

Matter & Density Notes

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The particle model: a scientific idea used to explain the properties of solids, liquids and gases.

Matter can exist in many different forms. There are four that we see in everyday life, these are solids, liquids, gases and plasma (fire). For the GCSE we only study three states these are **solids**, **liquids** and **gases**.

We need to understand the following about each of the three states of matter:

1. **How the particles are arranged in each state.**
2. **How the particles move in each state.**
3. **What the forces between the particles are like in each state.**
4. **What are the properties of each state.**

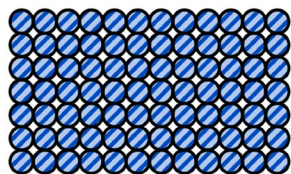
Solids

Particle arrangement: solids have a fixed volume, which means they cannot be compressed into a smaller space.

Particle movement: Particles vibrate about their fixed positions so they don't move freely.

Forces between particles: There are strong forces of attraction holding the particles in place.

Properties: Solids are incompressible which means they cannot be compressed into a smaller space. Solids typically have a high density. Solids have a definite shape which means that they will not flow.



The figure shows the arrangement of particles in a solid.

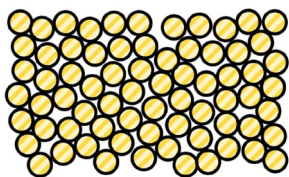
Liquids

Particle arrangement: liquids also have a fixed volume but are further apart than they are in solids.

Particle movement: particles are constantly moving **randomly**, sliding past one another. This movement allows liquids to flow.

Forces between particles: there are weak forces holding particles to each other.

Properties: liquids are incompressible. Liquids can flow and take the shape of any container they are placed into.



The diagram shows the arrangement of particles in a liquid.

Gases

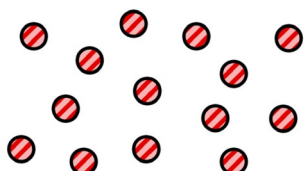
Particle arrangement: particles are far apart from each other.

Particle movement: particles move rapidly and randomly in all directions.

Forces between particles: there are forces between particles but they are very weak and easy to overcome.

Properties: gases are compressible, this means they can be compressed into a smaller volume.

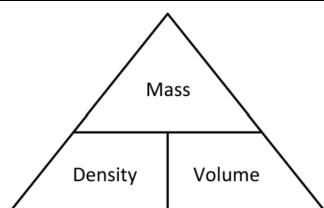
Gases don't have a definite shape meaning they will take the shape of their container.



The diagram shows the arrangement of particles in a gas.

Density

Density: the mass of a substance divided by the volume of the substance. The units of density depend on the units of mass and volume given in a question, they are usually either g/cm^3 or kg/m^3 .



Useful rearrangements:

$$\text{Density} = \text{mass} \div \text{volume}$$

$$\text{Mass} = \text{density} \times \text{volume}$$

$$\text{Volume} = \text{mass} \div \text{density}$$

A few example calculations involving density 😊

Example 1: A balloon contains some helium gas. The helium in the balloon has a mass of 0.00454 kg . The balloon has a volume of 0.0245 m^3 . Calculate the density of helium. Give your answer to 3 significant figures.

$$\text{Density} = \text{mass} \div \text{volume}$$

$$\text{Density} = 0.00454 \div 0.0245$$

$$\text{Density} = 0.185 \text{ kg/m}^3$$

Example 2: The mass of an orange was 120 g . The density of the orange was 0.88 g/cm^3 . Calculate the volume of the orange. Give your answer in cm^3 .

$$\text{Volume} = \text{mass} \div \text{density}$$

$$\text{Volume} = 120 \div 0.88$$

$$\text{Volume} = 136 \text{ cm}^3$$

Example 3: The reservoir stores $8\,600\,000 \text{ m}^3$ of water. The density of the water is 996 kg/m^3 . Calculate the mass of water in the reservoir. Give your answer in standard form.

$$\text{Mass} = \text{density} \times \text{volume}$$

$$\text{Mass} = 996 \times 8\,600\,000$$

$$\text{Mass} = 8\,565\,600\,000 \quad \text{Mass} = 8.57 \times 10^9 \text{ kg}$$

Heat Energy Changes

How does this sound? You take a bowl out of the cupboard, put some really hot food in it, then grab a fork ready to eat... you pick the bowl and notice it's way too hot and immediately put it back down! Familiar right?

The bowl was cool when you took it out and now, only a few moments later, the bowl is too hot to touch.

What happened? Well the heat moved from the hot food to the bowl. Heat can move? Yes indeed! 😊 When heat moves we call it heat transfer. Heat can move through substances and because there are different types of substances there are different types of heat transfer.

First of all, let's look at a few definitions that will be mentioned quite a bit 😊

Heat: the amount of energy being transferred. Heat always moves from hot to cold due to a difference in temperature. Because it is a form of energy, it is measured in Joules (J).

Internal energy: the total amount of energy trapped inside a substance. To find it, we add two things, the **kinetic energy** (how fast the particles are moving or vibrating) and the **potential energy** (the energy stored in the bonds holding the particles together).

Temperature: a measure of the average kinetic energy of each particle in a substance. Temperature is measured in degrees Celsius ($^{\circ}\text{C}$).

Internal Energy and Temperature

As we have seen above the internal energy is the total amount of energy inside a substance and to find it, we add together the kinetic energy and the potential energy. Whereas the temperature of a substance is the average of the kinetic energy of a substance. Let's see this in an example to understand this 😊

Example 1: a student has two cups each containing the **same amount** of tea. The figures below show the cups of tea.



Cup 1

Internal energy = 100 000 J

Temperature = 80 °C



Cup 2

Internal energy = 75 000 J

Temperature = 60 °C

The student pours both cups of tea into one larger cup.

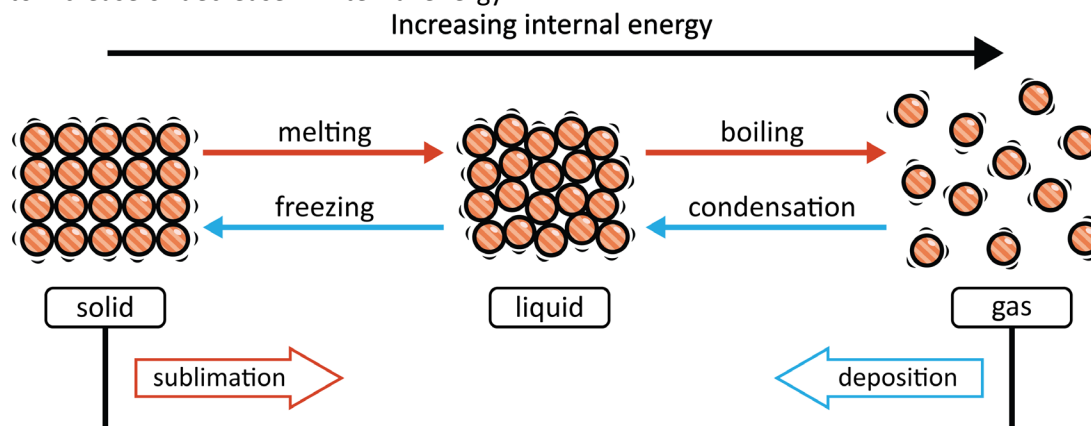
What is the internal energy and temperature of the bigger cup? (Assume no energy is lost to the surroundings)

$$\text{Internal energy} = 100\,000\text{ J} + 75\,000\text{ J} = 175\,000\text{ J}$$

$$\text{Temperature} = (80\text{ °C} + 60\text{ °C}) \div 2 = 70\text{ °C}$$

Changes of State

When a substance is heated or cooled, two changes may happen to the particles within the material, they can gain or lose kinetic energy and chemical bonds can be broken or made between particles. The figure below shows the changes of state due to increase or decrease in internal energy.



Heat must be supplied to a substance for it to melt, evaporate or boil. For example, you need to heat ice to melt it, and you need to heat water to make steam. Heat must be removed from a substance to condense or freeze it. In other words, the substance must be cooled down.

Under certain conditions, some solids turn straight into a gas when heated. This process is called **sublimation**.

Sublimation: the direct change of a solid into a gas or vice versa. **Deposition:** is the direct change of a gas to a solid.

A good example of sublimation is solid carbon dioxide, also called 'dry ice'. At atmospheric pressure, it turns straight into gaseous carbon dioxide. Liquid carbon dioxide can exist under high pressure, such as in fire extinguishers.

When a substance changes state this is a physical change, not a chemical change.

What does this mean? The particles themselves don't change, they are just arranged differently and mass is conserved.