CIE Physics IGCSE

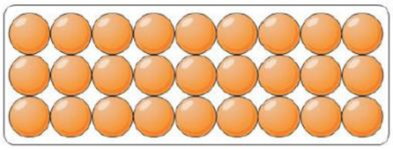
Topic 2: Thermal Physics

Summary Notes

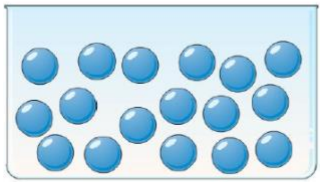
Simple kinetic molecular model of matter

Molecular model

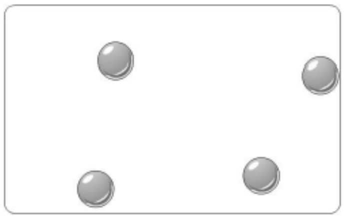
- Solids
    - Molecules close together in regular pattern
    - **Strong intermolecular forces of attraction**
    - Molecules vibrate but can't move about
    - Cannot flow, have fixed shape and cannot be compressed



- Liquids
    - Molecules close together in random arrangement
    - **Weaker intermolecular forces of attraction than solids**
    - Molecules move around each other
    - Flow, take the shape of their container and cannot be compressed



- Gases
    - Molecules far apart in random arrangement
    - **Negligible/very weak intermolecular forces**
    - Molecules move quickly in all directions
    - Flow, completely fill their container and can be compressed



Temperature, pressure and volume

Brownian motion:
- Gas molecules move rapidly and randomly
- This is due to collisions with other gas molecules
- **Massive particles may be moved by light, fast-moving molecules**

The temperature of a 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.

Gases exert pressure on a container due to collisions between gas molecules and the wall. **When the molecules rebound off the walls, they change direction so their velocity and therefore momentum changes. This means they exert a force because force is equal to the change in momentum over time.**

- At a constant volume, if the temperature increases, the pressure increases because the molecules move faster so they collide harder and more frequently with the walls.
- At a constant temperature, if the volume increases, the pressure decreases because the molecules collide less frequently with the walls.
    - **For a gas at fixed mass and temperature, $pV = constant$, where p is the pressure in Pascals and V is the volume in m^3.**

Evaporation

- Evaporation is the escape of molecules with higher energy from the surfaces of liquids.
- After they escape, the remaining molecules have a lower average kinetic energy which means the temperature is lower (i.e. evaporation cools the liquid).
- **To increase the rate of evaporation:**
    - **Increase temperature: more higher energy molecules**
    - **Increase surface area: more molecules at the surface**
    - **Draught: molecules are removed before returning to the liquid**

Evaporation cools a body in contact with an evaporating liquid (i.e. skin with sweat on it) because the liquid absorbs energy from the body so that it can continue to evaporate.

Thermal properties and temperature

Thermal expansion

When something is heated, it expands because the molecules take up more space:

- **When a solid is heated, the molecules vibrate more but stay in place, so the relative order of magnitude of the expansion is small.**
- **When a liquid is heated, it expands for the same reason as a solid, but the intermolecular forces are less so it expands more.**
- **When a gas is heated, the molecules move faster and further apart, so the relative order of magnitude of the expansion is the greatest.**

Some applications and consequences of thermal expansion include:

- Railway tracks having small gaps so that they don't buckle when they expand
- The liquid in a thermometer expands with temperature and rises up the glass

Thermal capacity

When the temperature of a body rises, its internal energy increases and its molecules vibrate more.

- **The specific heat capacity is the amount of energy required to raise the temperature of 1kg of a substance by 1℃.**
    - $change\ in\ thermal\ energy = mass \times specific\ heat\ capacity \times temperature\ change \quad \Delta E = mc\Delta T$ **where ΔE is the change in thermal energy in J, c is the specific heat capacity in Jkg^{-1}℃$^{-1}$, m is the mass in kg and ΔT is the change in temperature in ℃.**
- The thermal capacity of a body is how much energy needs to be put in to raise its temperature by a given amount.
    - **The thermal capacity of a system is given by:** $\boldsymbol{thermal\ capacity = mc}$

Melting and boiling

Melting and boiling occur when energy is put in to a body without a change in temperature.

- The melting point is the temperature at which a given solid will melt when heated.
- The boiling point is the temperature at which a given liquid will turn into a gas when heated.
- Condensation is when some molecules in a gas do not have enough energy to remain as separate molecules, so they come close together and form bonds, becoming liquid.

- Freezing is when the molecules in a liquid slow down enough that their attractions cause them to arrange themselves into fixed positions, becoming solid.

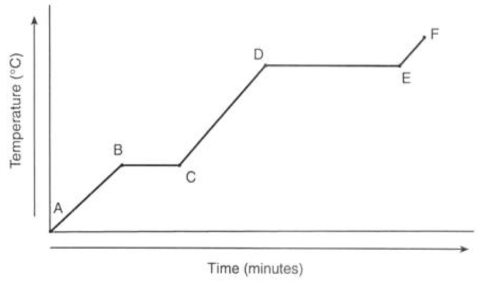
Evaporation is different to boiling because it can happen at any temperature and only occurs at the surface of the liquid.

- **The specific latent heat is the amount of energy needed to change the state of 1kg of a substance.**
    - **Specific latent heat of fusion is the energy to melt/freeze**
    - **Specific latent heat of vaporization is energy to boil/condense**
- $energy = mass \times specific\ latent\ heat$ $E = ml$ **where E is the energy needed in J, m is the mass in kg, and l is the specific latent heat in Jkg^{-1}.**

When a body changes state, energy goes towards making the molecules more free from each other rather than increasing their kinetic energy.

Graph showing the temperature of ice with time when energy is put in at a constant rate:

- From A to B the ice is rising in temperature
- From B to C it is melting into water
- From C to D the water is rising in temperature
- From D to E the water is boiling into steam
- From E to F the steam is rising in temperature



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Measuring Temperature

Thermocouple:

- **Contains two different metals which meet**
- **The temperature difference between them causes a tiny voltage which makes a current flow; the greater the temperature difference the greater the current.**
- **Used for high temperatures which vary rapidly**

Liquid-in-glass thermometer:

- As temperature rises or falls, the liquid expands or contracts.
- Amount of expansion can be matched to temperature on a scale.

Sensitivity, range and linearity:

- **Sensitivity is the change in length per change in temperature.**
    - **To increase the sensitivity of a thermometer, use a bigger bulb or a narrower bore.**
- **Range is the difference between maximum and minimum temperatures.**
    - **To increase the range of a thermometer, use a wider bore or a longer stem.**
- **Linearity is when a given change in temperature causes the same change in length.**

Fixed points are used to calibrate thermometers. For example, the fixed points of the celsius scale are the melting point and the boiling point of water.

Thermal processes

Conduction

- Thermal energy in solids and liquids can be transferred by conduction.
- **Non-metals are usually poor conductors known as insulators. As a non-metal is heated up, the molecules vibrate more and cause adjacent molecules to vibrate more also, transferring heat energy from hot parts to cooler parts.**
- **Metals are usually good conductors. The electrons can leave the atoms and move freely among positively charged ions. As the metal is heated, the ions and electrons vibrate more. The free electrons collide with ions throughout the metal and transfer heat energy from hot parts to cooler parts.**

Convection

- Thermal energy in fluids (liquids and gases) can be transferred by convection.
- Convection occurs when molecules in a fluid with high thermal energy move to an area with low thermal energy.
- When part of a fluid is heated, it expands and becomes less dense. It therefore rises up to less dense areas in the fluid. Denser, colder fluid falls down to take its place.
- Examples of convection include water boilers and hot air balloons.

Radiation

- Thermal energy is also transferred by infrared radiation which does not require a medium. Infrared radiation is part of the electromagnetic spectrum.
- Black bodies with a dull texture are the best absorbers and emitters of radiation. White bodies with a shiny texture are the best reflectors of radiation.
- **The higher the temperature and the greater the surface area of a body the more infrared radiation emitted.**