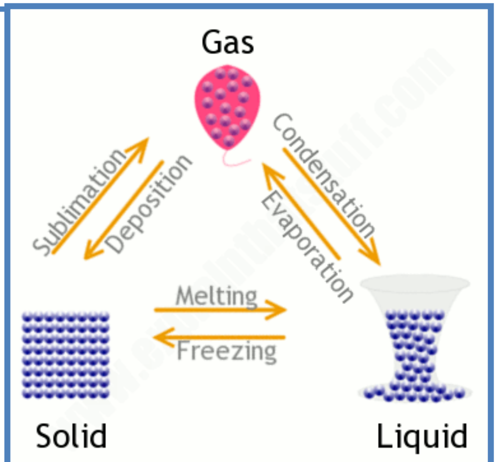
P6 - Particle model of matter

States of matter and changes of state

Study the diagram. The particle model is used to explain differences between solids, liquids and gases, and to explain how changes from one state to another happen. Make sure you know how to draw the particles arrangement in each state, and know all the names for each state change shown on the diagram.

In a solid, the particles are **fixed in position** and only vibrate – they can't flow around. In a liquid, the particles are still **very close together** but they can **flow** past each other. In a gas, the particles move **randomly** and there is **empty space** between them.

In changes of state, no new substance is produced and there is no change in the **mass** of the substance. This is because no particles are created or destroyed.



Density and the particle model

The particle model explains why 1 kg of a gas will have a **much** larger volume than 1 kg of a solid. This is because there is empty space between the particles in a gas, whereas in a solid, they are tightly packed together. Looking at the equation below, you should see that in this example the *m* is the same (1 kg), but the volume for the gas is much larger. Since we divide by volume, this must mean that the **density** of the gas is much smaller than the density of the solid.

Density of regular and irregular shaped objects

To calculate the density of a regular shaped object we can use a ruler to measure length and then calculate the volume. We find the mass of the object by using a mass balance then calculate the density using the equation.

To calculate the density of an irregular shaped object we use a displacement can. The can is filled with water just above the spout. The irregular shaped object is placed in the can and the water level rises. The displaced water will come out of the spout and can be collected in a measuring cylinder. The volume of this displaced water is the volume of the irregular shape. The density equation can then be used to find the density of the object.

Key Terms	**Definitions**
Model	Models are used all the time in science. A model represents the real world and can explain many things about the universe. However, models are never perfect and there are limits to what they can explain. That doesn't stop them being extremely useful though!
Particle model	The model that represents molecules or atoms as small, hard spheres. The important things to think about when using the particle model are the **arrangement** of the particles in each state of matter and the **kinetic energy** of the particles.
State of matter	The physical arrangement of particles determines the state of a particular substance: solid, liquid or gas. Changing from one state of matter to another is a physical process, NOT a chemical process. No new substance is produced, and if you reverse the state change, you have a substance with exactly the same properties as the stuff you started with.
Density	The quantity that defines how much material (i.e. mass) is in a certain volume. See equation. If you have two objects the same size but different densities, the more dense object will feel heavier in your hand as there is more mass in the same volume.
Melt/freeze	The change of state from solid to liquid/liquid to solid.
Evaporate/ condense	Change of state from liquid to gas/ gas to liquid.
Boil	Like evaporation, boiling is a change of state from liquid to gas. However, boiling involves heating of the liquid so it boils, rather than particles on the surface of the liquid becoming gas (like in evaporation).

Equation	**Meanings of terms in equation**
$\rho = \frac{m}{V}$ * —	*ρ = density (kilograms per metre cubed, kg/m³)* *m = mass (kg)* *V = volume (metres cubed, m³)*

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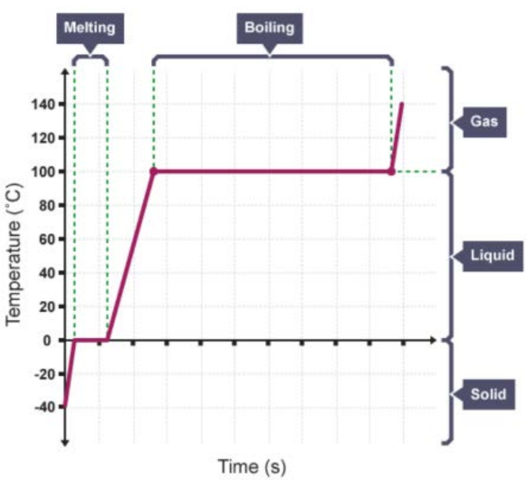
Internal energy and energy transfers

Heating changes the energy stored in a system by increasing the energy of the particles. This has the effect of either raising the temperature of the system (changing the kinetic energy) or produces a change of state (changes the potential energy)

An increase in temperature depends on the mass of the substance heated, the type of material and the energy input into the system and can be calculated using the specific heat capacity equation.

The energy needed for a substance to change state is called latent heat. When a substance changes state the energy supplied changes the energy stored (internal energy) but not the temperature. This is why the graph is horizontal when there is a change of state.



The graph is horizontal at two places. These are the places where the energy is not being used to increase the speed of the particles, increasing temperature, but is being used to break the bonds between the particles to change the state.

The longer the horizontal line, the more energy has been used to cause the change of state. The amount of energy represented by these horizontal lines is equal to the latent heat.

Key Terms	Definitions
Internal Energy	Energy stored inside a system by the particles. It is the total kinetic energy and potential energy of all the particles in a system.
Specific heat capacity	The amount of energy needed to raise the temperature of one kilogram of the substance by one degree Celsius.
Specific latent heat	The amount of energy needed to change the state of one kilogram of the substance with no change in temperature
Specific latent heat of fusion	To change the state from solid to liquid
Specific latent heat of vaporisation	To change the state from liquid to vapour

Equation	Meanings of terms in equation
$\rho = \frac{m}{V}$ *	*ρ = density (kilograms per metre cubed, kg/m³)* *m = mass (kg)* *V = volume (metres cubed, m³)*
$\Delta E = mc\Delta\theta$	ΔE = change in energy (Joules, J) M = mass (Kilograms, Kg) c= specific heat capacity, (joules per kilogram per degrees Celsius, J/Kg °C) $\Delta\theta$ = change in temperature, (degrees Celsius, °C)
E=ml	E = Energy for a change in state, (Joules, J) m = mass (Kilograms, Kg) l = specific latent heat (Joules per kilogram, J/Kg)

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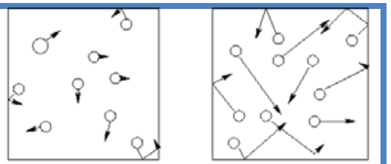
Pressure in gases



Cooler gas- less kinetic energy

Hotter gas – more kinetic energy

Particles in a gas are constantly moving – so they store **kinetic energy**. They collide with the walls of their container, and exert a force when they do. The total force exerted on a certain area of the wall is the **gas pressure**.

The amount of kinetic energy that the particles have is related to the temperature of the gas. The higher the temperature, the more kinetic energy they have. This means they move faster, on average. Therefore, there are more collisions with the container walls and they exert a greater force when they collide with the walls. Thus, **increasing** the temperature of a gas (keeping the volume the same) **increases** the pressure of the gas.

The pressure from gas molecules may increase if there are more molecules colliding each second or if the molecules are moving faster.

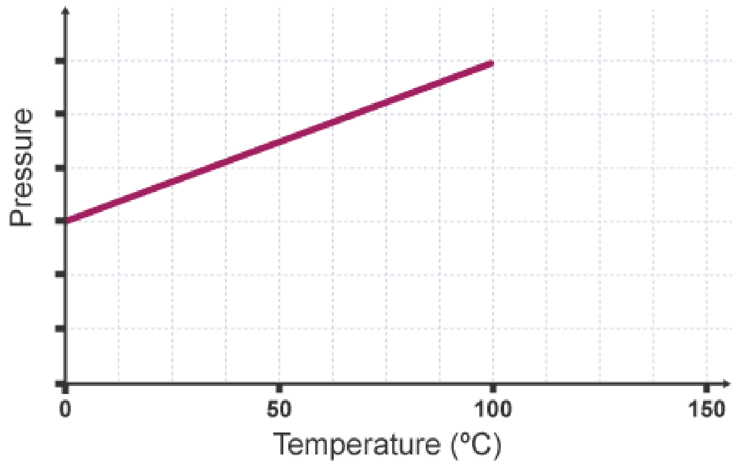
Pressure and Temperature

If the volume of gas stays the same, the pressure of a gas increases at the same rate as the temperature increases. Pressure is proportional to temperature.

The gas particles travel faster and collide with the walls of the container more frequently and with more force.

Key Terms	Definitions
Pressure	Pressure is caused by the force exerted by particles in a gas when they hit the walls of a container.
Atmospheric pressure	The pressure from air particles in the atmosphere. At sea level this is 100,000 N/m^2
Temperature of a gas	The temperature is a measure of the average kinetic energy of the particles – the higher the temperature the higher the average kinetic energy

Equation	Meanings of terms in equation
$P = \frac{F}{A}$ *	*P = Pressure (Newtons per meter squared (N/m^2))* *F = Force (N)* *A = Area (metres squared, m^2)*



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P6 - Particle model of matter (Physics only)

Pressure and volume

A gas can be compressed or expanded by changes in pressure. The pressure produces a force at right angles to the wall of the container.

If the volume of gas decreases the pressure will increase if the temperature remains constant. Volume is inversely proportional to pressure.

This is because the same number of particles collide with the walls of the container more frequently as there is less space. However, the particles still collide with the same amount of force.

If the volume of the gas is expanded, pressure will decrease if the temperature remains constant.

This is because the same number of particles collide with the walls of the container less frequently as there is less space. However, the particles still collide with the same amount of force.

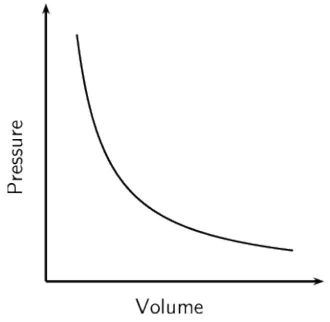
For a fixed mass of gas at a constant temperature

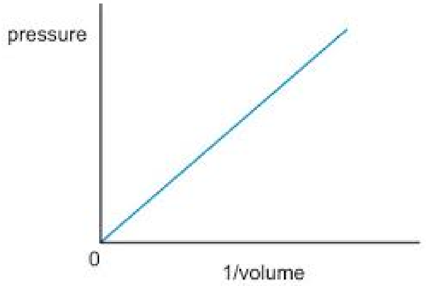
Pressure x volume = constant

This is also known as Boyles Law.

The change in volume or pressure can be calculated using the equation:

$P_1V_1 = P_2V_2$





Equation	Meanings of terms in equation
• pV = constant	P = *Pressure (Newtons per meter squared (N/m^2)) or Pascals (Pa)* *V = Volume (m^3)*
• $P_1V_1 = P_2V_2$	P_1 = *pressure before the change* V_1 = *volume before the change* P_2 = *Pressure after the change* V_2 = *volume after the change*

Work and Energy

Pressure can be increased by:

- Increasing the temperature (Increasing the force of the collisions)
- Decreasing the volume (Increasing the number of collisions per second)

Forces applied to particles result in a transfer of energy. If a gas is compressed work is done on the gas. This mechanical work transfers energy to the internal energy store of the gas, increasing its temperature.

If a gas does not have a fixed temperature then increasing the pressure by decreasing the volume of a gas leads to an increase in temperature. This is because temperature is a measure of the average kinetic energy of the particles. If the particles move faster, the internal energy of the gas increases and so the temperature must increase. – this happens when a bicycle pump is used to pump up a tyre. The pump gets warmer.