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THERMAL PHYSICS

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Simple kinetic molecular model of matter
States of matter

Solids

- cannot flow
- fixed volume, fixed shape
- density is higher than a gas

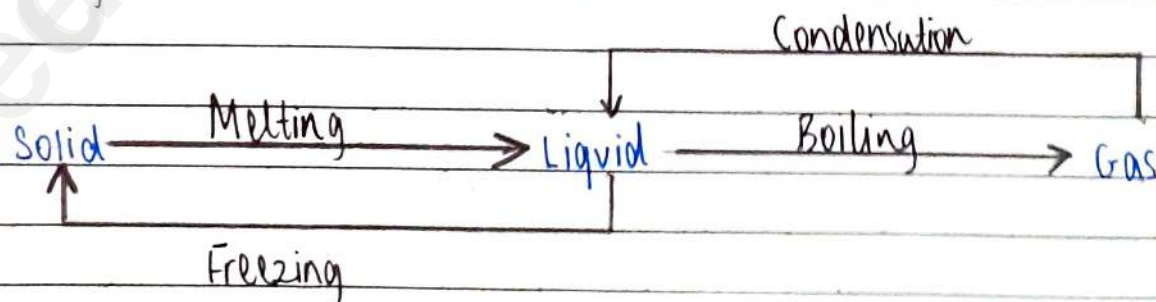
Liquids

- can flow
- fixed volume, takes shape of container
- density is higher than a gas

Gases

- can flow
- volume can be changed, fills container
- density is less

Change of state



- Solid to gas is sublimation
- Gas to solid is deposition

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Molecules and motion

- Molecules in a solid are in rigid structure and only vibrate.
- Molecules in a liquid move about in contact with each other.
- Molecules in a gas are far apart and move at a high speed.

Pressure and temperature in a gas

- Pressure of a gas on a surface is due to the molecules repeatedly hitting the surface.
- Increasing the temperature of a gas increases the average speed of its molecules.
- Impact with the surface creates a tiny force.
- Molecules move at different speeds, which can change after collision.

Brownian motion

- The random movement of particles in a fluid due to collisions with individual fluid molecules.
- Massive particles can be moved by light and fast-moving molecules.

Melting and boiling point

- Melting point is the temperature at which a solid changes state to a liquid. Melting point of water is 0°C .
- Boiling point is the temperature at which a liquid changes state to a gas. Boiling point of water is 100°C .

Condensation and solidification

- Condensation is the change of state at which a gas changes to a liquid at the boiling point.
- Solidification is the change of state at which a liquid changes to a solid at the melting point.

- A saturated vapour cannot hold more vapour.
- An unsaturated vapour can hold more vapour.
- In a saturated room, vapour condenses at the same rate as the liquid evaporates.

Evaporation

- Weak forces of attraction exist between the molecules of a liquid.
- Molecules with sufficient kinetic energy break away from the attraction of other molecules and escape from the liquid.
- The average kinetic energy of the remaining molecules in the liquid decreases so the liquid becomes cooler.
- An object in contact with an evaporating liquid is cooled.

Factors affecting evaporation

Evaporation of a liquid is increased by:

- increasing surface area
- increasing temperature
- creating a draught across the surface

Boiling

- occurs at a specific temperature
- occurs in the whole liquid
- fast process
- does not cause cooling

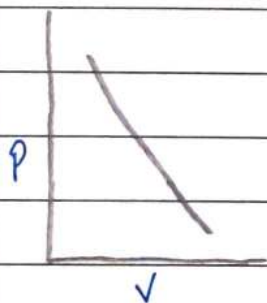
Evaporation

- occurs at a range of temperatures
- occurs at the surface of the liquid
- slow process
- causes cooling

Pressure changes

Boyle's Law

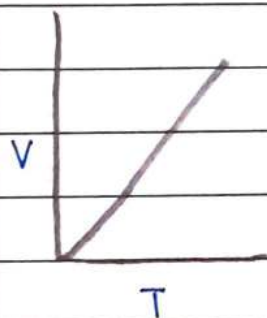
- For a given sample of gas having mass 'm', when temperature is controlled, its pressure is inversely proportional to its volume.



$$\text{pressure} = \frac{\text{constant}}{\text{volume}}$$

Charles's Law

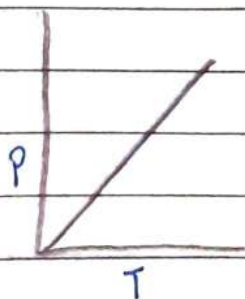
- For a given sample of gas having mass 'm', when pressure is controlled, its volume is directly proportional to its temperature.



$$\text{Volume} = \text{constant} \times \text{Temperature}$$

Pressure Law

- For a given sample of gas having mass 'm', when volume is controlled, its pressure is directly proportional to its temperature.



$$\text{Pressure} = \text{constant} \times \text{Temperature}$$

Matter and thermal properties

- Thermal expansion is the increase of length of a solid or increase of volume of a liquid or gas due to an increase in temperature.
- Expansion gaps are necessary in buildings, bridges and railway tracks.
- Steel tyres are fitted on train wheels by heating.
- Gases expand much more than liquids and solids.
- Volume of a solid increases by 0.01% for a 1°C increase.
- Gases expand 30 times more.

Heat

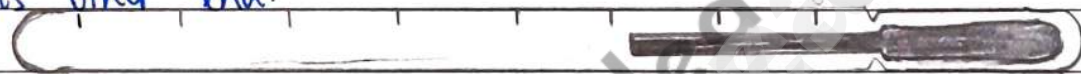
- an energy
- measured by a calorimeter
- unit is calories or joules

Temperature

- measure of hotness of an object
- amount of average kinetic energy of molecules
- measured by thermometer
- unit is °C, °F, °K

Measurement of temperature

- The fixed points of the Celsius scale are ice point (0°C) and steam point (100°C).
- Thermometers make use of a physical property that varies with temperature. This is the thermometric property. The thermometric property of a liquid-in-glass thermometer is the thermal expansion of the liquid.
- The liquid-in-glass thermometer consists of a thin glass bulb joined to a capillary tube with a narrow bore which is sealed at its other end.



When the bulb becomes warmer:

- the liquid in the bulb expands and is forced into the capillary tube.
- the liquid increases in length.
- The thinner the bulb wall, the faster the response.
- The liquid contains mercury or coloured alcohol. Alcohol has a lower freezing point than mercury.
- Thermocouple thermometer is an electrical thermometer that makes use of voltage between two different metals in contact with each other.
- Thermocouple thermometers are used to measure rapidly changing and high temperatures.
- One end of the wires are welded together creating a junction, and is put in melting ice. The other junction experiences a change in temperature, which is indicated by the voltmeter reading.

Range

- The lowest to the highest temperature a thermometer can measure.

Sensitivity

- Change of thermometric property for a 1°C rise of temperature.
- A thermometer with a thin capillary tube is more sensitive than one with the same liquid that has a wider capillary tube. Bigger bulbs are more sensitive, so more expansion.

Linearity

- The liquids expands equally for any difference in temperature.
- The bigger the difference, the poorer the linearity of scale.
- Scientific liquid-in-glass thermometers are graduated unevenly along the scale so they give readings exactly in $^{\circ}\text{C}$.

Thermal processes

Conduction

- a process of heat transfer where particles in contact transfer heat.
- takes place in solids.
- metals conduct better than non-metals.
- copper is a better conductor than steel.
- metals contain free electrons that break from atoms, leaving them as positive ions. They move and collide with positive ions.
- when a metal is heated at one end, the free electrons at the end gain kinetic energy and move faster.
- they diffuse and collide with the ions in the cooler part.

- Energy is transferred.

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- In a non-metallic solid, there are no free electrons. Energy transfer takes place because atoms vibrate.
- Materials such as wool and fibre glass are good insulators because they have trapped air, which is a good insulator.

Convection

- a process of heat transfer where particles displace themselves in order to transfer heat.
- takes place in fluids.
- heating makes the fluid less dense.
- during the day, the land becomes hot and the hot gas rises. It is replaced with cool air from the sea (above the sea).

Radiation

- a process of heat transfer where a medium is not required to travel through.
- infra-red radiation is electromagnetic radiation just beyond the red part of the visible spectrum. It can be detected by its heating effect. It is involved in energy transfer.
- Dull black surfaces emit infra-red radiation better than shiny white surfaces.
- Dull black surfaces absorb radiation.
- Shiny white surfaces reflect radiation.

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- To compare radiation from two substances measure how fast two beakers (one shiny and white, and one dull and black) warm cool water in them.
- Fill equal volume of water in each beaker. The beakers should have equal surface areas and equal initial temperatures.
- Place the beakers in a sunlit room.
- The hotter a body is, the more radiation it emits.
- The greater the surface area and temperature, the more radiation it emits.

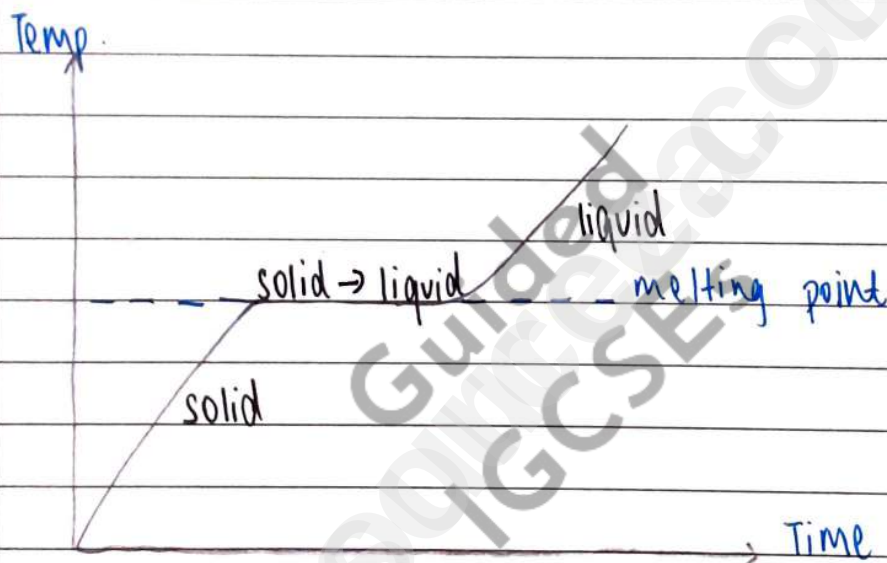
Consequences of energy transfer

- A vehicle radiator is designed to transfer heat energy from the engine to the surroundings.
- Water is heated through channels in the engine. The hot water flows through the radiator, and loses heat energy due to conduction through the metal part of the radiator.
- The radiator has a large surface area, and heat loss is increased through convection in the air and by radiation.
- A vacuum flask.
- A heat sink.
- To reduce heat transfer at home:
 - cavity walls
 - painting (white)
 - fitting white blinds and shutters
 - building thick walls

For any pure substance :

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change	initial	final	temperature
melting	solid	liquid	melting point
freezing	liquid	solid	melting point
boiling	liquid	gas	boiling point
condensing	gas	liquid	boiling point



Latent heat

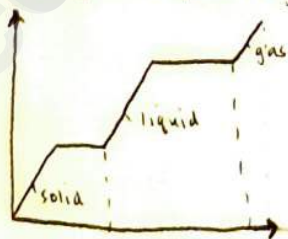
- heat required to change the state of a substance

Heat of fusion

- change from solid to liquid

Heat of vaporization

- change of liquid to gas

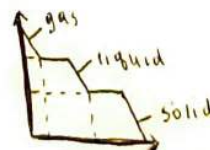


liquid → gas

- ↳ thermal energy is absorbed and used to overcome intermolecular forces

liquid → solid

- ↳ thermal energy is given out and the intermolecular forces are strengthened



[—] - flat lines represent changes of state and processes carried out

When heat of fusion is released, it is liquid to solid.

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