

Kinetic model of matter and thermal properties of matter

Typed version of the handwritten O Level Physics class notes. The original handwritten pages are on the same page of megalecture.com.

Kinetic model of matter

	Solids	Liquids	Gases
Inter-particle forces	very strong attraction	strong attraction	weak attraction
Inter-particle distances	close	far apart	very far apart
Shape	fixed shape	takes the shape of the container	entirely fills the container
Compression	not easily compressed	not easily compressed	easily compressed
Motion of particles	vibration about fixed points	random rotation and translation	random rotation and translation

Temperature and molecular motion

- At high temperature, molecules have higher kinetic energy.
- At high temperature, molecules have greater speed.
- At high temperature, molecules have become more vigorous.
- At high temperature, molecules collide more frequently, resulting in more pressure.

Pressure exerted by a gas

- According to the kinetic molecular theory, gas molecules are always in continuous and random motion.
- They collide with each other and with the walls of the container.
- Due to the collisions they exert a force per unit surface area of the container, and pressure is produced.

Evaporation

- The liquid molecules are always moving randomly at different speeds.
- When the molecules gain heat energy, their average kinetic energy increases.
- The molecules which are more energetic are able to overcome the forces of attraction in the liquid and escape from the surface of the liquid into the atmosphere.

Factors affecting evaporation:

1. Increase in temperature → more evaporation: molecules gain more kinetic energy.
2. Increase in surface area → more evaporation: more surface for the molecules to escape from.



3. Decrease of humidity → more evaporation (humidity reduces it: water vapours are already present).
4. Increase of wind speed → more evaporation: air carries away escaped molecules and reduces the chance of them coming back.
5. Decrease in atmospheric pressure → more evaporation: more molecules escape the surface.
6. Decrease in the boiling point → more evaporation.

The molecules that escape take a lot of energy with them, hence the average kinetic energy decreases, causing the temperature to decrease: a **cooling effect**.

Thermal properties of matter

- **Melting:** the process of change of state from solid to liquid. The change occurs at a fixed (constant) temperature, called the melting point.
- **Solidification:** the reverse process of melting, changing a liquid into a solid. A pure substance solidifies at a temperature equal to its melting point. During solidification, temperature remains constant and heat is released by the substance.
- **Boiling:** change of state from a liquid into a vapour. The change occurs at a fixed (constant) temperature, called the boiling point.
- **Condensation:** the process in which a vapour changes into a liquid at the same constant temperature; heat is given out by the substance.

(Margin sketches: pressure against volume is a falling curve, an inverse proportion; pressure against $1/\text{volume}$ is a straight line, a direct proportion.)

Boiling	Evaporation
Occurs at a fixed temperature	Occurs at any temperature
Quick process	Slow process
Takes place within the liquid	Takes place on the surface
Bubbles are formed in the liquid	No bubbles are formed
Temperature remains constant	Temperature may change
Heat is supplied by an energy source	Heat is absorbed from the surroundings

Heating curve

- When ice at $-10\text{ }^{\circ}\text{C}$ is heated, it first converts into water and then steam.
- The temperature changes occurring with time are recorded.
- A graph between temperature and time is then plotted, called the heating curve: a rise (solid), a flat step at the melting point (solid + liquid, latent heat), a rise (liquid, heat capacity), a flat step at the boiling point (liquid + gas), then a rise (gas).
- From $-10\text{ }^{\circ}\text{C}$ to $0\text{ }^{\circ}\text{C}$ the temperature of the ice increases. At $0\text{ }^{\circ}\text{C}$ it remains constant because ice is converting into water: the heat used during this stage becomes latent heat of fusion.

A larger temperature difference means a greater heat flow. Thermal equilibrium means no temperature

difference.

Cooling curve: the reverse: a fall (gas), a flat step at the boiling point (gas + liquid), a fall (liquid), a flat step at the freezing point (liquid + solid), then a fall (solid).

Thermal expansion

The increase in the volume of a substance on heating. When a substance is heated, its molecules gain heat energy and move apart from each other; the average gap between the molecules increases and the substance expands.

Order of expansion: the amount of expansion depends upon the strength of the intermolecular forces of a substance: the stronger the forces, the less the expansion, and vice versa. For the same quantity of heat supplied, expansion of gases > expansion of liquids > expansion of solids, roughly in the ratio solids : liquids : gases = 1 : 10 : 100.

Internal energy: the sum of the kinetic energy (dependent on temperature; heat capacity) and potential energy (dependent on state; latent heat) of a substance. Higher temperature means higher kinetic and potential energy, so higher internal energy. Side note: the potential energy is greatest for a gas, less for a liquid and least for a solid, inversely related to the intermolecular forces.

Effect of temperature changes on volume

- The volume increases with increase in temperature.
- In solids, the increase in volume is extremely small with a change in temperature, so the effect on the density of a solid is negligible.
- In liquids, the increase in volume is large enough with an increase in temperature, so there will be appreciable effects on the density of liquids: as temperature increases, volume increases and the density of liquids decreases.
- Since the increase in volume of a gas is much greater, the density of gases is greatly affected by a rise in temperature, e.g. the formation of sea and land breezes because of this effect.

Side notes: melting does not start until the melting point is reached, not even a drop; heat capacity and latent heat are not both in play at the same time.

Heat capacity (energy that changes temperature)

The heat energy required to raise the temperature of any mass of a substance through 1 K. (E.g. heating from -10°C , say to 0°C : the rise in temperature when heating.)

$Q = C\Delta\theta$, so $C = Q / \Delta\theta$, where Q is the heat energy supplied (J), C the heat capacity (J/K or J/ $^{\circ}\text{C}$) and $\Delta\theta$ the increase in temperature (K or $^{\circ}\text{C}$).

Insulators have a high heat capacity; conductors require less energy to show a change in temperature, which is exactly why mercury is more responsive.

Specific heat capacity

The heat energy required to raise the temperature of 1 kg of a substance through 1 K.

$Q = mc\Delta\theta$, so $c = Q / (m\Delta\theta)$, where Q is the heat energy supplied (J), m the mass of the substance (kg), c the specific heat capacity (J/(kg K) or J/(kg $^{\circ}\text{C}$)) and $\Delta\theta$ the increase in temperature (K or $^{\circ}\text{C}$).

Latent heat (energy that changes state)

The amount of heat energy required to change a substance from one state to the other at a constant temperature.

Specific latent heat of fusion: the amount of heat energy required to change 1 kg of solid into liquid, and vice versa, without a change in temperature. $Q = ml_f$, where Q is the quantity of heat energy (J), m the mass of substance (kg) that has changed state and l_f the specific latent heat of fusion (J/kg). Side note: at 0 °C the substance is changing state, so bonds are being broken, but the separation is only slight.

Specific latent heat of vaporisation: the amount of heat energy required to change 1 kg of liquid into vapour, and vice versa, without a change in temperature (greater than the heat of fusion: the separation has to be made very large, so the work done is greater). $Q = ml_v$, where Q is the quantity of heat energy (J), m the mass of substance (kg) that has changed state (the difference in mass at the start and at the end) and l_v the specific latent heat of vaporisation (J/kg).

Q. Give a molecular explanation for latent heat. There are strong forces of attraction between solid as well as liquid molecules; energy is required to overcome those forces. The amount of energy required for this purpose is called latent heat.

Applications of thermal energy

1. **Thermostats.** A bimetallic strip is made up of two different metals. On heating, the strip bends due to the different rates of expansion of the given metals; on cooling, the strip becomes straight again. It is used in thermostats to maintain a steady temperature. In a brass–iron strip the brass expands more, so on heating the strip curves with brass on the outside; on cooling the metal that expanded more also contracts more, so the strip curves the other way.
2. **Railway tracks** can be bent or damaged on a very hot day if there is no allowance for the expansion of the rails.
3. **Power lines.** The overhead power lines expand and sag in summer, and contract and tighten in winter.
4. **Pavements and roads.** Concrete blocks of pavements and road surfaces are laid with soft material between them, which can be squashed when the blocks expand in summer.
5. **Fixing a metal tyre.** On heating, the tyre expands and passes over the wheel; on cooling, the tyre contracts to give a tight fit on the wheel. (The tyre is too small when cold, too big when hot, and a tight fit when cold again.)

Rate of thermal expansion increases from solids to liquids to gases. Disadvantages of expansion: wear and tear, deformation. To avoid them: leave gaps to allow things to expand.

Checked by Mega Lecture

This typed version follows the handwritten notes. The Urdu side notes are given in English and marked "side note". The heating and cooling curves and the bimetallic-strip and tyre sketches are described in words. One clarification: the expansion ratio 1 : 10 : 100 is written as solids : liquids : gases, the order the notes describe. Spelling corrected. Spotted a mistake? Tell us on WhatsApp: +92 336 780 1123.