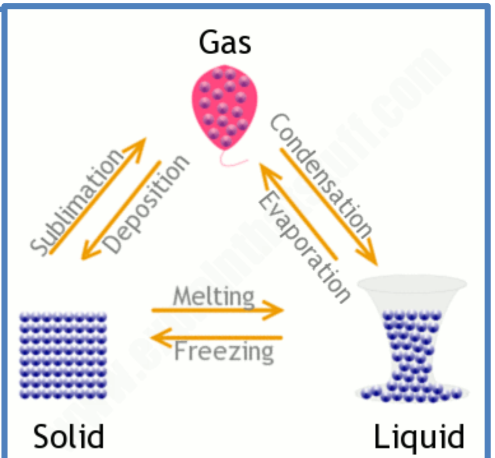
Physics Knowledge Organiser
Topic 8: The Particle Model of Matter

States of matter and changes of state

Study the diagram. The particle model is used to explain differences between solids, liquids and gases, and to explain how changes from one state to another happen. Make sure you know how to draw the particles in each state, and know all the names for each state change shown on the diagram.

In a solid, the particles are **fixed in position** and only vibrate – they can't flow around. In a liquid, the particles are still **very close together** but they can **flow** past each other. In a gas, the particles move **randomly** and there is **empty space** between them.

In changes of state, no new substance is produced and there is no change in the mass of the substance. This is because no particles are created or destroyed.

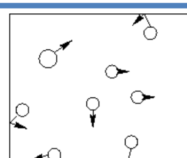


Density and the particle model

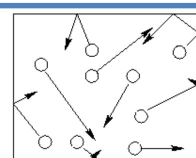
The particle model explains why 1 kg of a gas will have a **much** larger volume than 1 kg of a solid. This is because there is <u>empty space</u> between the particles in a gas, whereas in a solid, they are tightly packed together. Looking at the equation below, you should see that in this example the m is the same (1 kg), but the volume for the gas is much larger. Since we <u>divide</u> by volume, this must mean that the **density** of the gas is much smaller than the density of the solid.

Pressure in gases

Particles in a gas are constantly moving – so they have **kinetic energy**. They <u>collide</u> with the walls of their container, and exert a force when they do. The total force exerted on a certain area of the wall is the **gas pressure**.



Cooler gas – less kinetic energy



Hotter gas – more kinetic energy

The amount of kinetic energy that the particles have is related to the temperature of the gas. The higher the temperature, the more kinetic energy they have. This means they move faster, on average. Therefore, there are more collisions with the container walls and they exert a greater force when they collide with the walls. Thus, **increasing** the <u>temperature</u> of a gas (keeping the volume the same) **increases** the <u>pressure</u> of the gas.

Key Terms	Definitions
Model	Models are used all the time in science. A model represents the real world and can explain many things about the universe. However, models are never perfect and there are limits to what they can explain. That doesn't stop them being extremely useful though!
Particle model	The model that represents molecules or atoms as small, hard spheres. The important things to think about when using the particle model are the **arrangement** of the particles in each state of matter and the **kinetic energy** of the particles.
State of matter	The physical arrangement of particles determines the state of a particular substance: solid, liquid or gas. Changing from one state of matter to another is a physical process, NOT a chemical process. No new substance is produced, and if you reverse the state change, you have a substance with exactly the same properties as the stuff you started with.
Density	The quantity that defines how much material (i.e. mass) is in a certain volume. See equation. If you have two objects the same size but different densities, the more dense object will feel heavier in your hand as there is more mass in the same volume.
Melt/freeze	The change of state from solid to liquid/liquid to solid.
Evaporate/ condense	Change of state from liquid to gas/ gas to liquid.
Boil	Like evaporation, boiling is a change of state from liquid to gas. However, boiling involves heating of the liquid so it boils, rather than particles on the surface of the liquid becoming gas (like in evaporation).
Pressure	Pressure is caused by the force exerted by particles in a gas when they hit the walls of a container.

Equation	Meanings of terms in equation
$\rho = \frac{m}{V}$ *	*ρ = density (kilograms per metres cubed, kg/m^3)* *m = mass (kg)* *V = volume (metres cubed, m^3)*

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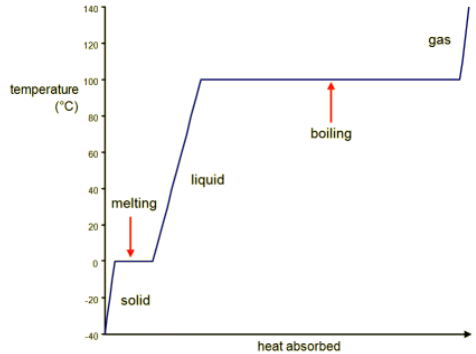
Internal energy and the particle model

Any substance, whether solid, liquid or gas, **stores energy**. The particles (atoms and molecules) have kinetic energy (since they can move/vibrate) and potential energy. The total of the kinetic energy and the potential energy of the particles is called the **internal energy**.



When you heat something up, you increase the energy of the particles in the substance (or 'system'). When heating one state, you simply increase the temperature of the substance by increasing the kinetic energy of the particles. However, when a state change is occurring, the temperature does not increase. This is because the particles are increasing in potential energy (which doesn't affect the temperature). That's why the graph above goes horizontal when the changes of state are taking place.

Specific heat capacity

Some substances are harder to warm up than others, and cool down less easily. The measurement of this is called **specific heat capacity**. Learn the definition opposite.
So, when heating something, the temperature rise that will actually happen depends on the specific heat capacity (which is different with different substances) of the substance being heated, the mass of the substance and the amount of energy put in. These four quantities are linked in the equation to the right.

Changes of state and specific latent heat

As noted above, during heating to cause changes of state the potential energy of particles increases but the kinetic energy does not. So the temperature stays the same. The **energy needed for a substance to change state is called the latent heat**. The specific latent heat is specific to a substance, and is the energy required to change its state (using 1 kg of the substance), with no change in temperature. The energy needed for a state change depends on mass and specific latent heat of a substance – as the second equation shows.

But which change of state? We use the symbol *L* for any change of state, but call it the **specific latent heat of fusion** for changes from solid to liquid. We call it the **specific latent heat of vaporisation** for changes from liquid to gas (vapour).

Key Terms	Definitions
Internal energy	The energy stored by the particles in a system (solid, liquid or gas). Internal energy is the sum of the potential energy of particles and the kinetic energy of the particles.
Kinetic energy	The energy associated with movement. The kinetic energy of particles in any state of matter is related to the temperature of the matter.
Temperature	A measure of the average kinetic energy of particles in a substance. As temperature increases, the average kinetic energy increases. Note: temperature does not measure the potential energy of particles, just their kinetic energy.
Heating	Heating is one way to transfer energy from one store to another. On this page, we talk about how heating substances increases the internal energy of that substance (both the kinetic and potential energy of particles).
Specific heat capacity	The amount of energy required to raise the temperature of 1 kg of a substance by one degree Celsius.
Latent heat	Latent heat is linked to the potential energy of particles in a system – it is the energy needed for a substance to change state. It cannot be measured with a thermometer, since it is not linked to the kinetic energy of particles.
Specific latent heat	When a substance is changing state, you can keep heating it but the temperature stays the same. The energy isn't disappearing (that's impossible!), but is adding to the internal energy. Specific latent heat measures this: it is **the amount of energy required to change the state of 1 kg of a substance** (without changing the temperature at all).

Equation	Meanings of terms in equation
$\Delta E = m\,c\,\Delta\theta$	*ΔE = change in thermal energy (joules, J)* *m = mass (kg)* *c = specific heat capacity (joules per kilogram per degree Celsius, J/kg °C)* *Δθ = temperature change (°C)*
$E = m\,L$	*E = energy (joules, J)* *m = mass (kg)* *L = specific latent heat (J/kg)*