WJEC (Wales) Physics GCSE

1.8: Kinetic Theory

Detailed Notes

(Content in **bold** is for higher tier **only**)

Pressure

Pressure is the **force** exerted per **unit area**.

$$p = \frac{F}{A}$$

p is pressure in Pascals (Pa), F is force in Newtons (N) and A is area in square meters (m^2)

One **pascal** is equal to one newton per square meter **(N/m^2)**. Area can be measured in other units but it is typically in meters.

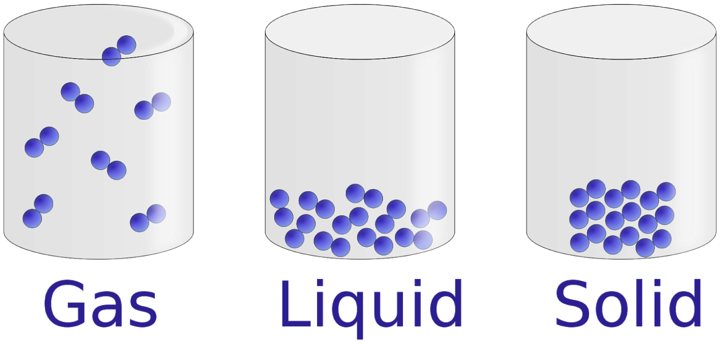
Pressure **increases** when the force applied to an area **increases** or when the size of the area it is applied to **decreases**. Pressure **decreases** when the force applied to an area **decreases** or when the size of the area it is applied to **increases**.

Change of State

As a substance changes state, its mass remains fixed. However, the volume it occupies can change and therefore so does its density. This can be explained using kinetic theory.

As a solid is heated, the constituent molecules gain energy and therefore vibrate more. Eventually the vibration is so vigorous that the bonds holding molecules in a solid lattice are broken, allowing them to move more freely. In this liquid state, molecules form transient bonds with one another. The solid-liquid transition is generally associated with an increase in volume. Therefore as a liquid, the same mass of substance will generally occupy a greater volume and so the liquid form will generally have a lower density.

A somewhat similar process takes place during the liquid-gas transition, whereby more heat energy is inputted into the system. As a result molecules have more kinetic energy and become more sparsely populated. Consequently, gases occupy the greatest volume for a given mass of substance.



Comparing volume of solids, liquids and gases (WAMC.tes.com).

When a substance is cooled, heat energy is removed and the internal energy decreases. When enough energy has been removed, bonds may begin to form between the particles causing liquids to freeze (liquid-solid) or gases to condense (gas-liquid), and perhaps freeze.

The Behaviour of Gases

Charles' Law

This law relates the **temperature and volume** of a gas at **constant pressure**. If the temperature of a fixed mass of gas is **increased** at a constant pressure, the volume it occupies will also **increase**. Therefore the ratio of volume to temperature will be **constant**.

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

T is temperature in Kelvin (K).

Boyles's Law

This law relates the **volume and pressure** of a gas held at a **constant temperature**. Volume and pressure are **inversely related** so that if the volume of the gas increases, its pressure will decrease.

$$p_1V_1 = p_2V_2$$

Changing Temperature

When the temperature of a gas is changed at a **fixed volume**, the **pressure** of the gas changes.

If the temperature of the gas is **increased**, particles will **gain kinetic energy** and **move faster**. Therefore the **frequency of particle collisions** with the inside wall of the container will increase, producing an **outward pressure**. If the temperature of the gas **decreases**, the gas particles will also **lose kinetic energy** and **move slower**, meaning less frequent collisions will occur with the inside wall of the container. Therefore the outward **pressure decreases**. As a result there is an **inward acting pressure** as the (ambient) pressure outside the container is **greater than that inside**.

These laws can be combined to give the following relationship:

$$\frac{pV}{T} = k$$

k is a constant and T is temperature in Kelvin (K).

This law tells us that if the temperature of a gas is increased/decreased the volume of the gas must increase/decrease and/or the pressure of the gas must increase/decrease such that the product of the pressure and volume divided by the temperature remains constant.

Similarly if the volume increases/decreases, the pressure must decrease/increase and/or the temperature must increase/decrease. If the pressure increases/decreases, the volume must decrease/increase and/or the temperature must increase/decrease.

Temperature Scales

The most commonly used temperature scale is the **Celsius (ºC) Scale** which is based on the properties of water. 0ºC is the freezing point of pure water and 100ºC its boiling point. The lower limit of this scale is **absolute zero (-273ºC)** at which point molecules **no longer move or vibrate**. There is no energy left for the substance to lose, so it cannot cool any further.

In science, the **Kelvin (K) Scale** is more commonly used as it is **directly proportional** to the **average internal energy** of particles in the mass under study. This scale begins at **absolute zero (0K)** meaning there are no negative temperatures, making calculations easier. It can easily be converted to the Celsius Scale as a 1ºC change is **equivalent** to a 1K change in temperature.

$$T \text{ in } {}^{\circ}C = T \text{ in } K - 273$$
$$T \text{ in } K = T \text{ in } {}^{\circ}C + 273$$

Thermometers are used to measure temperature as the liquid within it **expands** when heated, causing it to rise up the scale marked onto the outer tube.

Heat Transfer

Thermal Capacity

Heat and temperature are not the same thing. Temperature is a measure of how hot a substance is, whereas heat is the amount of **thermal energy** a substance has. Therefore heat is measured in **Joules (J)**. When a substance is heated, the change to its temperature depends on what it is, its mass and the amount of energy supplied.

$$Q = mc\Delta T$$

Q is energy is Joules (J), m is mass in kg, ∆T is the change in temperature in ºC or Kelvin and c is the specific heat capacity.

Specific heat capacity (s.h.c) of a substance is the amount of energy required to increase **1kg** of it by **1ºC (or 1K) without a change of state**. It is measured in **J/kg/ºC** (or J/kg/K Joules per kilogram per kelvin). Each substance has a unique specific heat capacity. Those with a **high**

s.h.c. can store lots of **heat** in a relatively small mass. Water is an example of this, making it useful in central heating systems.

Latent Heat

When a substance changes state, its **temperature does not change** despite energy being transferred. **Specific latent heat** (s.l.h) of a substance is the amount of energy required to change the state of **1kg** of that substance **without any change to its temperature**. It is measured in **J/kg**.

$$Q = mL$$

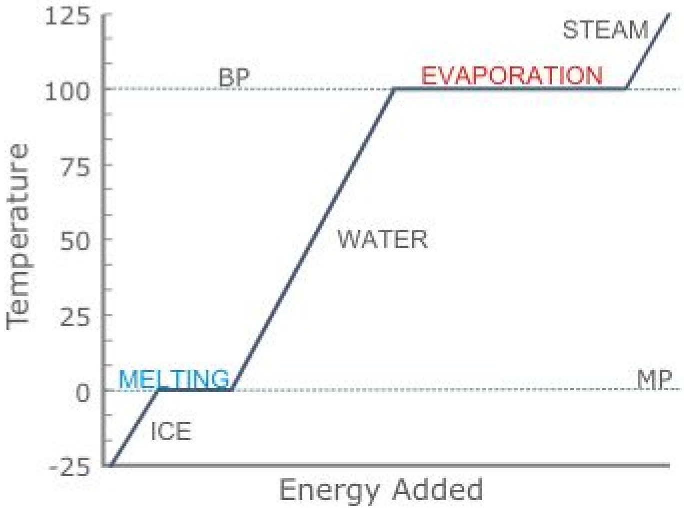
Q is energy is Joules (J), m is mass in kg, L is specific latent heat in J/kg.

The value of specific latent heat is different for each substance and can show how easily a substance can change state.

S.l.h for **melting** can be referred to as the **latent heat of fusion**, whereas the s.l.h. for **boiling** can be referred to as the **latent heat of vaporisation**.

Heating Curves

Graphs of **temperature** against **heat absorbed** (energy) can be plotted to show how a substance can change state over time, known as **heating curves**. The graph has **plateaus** in temperature which is where the substance actually changes state. **More energy** is required to **boil** a substance than melt it, meaning the plateau is greater for boiling than for melting.



Heating curve for water (wordpress.com).

Cooling curves can also be drawn for condensing and freezing. They look the same but are just in reverse.