OCR (B) Physics GCSE

Chapter 6: Matter, Models and Explanations

Summary Notes

(Contents in bold is for Higher Tier Only)

P6.1 How does Energy transform Matter?

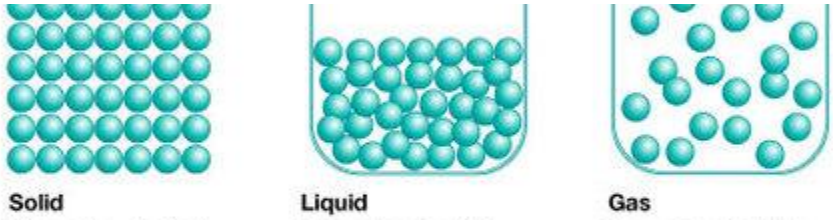
Density

The density is defined as the mass per unit volume:

$$\rho = m \div V$$

Where the density ρ, in kilograms per metre cubed, kg/m^3, mass, m, in kilograms, kg and volume, V, in metres cubed, m^3

Density depends on the spacing of the atoms in matter. Solids and liquids have similar densities as the space between particles does not change significantly. Usually liquids have a lower density than solids (main exception is ice and water). Gases have a far lower density and the spacing between atoms increase x10, as the particles have lots of energy to move, so volume increases greatly and therefore the density decreases greatly compared to solids/liquids.



Remember if questions involve change in state and ask for new volume/pressure, the mass is the same!

Specific Heat Capacity

The amount of energy required to raise the temperature of 1kg of a substance by 1°C.

$$\Delta E = mc\Delta T$$

Where ΔE is the change in thermal energy, in joules J, specific heat capacity, c in joules per kilogram per degree Celcius Jkg-1°C-1, mass m in kilograms kg and temperature change ΔT in degrees Celcius °C .

Specific Latent Heat

The amount of energy needed to change the state of 1kg of a substance without a change in temperature

- The substance needs to be at the right temperature to change state first
- Specific Latent Heat of fusion is energy to melt/freeze
- Specific Latent Heat of vaporisation is energy to boil/condense

energy for a change of state = mass × specific latent heat

$$E = mL$$

Where E, is the Energy in joules J, m is the mass in kilograms kg and specific latent heat L in joules per kilogram J/kg.

Internal Energy

Energy which is stored by particles (atoms and molecules) within a system in the forms of:

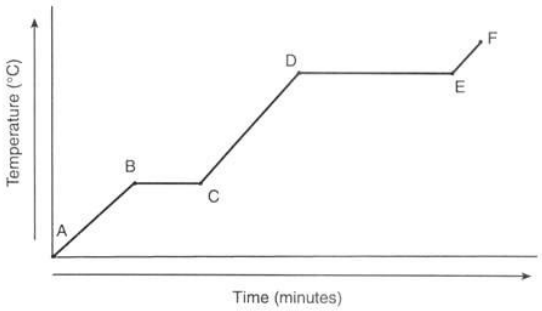
- Kinetic Energy (vibration of atoms etc.)
- Potential Energy (between the particles)

Heating increases the energy the particles have and thus, increases the internal energy. This either raises the temperature of the system or produces a change of state

Energy is absorbed when melting and evaporating and energy is released when freezing and condensing. Sublimation is when solid goes straight to gas – "dry ice" (solid CO_2 does this).

Graph here shows the temperature of ice:

- At A it is Solid.
- At B, reaches 0°C .
- From B to C there is no temperature change because the energy is used through melting.
- From C to D it is in liquid state.
- From D to E the water is boiling. This takes longer, because evaporation takes more energy
- From E to F the gas is heating.



P6.2 How does the Particle Model explain the effects of Heating?

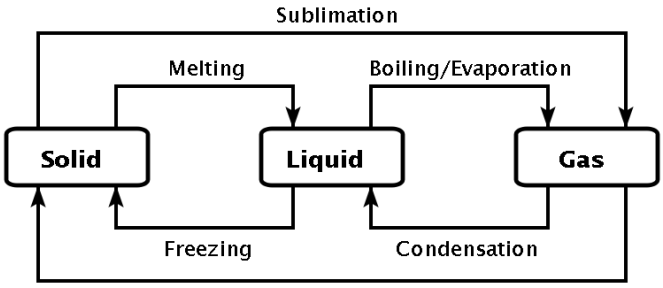
Changes of State

Mass is conserved during a change of state.

- If 20g of liquid evaporates, the gas produced will also weigh 20g

These *physical* changes are reversible, and **not** *chemical* changes

- They are not chemical because the material retains its original properties when reversed



Pressure

Particles in a gas move randomly in every direction and they exert forces on their container, which is felt as pressure. Pressure produces a net force at right angles to any surface.

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

Where the pressure, p, is in pascals Pa, the force normal to the surface, F, in newtons N and the area of the surface, A, in metres squared, m^2.

Heating in terms of Particles

The particle model can be used to describe and predict physical changes when matter is heated:

- In solid state, particles are vibrating;
- In liquid state, they are vibrating and jostling around;
- In gas state, they are moving freely in random directions. .
- The hotter something is, the higher its temperature is and the faster its particles are vibrating or moving.

Pressure in terms of Particles

A substance in the gas state exerts pressure on its container because the momentum of the particles changes when they collide with walls of the container

- The molecules of a gas are in constant random motion. The temperature of the gas is related to the average kinetic energy of the molecules.
- The higher the temperature, the greater the average kinetic energy and so the faster the average speed of the molecules.
- When the molecules collide with the wall of their container they exert a force on the wall. The total force exerted by all of the molecules inside the container on a unit area of the walls is the gas pressure.
- Changing the temperature of a gas, held at constant volume, changes the pressure exerted by the gas (known as the Pressure law).

P6.3 How does the Particle Model relate to Material under Stress?

Springs

To stretch, bend or compress an object, more than one force has to be applied. If it is pulled in opposite directions on either side of the object, it will stretch. If a single force is applied to an object, it will just move in that direction. If it is fixed at one point and stretched, a force is still being applied by the fixed point.

Deformation is a change in shape. **Elastic Deformation is when the object returns to its original shape when the load has been removed (e.g. Elastic band). Plastic Deformation is when the object does not return to its original shape when the load has been removed (e.g. a spring when pulled too far).**

Hooke's Law

The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.

$$F = kx$$

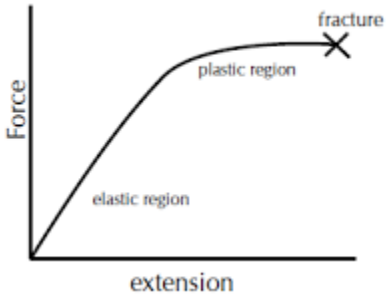
where:

- F is the force applied to the spring, N
- K is the spring constant, Nm-1
- X is the extension, m

Force-Extension Graph

Linear line for a Force/Extension Graph

- This is elastic region
- It is following Hooke's Law
- Gradient is k



The point it stops being linear is the limit of proportionality.

- From then on, it does not obey Hooke's Law

Non-Linear line

- There is plastic behaviour here
- It is not following Hooke's Law
- If shallow, lots of extension for not a lot of force (Easy to stretch)

If graph is just linear, with no non-linear end section, the material is brittle, so snaps instead of stretches after the elastic limit

Work Done

When a force stretches/compresses a spring, the spring does work, and elastic potential energy is stored in the spring:

$$W = \frac{1}{2}kx^2$$

Where work done, W, is in Joules [J], spring constant, k, in Nm and extension, x, in m.

Provided the spring does not inelastically deform:

Work done on the spring = Elastic potential energy stored

P6.4 How does the Particle Model relate to Pressures in Fluids? (Physics only)

Pressure in Gases (Physics only)

Changing the volume of a gas affects the pressure:

- A gas can be compressed or expanded by pressure changes. The pressure produces a net force at right angles to the wall of the gas container
- Increasing the volume in which a gas is contained, at constant temperature, can lead to a decrease in pressure (known as Boyle's law), this is due to the reduced number of collisions per unit area.

For a gas at fixed mass and temperature: Increasing the volume of a container will lead to a decrease in pressure.

$$P_1V_1 = Constant$$

Where the pressure P is in pascals, Pa and the volume, V, in metres cubed, m^3.

The Earth's Atmosphere (Physics Only)

The atmosphere is a thin layer (relative to the size of the earth) of air around the Earth which gets less dense with increasing altitude. This is because it is the total weight of the air above a unit area at a certain altitude.

- The weight of the air is the force which causes the pressure
- So, with higher elevation, there are fewer air molecules above the unit area than the same area at lower heights, so there is a smaller weight, so less pressure

Idealised Assumptions, for a simple model of the atmosphere:

- Isothermal, so it is all at the same temperature
- Transparent to solar radiation
- Opaque to terrestrial radiation

Upthrust (Physics Only)

A partially (or totally) submerged object experiences a greater pressure on the bottom surface than on the top surface. This creates a resultant force upwards which is known as upthrust.

An object floats if its weight is less than the weight of the water it displaces. A 1000kg boat will sink into the water until it has displaced 1000kg of water, providing the boat doesn't completely submerge before it displaces this amount, then it will float.

A ping pong ball floats on water as its density is less than the density of the water, so for the volume displaced, the weight of the equivalent amount of water is greater than the weight of the ping pong ball, so the resultant force is buoyancy, so it floats

Pressure in a Fluid (Physics Only)

Pressure in a liquid varies with depth and density, and this leads to an upwards force on a partially submerged object.

- **The buoyancy force is the upwards force that counteracts the weight of the floating object**
- **This is equal to the weight of the fluid displaced by the object**

Increasing the depth, the greater the weight of the water above you, so greater force felt, so greater pressure:

$$p = h\rho g$$

Where:

- **P = pressure due to column of fluid in pascals Pa**
- **h = height of the column in metres, m**
- **ρ = density of fluid in kilograms per metre cubed kg/m^3**
- **g = gravitational field strength g is in newtons per kilogram N/kg which is normally 10.**

P6.5 How can Scientific Models help us understand the Big Bang? (Physics Only)

Solar System (Physics only)

Our solar system is a small part of the Milky Way galaxy, and consists of:

- The sun lies at the centre of our solar system, it is heliocentric.
- Eight planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune
  - Smaller planets are made of primarily rock, then the larger planets are primarily gas
  - All planets orbit the Sun on the same plane
  - All planets rotate, just at different speeds
  - Larger planets have rings, as their gravitational field is so strong it attracts debris
- Dwarf planet also orbit the sun (including Pluto, Ceres)
- There are also asteroids and comets
- Natural satellites i.e. the moons that orbit planets

Planetary Orbits (Physics only)

As the planet orbits the sun, the gravitational force causes the planet to change direction constantly (it moves in a circle around the sun). This means the velocity is always changing. Hence the force causes the planet to accelerate without increasing its speed.

For a stable orbit, if the planet moves closer to the sun, (i.e. its orbital radius decreases), the gravitational attraction to the sun increases (Force increases, and so does acceleration), so the orbital speed of the planet increases.

Life Cycle of Star (Physics only)

- Dust and gas cloud is present in a galaxy
- The gravitational attraction between the gas/dust particles draws them together
- The cloud becomes more concentrated, as the particles get closer
- The temperature and pressure of the cloud increases as the particles get pushed so close together
- Eventually the pressure gets so great that the gas/dust particles are able to fuse together
- Fusion occurs as the light (mainly hydrogen gas) nuclei fuse together to form helium nuclei
- This creates a large amount of energy
- This release opposes the collapsing of the cloud due to gravity
- So eventually an equilibrium forms, where the energy released due to fusion balances the pressure of gravitational collapse
- This means a star has now formed, and it will stay like this for billions of years
- Eventually the star runs out of gas to fuse
- This means it is not in equilibrium, so it collapses

Increasing the pressure of a gas (Physics only)
Doing work on a gas increases its temperature:

$$work\ done = pressure \times volume$$

Adding more particles to a fixed volume

- **Doing work on a gas means compressing or expanding the gas, so changing the volume**
- **Pumping more gas into the same volume means more particles are present, so more collisions occur per unit time with the walls, so pressure increases.**
- **Energy is transferred to the particles when more gas is added into the fixed volume, so this heats the gas**

A fixed number of particles for a smaller volume

- **The particles collide with the wall which is moving inward**
- **So, the particles gain momentum, as the rebound velocity is greater than the approaching velocity**
- **So as the particle has a greater velocity, the pressure increases as the particles collide with the walls more frequently (time between collisions decreases)**
- **And the temperature also increases, as the kinetic energy of each particle increases.**

Red Shift (Physics only)

- Light appears red shifted from galaxies which are moving away from Earth
- The change with distance of each galaxy's speed is evidence of an expanding universe

In the big bang the universe expands:

- The distance between the galaxies also expands
- So light from a galaxy has its wavelength "red-shifted" (increased) as it appears to move away from us
- As wavelength appears to get larger (more in the red-end of the visible spectrum)
- Frequency appears to decrease, as each time a wavelength is emitted, the source (galaxy) is further away

Evidence for the Big Bang (Physics only)

- Red Shift
  - This shows universe is expanding
  - So initially, it must have been formed from a single point
- CMBR - Cosmic Microwave Background radiation
  - When the universe was very young, everything, the first stars and rock, would be very hot, and should have emitted lots of short-wavelength radiation
  - This radiation, as the universe expanded over time, would have been stretched to become microwaves
  - This background radiation is present wherever you point a telescope in the sky
  - Which proves that the hot young universe has cooled and expanded since
- As the big bang accounts for all the experimental evidence, it is the most accepted model currently