4.3 Particle model of matter

The particle model is widely used to predict the behaviour of solids, liquids and gases and this has many applications in everyday life. It helps us to explain a wide range of observations and engineers use these principles when designing vessels to withstand high pressures and temperatures, such as submarines and spacecraft. It also explains why it is difficult to make a good cup of tea high up a mountain!

4.3.1 Changes of state and the particle model

4.3.1.1 Density of materials

The density of a material is defined by the equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

(recall)

$$\left[\rho = \frac{m}{V} \right]$$

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

The particle model can be used to explain

• the different states of matter

• differences in density.

Students should be able to recognise/draw simple diagrams to model the difference between solids, liquids and gases.

Students should be able to explain the differences in density between the different states of matter in terms of the arrangement of atoms or molecules.

Required practical activity 5: use appropriate apparatus to make and record the measurements needed to determine the densities of regular and irregular solid objects and liquids. Volume should be determined from the dimensions of regularly shaped objects, and by a displacement technique for irregularly shaped objects. Dimensions to be measured using appropriate apparatus such as a ruler, micrometer or Vernier callipers.

4.3.1.2 Changes of state

Students should be able to describe how, when substances change state (melt, freeze, boil, evaporate, condense or sublimate), mass is conserved.

Changes of state are physical changes which differ from chemical changes because the material recovers its original properties if the change is reversed.

4.3.2 Internal energy and energy transfers

4.3.2.1 Internal energy

Energy is stored inside a system by the particles (atoms and molecules) that make up the system. This is called internal energy.

Internal energy is the total kinetic energy and potential energy of all the particles (atoms and molecules) that make up a system.

Heating changes the energy stored within the system by increasing the energy of the particles that make up the system. This either raises the temperature of the system or produces a change of state.

4.3.2.2 Temperature changes in a system and specific heat capacity

If the temperature of the system increases, the increase in temperature depends on the mass of the substance heated, the type of material and the energy input to the system.

The following equation applies:

change in thermal energy = mass × specific heat capacity × temperature change

$[\Delta E = m\,c\,\Delta\theta]$ *(Physics equation sheet)*

change in thermal energy, ΔE, in joules, J
mass, m, in kilograms, kg
specific heat capacity, c, in joules per kilogram per degree Celsius, J/kg °C
temperature change, $\Delta\theta$, in degrees Celsius, °C.

The specific heat capacity of a substance is the amount of energy required to raise the temperature of one kilogram of the substance by one degree Celsius.

4.3.2.3 Changes of heat and specific latent heat

If a change of state happens:

The energy needed for a substance to change state is called latent heat. When a change of state occurs, the energy supplied changes the energy stored (internal energy) but not the temperature.

The specific latent heat of a substance is the amount of energy required to change the state of one kilogram of the substance with no change in temperature.

energy for a change of state = mass × specific latent heat *(Physics equation sheet)*

$[E = m\,L]$

energy, E, in joules, J
mass, m, in kilograms, kg
specific latent heat, L, in joules per kilogram, J/kg

Specific latent heat of fusion – change of state from solid to liquid

Specific latent heat of vaporisation – change of state from liquid to vapour

Students should be able to interpret heating and cooling graphs that include changes of state.

Students should be able to distinguish between specific heat capacity and specific latent heat.

4.3.3 Particle model and pressure

4.3.3.1 Particle motion in gases

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.

Changing the temperature of a gas, held at constant volume, changes the pressure exerted by the gas.

Students should be able to:

• explain how the motion of the molecules in a gas is related to both its temperature and its pressure

• explain qualitatively the relation between the temperature of a gas and its pressure at constant volume.

4.3.3.2 Pressure in gases (physics only)

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 (or any surface).

Students should be able to use the particle model to explain how increasing the volume in which a gas is contained, at constant temperature, can lead to a decrease in pressure.

For a fixed mass of gas held at a constant temperature:

pressure × volume = constant (Physics equation sheet)

$[\ pV = constant\ ]$

pressure, p, in pascals, Pa
volume, V, in metres cubed, m^3

Students should be able to calculate the change in the pressure of a gas or the volume of a gas (a fixed mass held at constant temperature) when either the pressure or volume is increased or decreased.

4.3.3.3 Increasing the pressure of a gas (physics only) (HT only)

Work is the transfer of energy by a force.

Doing work on a gas increases the internal energy of the gas and can cause an increase in the temperature of the gas.

Students should be able to explain how, in a given situation eg a bicycle pump, doing work on an enclosed gas leads to an increase in the temperature of the gas.