

AQA Physics (Combined Science) Unit 6.1: Energy

Required Practical

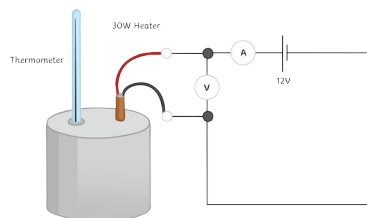
Investigating Specific Heat Capacity

independent variable – material

dependent variable – specific heat capacity

control variables – insulating layer, initial temperature, time taken

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



Method:

- Using the balance, measure and record the mass of the copper block in kg.
- Wrap the insulation around the block.
- Put the heater into the large hole in the block and the block onto the heatproof mat.
- Connect the power pack and ammeter in series and the voltmeter across the power pack.
- Using the pipette, put a drop of water into the small hole.
- Put the thermometer into the small hole and measure the temperature.
- Switch the power pack to 12V and turn it on.
- Read and record the voltmeter and ammeter readings – during the experiment, they shouldn't change.
- Turn on the stop clock and record the temperature every minute for 10 minutes.
- Record the results in the table.
- Calculate work done and plot a line graph of work done against temperature.

Equations

$$E = \frac{1}{2}mv^2$$

$$E_p = mgh$$

$$E_e = \frac{1}{2}ke^2$$

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

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

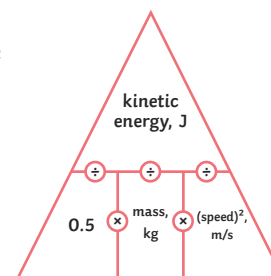
Kinetic and Potential Energy Stores

Movement Energy

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times \text{speed}^2$$

$$E_k = \frac{1}{2}mv^2$$

(J) (kg)(m/s)

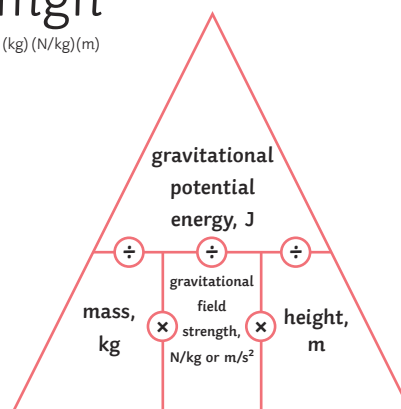


When something is off the ground, it has gravitational potential energy

gravitational potential energy = mass × gravitational field strength × height

$$E_p = mgh$$

(J) (kg) (N/kg)(m)



When an object falls, it loses gravitational potential energy and gains kinetic energy.

Stretching an object will give it elastic potential energy.

elastic potential energy = $\frac{1}{2} \times \text{spring constant} \times \text{extension}^2$

$$E_e = \frac{1}{2}ke^2$$

(J) (N)(m)

Transferring Energy by Heating

Heating a material transfers the energy to its thermal energy store - the temperature increases.

E.g. a kettle: energy is transferred to the thermal energy store of the kettle. Energy is then transferred by heating to the water's thermal energy store. The temperature of the water will then increase.

Some materials need more energy to increase their temperature than others.

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

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

(J) (kg) (J/kg °C) (°C)

Specific heat capacity is the amount of energy needed to raise the temperature of 1kg of a material by 1°C.



Energy Stores and Systems

Energy Stores	
kinetic	Moving objects have kinetic energy.
thermal	All objects have thermal energy.
chemical	Anything that can release energy during a chemical reaction.
elastic potential	Things that are stretched.
gravitational potential	Anything that is raised.
electrostatic	Charges that attract or repel.
magnetic	Magnets that attract or repel.
nuclear	The nucleus of an atom releases energy.

Energy can be transferred in the following ways:

mechanically – when work is done;

electrically – when moving charge does work;

heating – when energy is transferred from a hotter object to a colder object.

Conservation of Energy

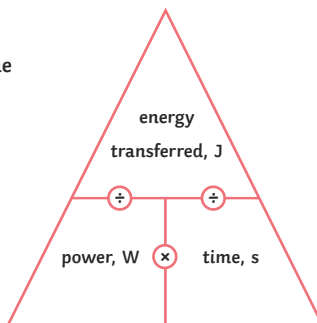
Energy can never be created or destroyed, just transferred from one form to another. Some energy is transferred usefully and some energy gets transferred into the environment. This is mostly wasted energy.

Power

Power is the rate of transfer of energy – the amount of work done in a given time.

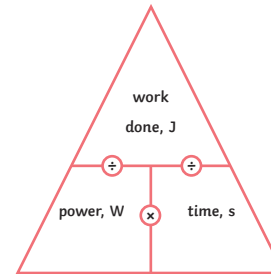
$$\text{power} = \text{energy transferred} \div \text{time}$$

$$P (W) = E (J) \div t (s)$$



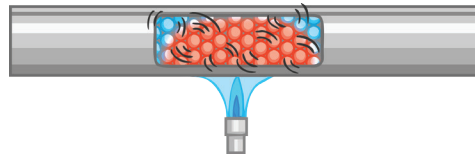
$$\text{power} = \text{work done} \div \text{time}$$

$$P (W) = W (J) \div t (s)$$



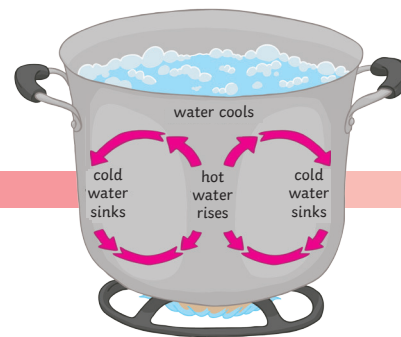
Energy Transfer

Lubrication reduces the amount of friction. When an object moves, there are frictional forces acting. Some energy is lost into the environment. Lubricants, such as oil, can be used to reduce the friction between the surfaces.



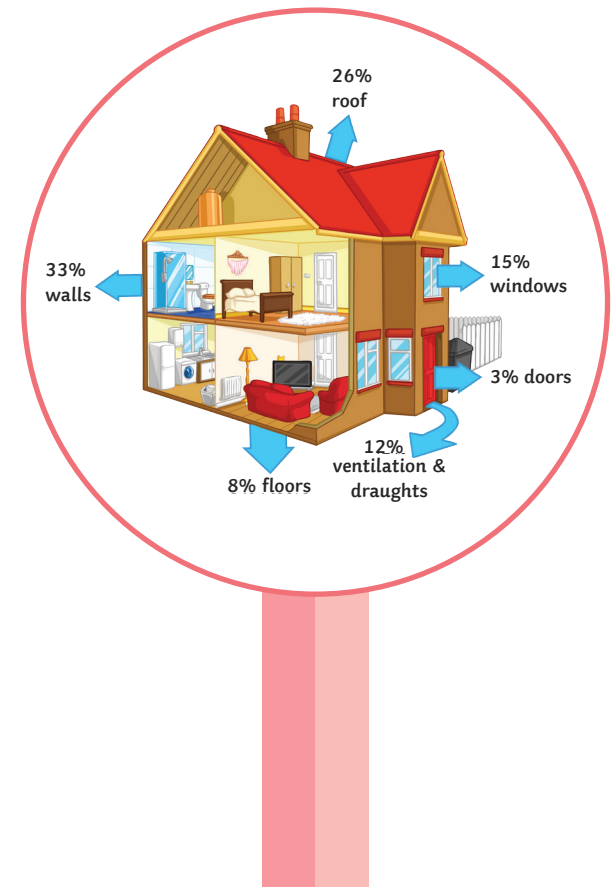
Conduction – when a solid is heated, the particles vibrate and collide more, and the energy is transferred.

Convection – when a liquid or a gas is heated, the particles move faster. This means the liquid or gas becomes less dense. The denser region will rise above the cooler region. This is a convection current.



Insulation – reduces the amount of heat lost. In your home, you can prevent heat loss in a number of ways:

- thick walls;
- thermal insulation, such as:
- loft insulation (reducing convection);
- cavity walls (reduces conduction and convection);
- double glazing (reduces conduction).

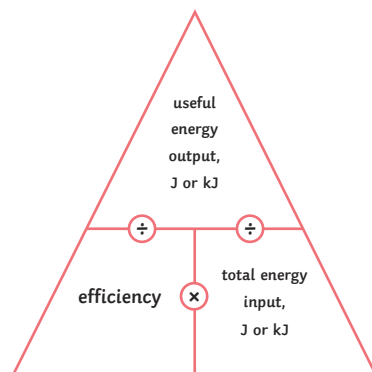


Efficiency

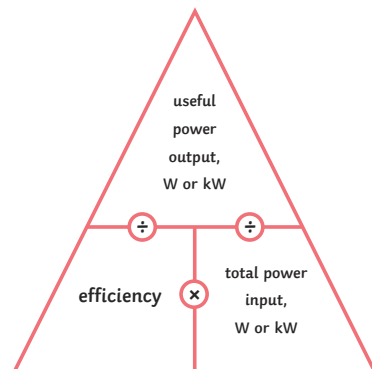
When energy is transferred, some energy is wasted. The less energy that is wasted during the transfer, the more efficient the transfer.

There are two equations to calculate efficiency:

$$\text{efficiency} = \frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$$



$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$



Some energy is always wasted. Nothing is 100% efficient.

Efficiency

Non-renewable – coal, oil, gas - they will all run out, they damage the environment, but provide most of the energy.

Renewable – they will never run out, can be unreliable and do not provide as much energy.

Energy Resource	Advantages	Disadvantages
solar – using sunlight	Renewable, no pollution, in sunny countries it is very reliable.	Lots of energy needed to build, only works during the day, cannot increase power if needed.
geothermal – using the energy of hot rocks	Renewable and reliable as the rocks are always hot. Power stations have a small impact on environment.	May release some greenhouse gases and only found in specific places.
wind – using turbines	Renewable, no pollution, no lasting damage to the environment, minimal running cost.	Not as reliable, do not work when there is no wind, cannot increase supply if needed.
hydroelectric – uses a dam	Renewable, no pollution, can increase supply if needed.	A big impact on the environment. Animals and plants may lose their habitats.
wave power – wave powered turbines	Renewable, no pollution.	Disturbs the seabed and habitats of animals. Unreliable.
tidal barrages – big dams across rivers	Renewable, very reliable, no pollution.	Changes the habitats of wildlife, fish can be killed in the turbines.
biofuels	Renewable, reliable, carbon neutral.	High costs, growing biofuels may cause a problem with regards to space, clearance of natural forests.
non-renewable – fossil fuels	Reliable, enough to meet current demand, can produce more energy when there is more demand.	Running out, release CO ₂ , leading to global warming, and also release SO ₂ which causes acid rain.

Trends in energy resources – most of our electricity is generated by burning fossil fuels and nuclear. The UK is trying to increase the amount of renewable energy resources. The governments are aware that non-renewable energy resources are running out; targets of renewable resources have been set. Electric and hybrid cars are also now on the market.

However, changing the fuels we use and building renewable power plants cost money. Many people are against the building of the plants near them and do not want to pay the extra in their energy bills. Hybrid and electric cars are also quite expensive.



Electricity – Separate Science

Required Practical

Investigating Resistance in a Wire

Independent variable: length of the wire.

Dependent variable: resistance.

Control variables: type of metal, diameter of the wire.

Conclusion: As the length of the wire increases, the resistance of the wire also increases.

Investigating Series and Parallel Circuits with Resistors

Independent variable: circuit type (series, parallel).

Dependent variable: resistance.

Control variables: number of resistors, type of power source.

Conclusion: Adding resistors in series increases the total resistance of the circuit. In a parallel circuit, the more resistors you add, the smaller the resistance.

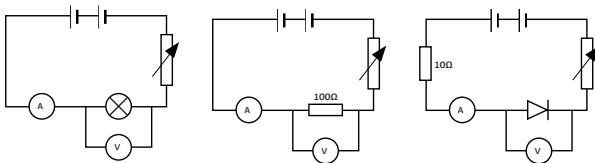
Investigating I-V Relationships in Circuits (Using a filament bulb, ohmic conductor, diode.)

Independent variable: potential difference/volts (V).

Dependent variable: current (A).

Control variable: number of components (e.g. 1 filament bulb, 1 resistor), type of power source.

Set up the circuits as shown below and measure the current and the potential difference.



Draw graphs of the results once collected.

Equations and Maths

Equations

Charge: $Q = It$

Potential difference: $V = IR$

Energy transferred: $E = Pt$

Energy transferred: $E = QV$

Power: $P = VI$

Power: $P = I^2R$

Maths

$1\text{ kW} = 1000\text{ W}$

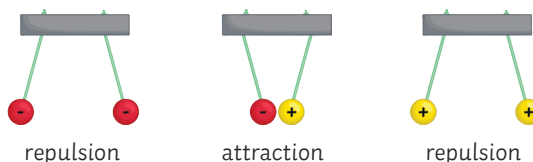
$0.5\text{ kW} = 500\text{ W}$

$50\,000\text{ W} = 50\text{ kW}$

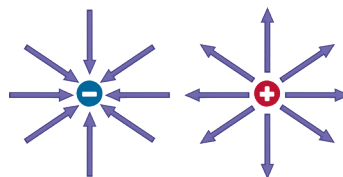
Static

A build-up of static is caused by friction. When materials are rubbed together, the electrons move from one to the other. One material becomes positively charged and the other is negatively charged. The positive charges do not move.

Too much static can cause a spark. If the potential difference is large enough, the electrons can jump across the gap - this is the spark.



Electric charges create an **electric field**. The closer you get to the object, the **stronger** the field. The electric field can be shown by drawing field lines, they go from **positive to negative**.

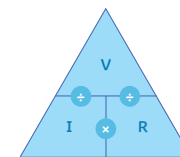


If a charged object is placed near the field, it will experience a force. The force becomes stronger as the charged object gets closer.

Resistance

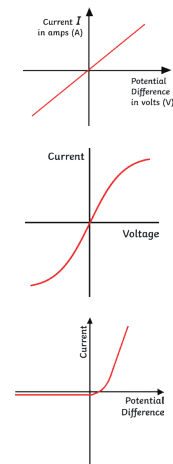
voltage (V) = current (A) × resistance (Ω)

$$V = IR$$



Graphs of I-V Characteristics for Components in a Circuit

- Ohmic conductor:** the current is directly proportional to the potential difference - it is a straight line (at a constant temperature).
- Filament lamp:** as the current increases, so does the temperature. This makes it harder for the current to flow. The graph becomes less steep.
- Diode:** current only flows in one direction. The resistance is very high in the other direction which means no current can flow.



Current and Circuit Symbols

Current: the flow of electrical charge.

Potential difference (voltage): the push of electrical charge.

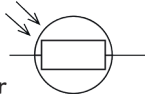
Resistance: slows down the flow of electricity.

cell		closed switch		fuse	
resistor		ammeter		LDR	
battery		voltmeter		LED	
variable resistor		bulb		thermistor	
open switch		diode			

Electricity – Separate Science

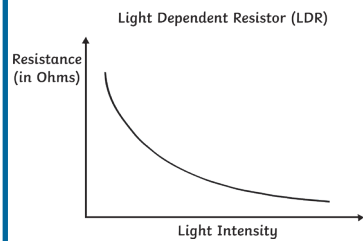
Circuit Devices

LDR – Light Dependent Resistor

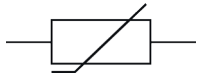


An LDR is dependent on light intensity. In bright light the resistance falls and at night the resistance is higher.

Uses of LDRs: outdoor night lights, burglar detectors.

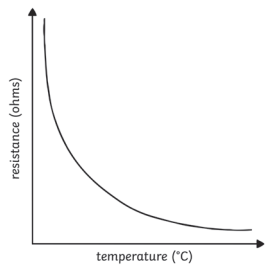


Thermistor



A thermistor is a temperature dependent resistor. If it is hot, then the resistance is less. If it becomes cold, then the resistance increases.

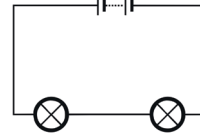
Uses of thermistors: temperature detectors.



Series and Parallel Circuits

Series Circuits

Once one of the components is broken then all the components will stop working.



$$V_{\text{total}} = V_1 + V_2$$

$$I_1 = I_2 = I_3$$

Potential difference – the total p.d. of the supply is shared between all the components.

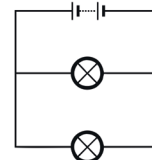
Current – wherever the ammeter is placed in a series circuit the reading is the same.

Resistance – In a series circuit, the resistance will add up to make the total resistance.

$$R_{\text{total}} = R_1 + R_2$$

Parallel Circuits

They are much more common - if one component stops working, it will not affect the others. This means they are more useful.



Potential Difference – this is the same for all components. $V_1 = V_2$

Current – the total current is the total of all the currents through all the components. $I_{\text{total}} = I_1 + I_2 + I_3$

Resistance – adding resistance reduces the total resistance.

Charge

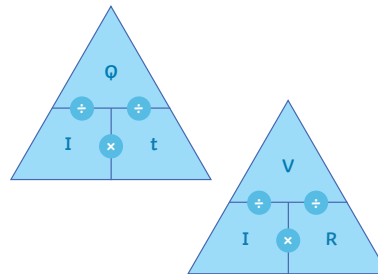
Electric current is the flow of electric charge. It only flows when the circuit is complete.

The **charge** is the current flowing past a point in a given time. Charge is measured in **coulombs (C)**.

Calculating Charge

charge flow (C) =
current (A) × time (s)
 $Q = It$

potential difference =
current × resistance
 $V (V) = I (A) \times R (\Omega)$

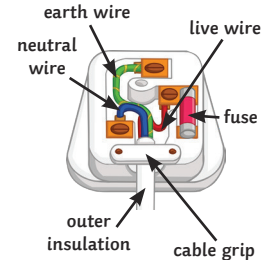


Electricity in the Home

AC – alternating current. Constantly changing direction - UK mains supply is 230V and has a frequency of 50 hertz (Hz).

DC – direct current. Supplied by batteries and only flows in one direction.

Cables – most have three wires: live, neutral and earth. They are covered in plastic insulation for safety.



Live wire – provides the potential difference from the mains.

Neutral wire – completes the circuit.

Earth wire – protection. Stops the appliance from becoming live. Carries a current if there is a fault.

Touching the live wire can cause the current to flow through your body. This causes an electric shock.

Energy Transferred – this depends on how long the appliance is on for and its power.

$$\text{energy transferred (J)} = \text{power (W)} \times \text{time (s)} \quad E = Pt$$

Energy is transferred around a circuit when the charge moves.

$$\text{energy transferred (J)} = \text{charge flow (C)} \times \text{potential difference (V)} \quad E = QV$$

$$\text{power (W)} = \text{potential difference (V)} \times \text{current (A)} \quad P = VI$$

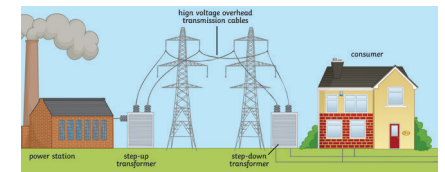
$$\text{power (W)} = \text{current}^2 (\text{A}) \times \text{resistance } (\Omega) \quad P = I^2R$$

The National Grid

The National Grid is a system of **cables** and **transformers**. They transfer electrical power from the power station to where it is needed. Power stations are able to change the amount of electricity that is produced to meet the demands. For example, more energy may be needed in the evenings when people come home from work or school. Electricity is transferred at a low current, but a high voltage so less energy is being lost as it travels through the cables.

Step-up transformers – increase the voltage as the electricity flows through the cables.

Step-down transformers – decrease the potential difference to make it safe.



AQA Physics (Separate Science) Unit 3: Particle Model of Matter

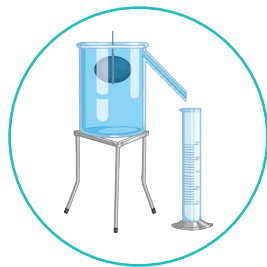
Required Practical

Measuring the density of a regularly shaped object:

- Measure the mass using a balance.
- Measure the length, width and height using a ruler.
- Calculate the volume.
- Use the density ($\rho = m/V$) equation to calculate density.

Measuring the density of an irregularly-shaped object:

- Measure the mass using a balance.
- Fill a eureka can with water.
- Place the object in the water - the water displaced by the object will transfer into a measuring cylinder.
- Measure the volume of the water. This equals the volume of the object.
- Use the density ($\rho = m/V$) equation to calculate density.



Density

Density is a measure of how much mass there is in a given space.

$$\text{Density (kg/m}^3\text{)} = \text{mass (kg)} \div \text{volume (m}^3\text{)}$$

A more dense material will have more particles in the same volume when compared to a less dense material.

Example

The density of an object is 8050 kg/m^3 and it has a volume of 3.4 m^3 . What is its mass in kg?

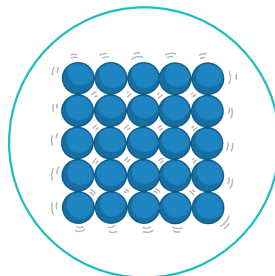
$$8050 = \text{mass} \div 3.4$$

$$8050 \times 3.4 = \text{mass}$$

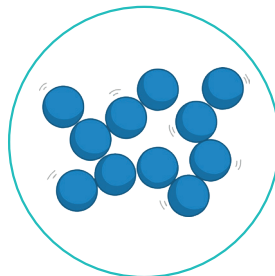
$$27\,370 \text{ kg}$$

States of Matter

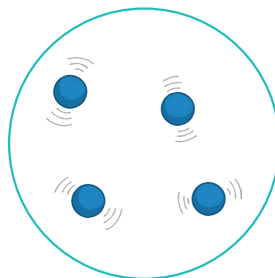
Solids have strong forces of attraction between the particles. The particles are held together very closely in a fixed, regular arrangement. The particles do not have much energy and can only vibrate.



Liquids have weaker forces of attraction between the particles. The particles are close together, but can move past each other. They form irregular arrangements. They have more energy than particles in a solid.

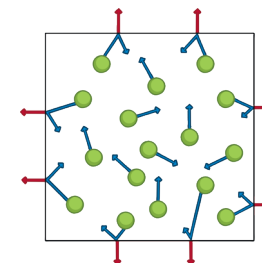


Gases have almost no forces of attraction between the particles. The particles have the most energy and are free to move in random directions.

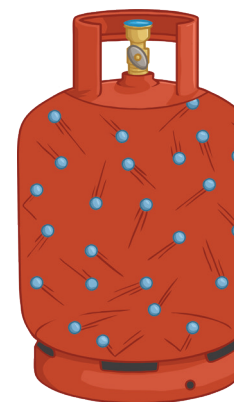


Motion in Gas Particles

Gas particles move about randomly, at high speed. They intercept other gas particles and anything else that is in the way. When this occurs, a pressure is exerted. If the gas is within a sealed container, pressure occurs when the gas particles hit the walls of the container. They produce a force at right angles to the wall of the container.

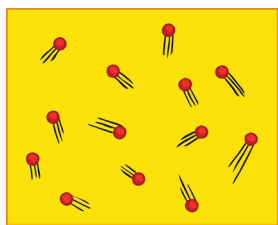


If the temperature of the gas increases, then the pressure will also increase. The hotter the temperature, the more kinetic energy the gas particles have. They move faster, colliding with the sides of the container more often.

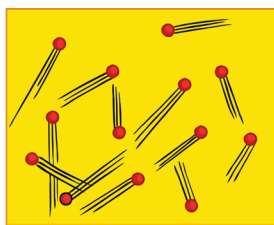


Internal Energy

Particles within a system have kinetic energy when they vibrate or move around. The particles also have a potential energy store. The total internal energy of a system is the kinetic and potential energy stores.



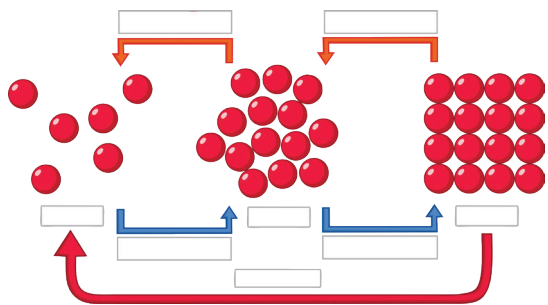
Low Temperature



High Temperature

If the system is heated, the particles will gain more kinetic energy, so increasing the internal energy.

Changing State

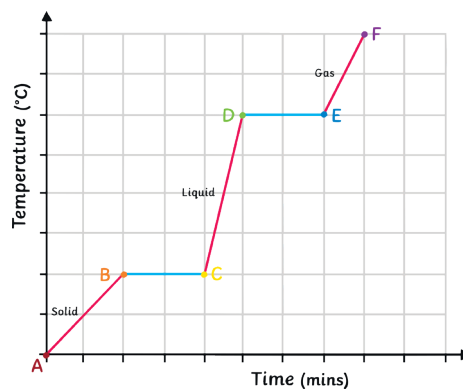


If a system gains more energy, it can lead to a change in temperature or change in state. If the system is heated enough, then there will be enough energy to break bonds.

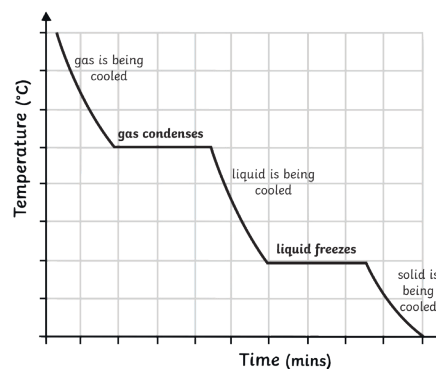
When something changes state, there is no chemical change, only physical. No new substance is formed. The substance will change back to its original form. The number of particles does not change and mass is conserved.

Specific Latent Heat

Energy is being put in during melting and boiling. This increases the amount of internal energy. The energy is being used to break the bonds, so the temperature does not increase. This is shown by the parts of the graph that are flat.



When a substance is condensing or freezing, the energy put in is used to form the bonds. This releases energy. The internal energy decreases, but the temperature does not go down.



The energy needed to change the state of a substance is called the latent heat.

Specific latent heat is the amount of energy needed to change 1kg of a substance from one state to another without changing the temperature. Specific latent heat will be different for different materials.

- solid $\rightarrow$ liquid - specific latent heat of **fusion**
- liquid $\rightarrow$ gas - specific latent heat of **vaporisation**

Specific Latent Heat Equation

The amount of energy needed/released when a substance of mass changes state.

$$\text{energy (E)} = \text{mass (m)} \times \text{specific latent heat (L)}$$

$$E = mL$$



Pressure in Gases

Heating

Heating up the gas particles provides them with more energy to move more quickly. This means they are likely to collide more frequently with other particles. This, in turn, increases the pressure.

Volume

If the volume of the container is increased, the number of collisions will decrease. This causes an overall decrease in pressure.

The equation for a fixed mass and a constant temperature is as follows (you will be given this in the exam):

$$P \times V = \text{constant}$$

P = pressure (Pa)

V = volume (m^3)

If the volume increases, the pressure decreases.

If the volume decreases, the pressure increases.

If the pressure of a gas changes, the volume of the gas can also change. A helium-filled balloon, once released, will rise into the atmosphere; the pressure outside of the balloon will decrease. The volume of the balloon will increase (due to less pressure outside the balloon), meaning the pressure inside the balloon will decrease.

Work Done on a Gas (Higher Tier Only)

Work done on a gas causes it to gain internal energy and so will increase the temperature. Pumping up the tyre of a bicycle involves doing work and this will increase the temperature of the gas inside the bicycle tyre.



Atomic Structure Knowledge Organiser – Foundation and Higher Separate Science

Developing the Model of the Atom

Scientist	Time	Contribution
John Dalton	Start of 19th century	Atoms were first described as solid spheres.
JJ Thomson	1897	Thomson suggested the plum pudding model – the atom is a ball of charge with electrons scattered within it.
Ernest Rutherford	1909	Alpha Scattering experiment – Rutherford discovered that the mass is concentrated at the centre and the nucleus is charged. Most of the mass is in the nucleus. Most atoms are empty space.
Niels Bohr	Around 1911	Bohr theorised that the electrons were in shells orbiting the nucleus.
James Chadwick	Around 1940	Chadwick discovered neutrons in the nucleus.

Isotopes

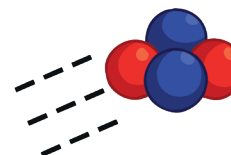
An isotope is an element with the same number of protons but a different number of neutrons. They have the same atomic number, but different mass numbers.

Isotope	Protons	Electrons	Neutrons
${}^1_1\text{H}$	1	1	0
${}^2_1\text{H}$	1	1	1
${}^3_1\text{H}$	1	1	2

Some isotopes are unstable and, as a result, decay and give out radiation. Ionising radiation is radiation that can knock electrons off atoms. Just how ionising this radiation is, depends on how readily it can do that.

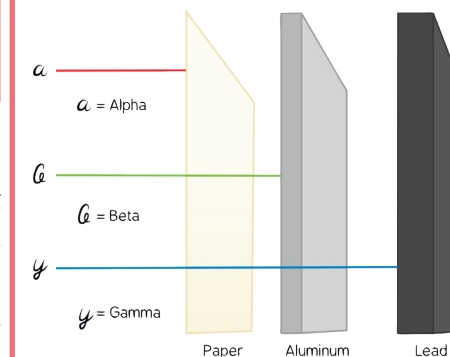
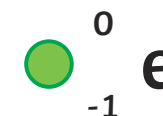
Alpha

Alpha radiation is an alpha particle emitted from the nucleus of a radioactive nuclei. It is made from two protons and two neutrons. They can't travel too far in the air and are the least penetrating – stopped by skin and paper. However, they are highly ionising because of their size.



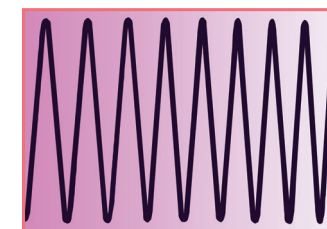
Beta

Beta radiation is a fast moving electron that can be stopped by a piece of aluminium. Beta radiation is emitted by an atom when a neutron splits into a proton and an electron.



Gamma

A gamma wave is a wave of radiation and is the most penetrating – stopped by thick lead and concrete.



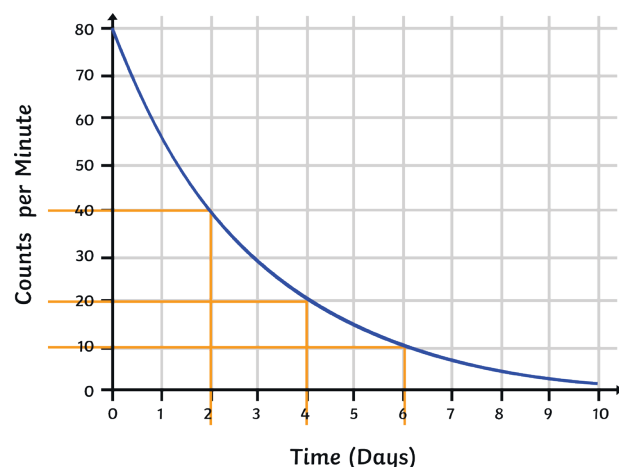
Half-life

The half-life is the time taken for the number of radioactive nuclei in an isotope to halve.

Radioactivity is a random process – you will not know which nuclei will decay. Radioactive decay is measured in becquerels Bq. 1 Bq is one decay per second.

Radioactive substances give out radiation from their nucleus.

A graph of half-life can be used to calculate the half-life of a material and will always have this shape:



Judging from the graph, the radioactive material has a half-life of two days.

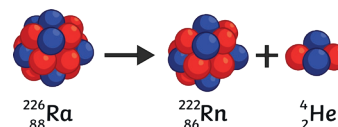
Irradiation

Irradiation occurs when materials are near a radioactive source. The source is sometimes placed inside a lead-lined box to avoid this.

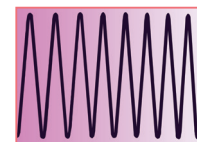
People who work with radioactive sources will sometimes stand behind a lead barrier, be in a different room or use a remote-controlled arm when handling radioactive substances.

Alpha Decay Equations

An alpha particle is made of two protons and two neutrons. The atomic number goes down by two and its mass number decreases by four.

**Gamma rays**

There is no change to the nucleus when a radioactive source emits gamma radiation. It is the nucleus getting rid of excess energy.

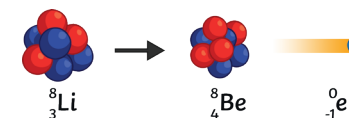
**Contamination**

When unwanted radioactive atoms get onto an object, it is possible for the radioactive particles to get inside the body.

Protective clothing should be worn when handling radioactive material.

Beta Decay Equations

A neutron turns into a proton and releases a an electron. The mass of the nucleus does not change but the number of protons increases.



Alpha radiation is more dangerous inside the body. It is highly ionising and able to cause a lot of damage. Outside the body it is less dangerous because it cannot penetrate the skin.

Beta radiation is less dangerous inside the body as some of the radiation is able to escape. Outside the body it is more dangerous as it can penetrate the skin.

Gamma radiation is the least dangerous inside the body as most will pass out and it is the least ionising. Gamma is more dangerous outside the body as it can penetrate the skin.



Background Radiation

This comes from natural sources like rocks, food and air. It also comes from man-made sources such as nuclear weapons, nuclear waste or nuclear accidents. The dose of radiation people receive varies dependent on how close they are to the source. Too much exposure to radiation can cause radiation poisoning. Radiation dosage is measured in **sieverts (Sv)**.

1000 millisieverts (mSv) = 1 sievert (Sv)

Uses of Nuclear Radiation

Although radiation can be dangerous, it also has its uses. The risks are always considered when using radiation. Gamma sources can be used as a medical tracer in the human body; isotopes can be injected or swallowed. As the isotope goes around the body, it can be monitored and medical issues can be spotted. Gamma radiation is emitted out of the body and does not cause the cells to become ionised. The isotope used will have a short half-life so it does not stay inside the body for too long. Tracers can be used to diagnose potentially life-threatening conditions which otherwise would not be spotted. The risk of using the radioactive tracer is much less than the risk of the condition they may diagnose.

Fission

Nuclear fission is the splitting of large radioactive nuclei into smaller ones. A neutron is absorbed by a large unstable radioactive nucleus. Next, the nucleus splits into smaller nuclei. As this happens, more neutrons and energy are released. The neutrons released go on to cause more reactions. This is called a chain reaction.

Fission is carried out in a nuclear reactor in order to generate energy. It is controlled by control rods which, when they are lowered down, slow down the reaction process. When they are raised, the reaction speeds up again. If this process is not controlled, then a nuclear weapon has been produced.

Different Half-Lives of Radioactive Isotopes

All radioactive isotopes have different half-lives. Some are very short and others are much longer. The uses of these will depend on the half-life. For example, you would use an isotope with a short half-life as a medical tracer so it is not in the body for too long.

Radiotherapy

High doses of radiation can be used to treat cancer. Gamma rays are focused directly onto the cancer cell, killing the cancer cell but not killing too many healthy cells. The damage to the healthy cells that may be close to the cancer can cause the patient to feel ill. However, killing the cancer cell makes it worth it.

Fusion

Nuclear fusion is the joining together of smaller radioactive nuclei to make a larger atom. Fusion occurs in the sun. This whole process releases a lot of energy, much more than fission. However, a very high temperature and pressure is needed for fusion to occur, so it is not used in the production of energy yet.

