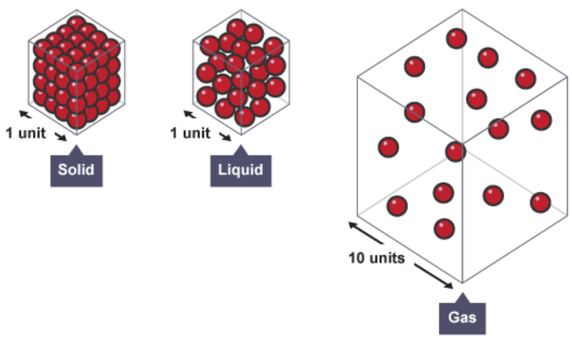
The Particle Model of Matter

Solids, liquids and gases

All **matter** contains particles. The difference between the different states of matter is how the particles are arranged:

- in a **solid** - particles are tightly packed in a regular structure
- in a **liquid** - particles are tightly packed but free to move past each other
- in a **gas** - particles are spread out and move randomly



There is little difference between the density of a liquid and its corresponding solid (e.g. water and ice). This is because the particles are tightly packed in both states. The same number of particles in a gas spread further apart than in the liquid or solid states. The same mass takes up a bigger volume - this means the gas is less dense.

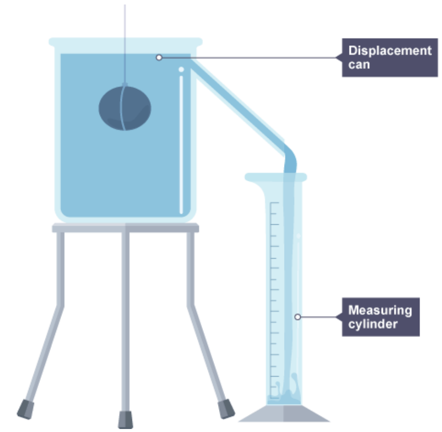
Density

Density describes how closely packed the particles are in a solid, liquid or gas. The density of a material is defined by the equation:

$$density = mass \div volume$$

- density (ρ) is measured in kilograms per metre cubed (kg/m^3)
- mass (m) is measured in kilograms (kg)
- volume (V) is measured in metres cubed (m^3)

Density Required Practical



Method 1: Regular solids

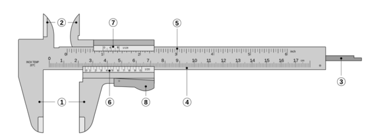
1. Use a ruler or **vernier callipers** to measure the length (l), width (w) and height (h) of a cube.
2. Place the cube on the top pan balance and measure its mass.
3. Calculate the volume of the cube using (l × w × h).
4. Use the measurements to calculate the density of the material using the formula $\rho = \frac{m}{V}$.

Method 2: Stone or other irregular shaped object

1. Place the stone on the top pan balance and measure its mass.
2. Fill the displacement can (**eureka can**) until the water is level with the bottom of the spout.
3. Place a measuring cylinder under the spout ready to collect the displaced water.
4. Carefully drop the stone into the can and wait until no more water runs into the cylinder.
5. Measure the volume of the displaced water.
6. Use the measurements to calculate the density of the stone using the formula $\rho = \frac{m}{V}$.

Method 3: Water (or any liquid)

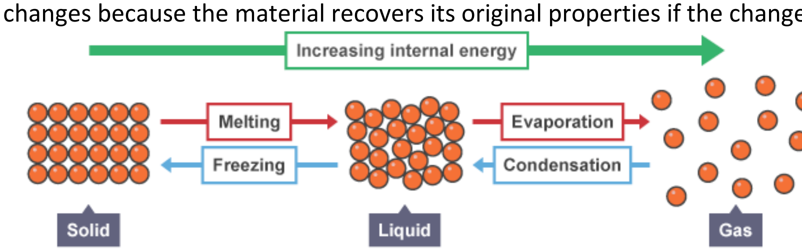
1. Place the measuring cylinder on the top pan balance and measure its mass.
2. Pour 50 cm^3 of water into the measuring cylinder and measure its new mass.
3. Subtract the mass in step 1 from the mass in step 2. This is the mass of 50 cm^3 of water.
4. Use the measurements to calculate the density of the water.



Vernier callipers are a measuring instrument used to find internal or external dimensions accurately, e.g. to the nearest 0.05 mm.

Changes of state

When substances change state 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.



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 that make up a system.

When a material is heated or cooled, two changes may happen to the particles within the material:

• **intermolecular forces** between the **particles** may strengthen or weaken. This changes the **potential energy** in the material. This happens during a **change of state.**

• the material **changes temperature** as the particles within it gain or lose **kinetic energy**. There is a change in the thermal store of energy within the material.

Whether the energy breaks bonds or just increases the speed of the particles depends on the temperature and **state** of the material.

Particle motion in gases

The molecules of a gas are in constant random motion. The higher the temperature, the more kinetic energy they have. If the volume is kept constant, by increasing the temperature the number of collisions with the sides of the container increase, therefore the pressure exerted by the gas increases.

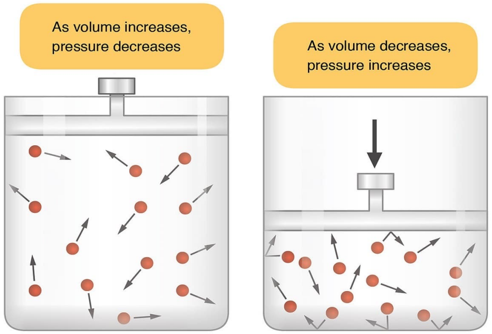
For a fixed mass of gas held at a constant temperature:

pressure × volume = constant

(p V = constant)

- Pressure, p, in pascals, Pa
- Volume, V, in metres cubed, m^3

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. e.g. a bicycle pump, doing work on an enclosed gas leads to an increase in the temperature of the gas.



Specific Heat Capacity

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.

Change in energy = mass x specific heat capacity x temperature change

$$\Delta E = m\,c\,\Delta\theta$$

- 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, Δθ, in degrees Celsius, °C.

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.

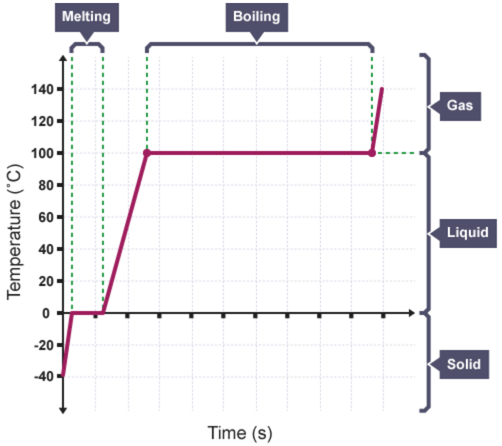
energy for a change of state = mass × specific latent heat

(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.

The graph is **horizontal** at two places. These are the places where the energy is not being used to increase the speed of the particles, increasing temperature, but is being used to weaken the forces between the particles to change the state.



The longer the horizontal line, the more energy has been used to cause the change of state. The amount of energy represented by these horizontal lines is equal to the latent heat.