BioMedical Admissions Test (BMAT)

Section 2: Physics

Topic P5 - Matter

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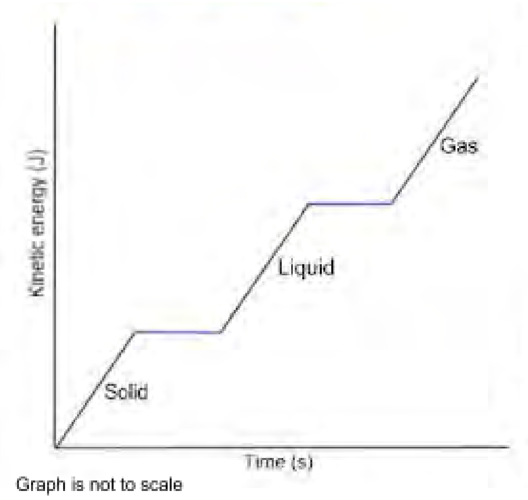
Kinetic Theory

Kinetic theory explains that in a substance **at different states**, **particles** are exactly the same but **have different amounts of kinetic energy** and are arranged differently.



If we look at the graph on the left we can see that over time the **kinetic energy** of the substance is increasing. This means the substance is being heated, the heat is causing the increase in kinetic energy.

It is important to understand that **changes of state require energy to weaken or break the bonds between particles**. Where the gradient of the graph is 0, heat **energy is being transferred to break bonds**, rather than increasing the kinetic energy the particles have.

A pure substance will change state completely at one temperature (its boiling or melting point) whereas an impure substance will change state over a range of temperatures and cannot be said to have a specific melting or boiling point.

Three different states - solid, liquid and gas - are described below using a particle model:

State	Amount of energy	Forces of attraction between particles	Movement of particles	Density of particles
Solid	Least	**Strong**	Only vibrate; **fixed** positions; close together	Very **dense**; lack of movement
Liquid	More	**Weaker**	Can move slightly; not fixed; further apart than solids	**Less dense** than the solid
Gas	Most	**Very weak**	Many directions; fast; far apart	**Least dense**

Exam Tip - When you are given a graph, take a moment to **read** the **axes** and **units before** trying to interpret them!

These particle models explain the **macroscopic** motion of these states, specifically that solids **cannot** flow as particles are held in a fixed position, whereas fluids (liquids and gases) **can** flow as the particles are not held in a fixed arrangement.

- When thermal energy is transferred **to** a body, its temperature **rises** unless it's changing state.
- When thermal energy is **removed** from a body, its temperature **decreases** unless it's changing state.
- When changing state, energy is absorbed or removed **without** the temperature changing. This is because the energy is changing the **separation** (bond strength) between particles.
- Once the body has completely changed state, it's temperature will begin to change again.

The thermal energy transferred during a state change is known as **latent heat** which is dependent on the mass and type of substance and which change in state is occuring

- liquid to gas = **vaporisation**
- solid to liquid = **fusion**

Latent heat of vaporisation applies to the **boiling** or **condensing** of a substance and latent heat of fusion applies to the **melting** or **freezing** of a substance.

The amount of energy required to change the state of a substance can be calculated by:

Energy (J) = mass (kg) x latent heat (J/kg)

This applies to both fusion and vaporisation and the latent heat values are unique to the substance.

Ideal Gases

A gas consists of identical particles in rapid random motion and not exerting forces on one another (apart from during collisions).

If we assume that these particles obey Newton's laws and that the volume of gas particles is negligible when compared to overall gas volume (both of which are true at room temperature) we can model their behaviour as an **ideal gas**.

A gas exerts a force on any object that it is in contact with, because of the random motions of the gas particles.

- Particles in a gas collide with objects, and each collision exerts a tiny force. These add up to an average force per unit area, or **pressure**, exerted by the gas.
- Gas particles in a container exert a force on the walls of the container. This equates to a certain force per unit volume also known as the **pressure** of the gas.

The pressure that the gas exerts is dependent on the temperature and the volume of the container:

Pressure x Volume = a constant
Pressure / Temperature = a constant

We can therefore say that the pressure of the gas is directly proportional to the temperature of the gas and inversely proportional to the temperature of the gas.

By combining these equations we obtain the following equation:

$$\frac{Pressure\ x\ Volume}{Temperature} = a\ constant$$

Density
The density of a substance is the mass per unit volume and can therefore be calculated by:
Density (kg/m^3) = Mass (kg) / Volume (m^3)

All samples which are composed of the same substance will have the **same** density even though their mass and volume may vary.

The volume of a regular object can be measured using a ruler whereas you can measure the volume of an irregular object by the volume of water it displaces.

Due to the arrangement of their particles, solids are slightly more dense than their equivalent liquids (1.1 x more dense) which in turn are far more dense than gases (1000 x more dense).

Pressure
Pressure is defined as force per unit area and can therefore be calculated by:

Pressure (Pa) = Force (N) / Area (m^2)

Pressure is measured in Pascals (Pa) where 1Pa = 1N/m^2 and by looking at the above equation, it makes sense that pressure can be increased by increasing the force applied or by decreasing the area that it is applied over.

Fluids are substances that can flow (liquids and gases). The pressure of fluids increases with depth and acts in all directions. The **hydrostatic pressure** exerted by a fluid can be calculated using the following equation:

Pressure (Pa) = depth (m) x fluid density (kg/m3) x gravitational field strength (N/Kg)

As the formula shows, pressure depends only on depth, fluid density and gravitational field strength; it does not depend on the shape of the container. Therefore the pressure exerted at any point along the line of equal depth will be the same.