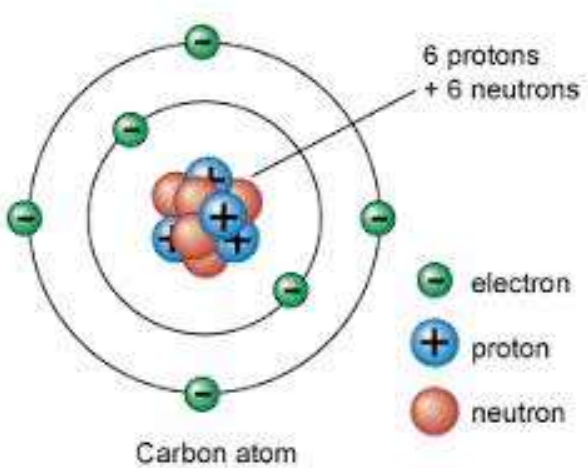
AQA P2 Topic 4

Electrical charges

P2.1 Static Electricity



The charge and mass of electrons, protons and neutrons

	Proton	Neutron	Electron
Charge	+1	0	-1
Mass	1	1	0.0005 (almost zero)

Protons = positively charged

Electrons = negatively charged.

Electrons are in the shells of atoms.

Charge of an atom = neutral as the + and the – are equal.

Static electricity

In insulator can become charged by friction through the transfer of electrons.

A substance that **gains** electrons becomes **negatively charged**, while a substance that **loses** electrons becomes **positively charged**.

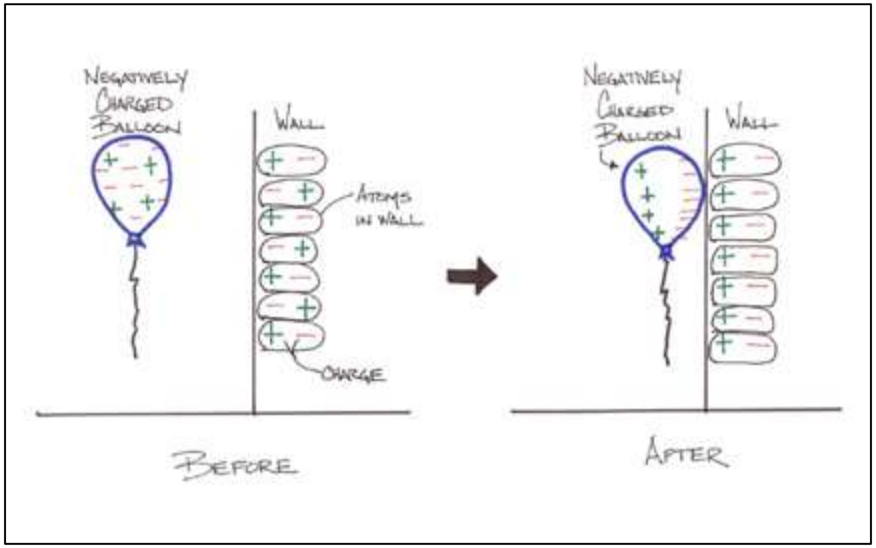
When a charged object comes near to another object they will either attract or repel each other.

If the charges are the same - **they repel**

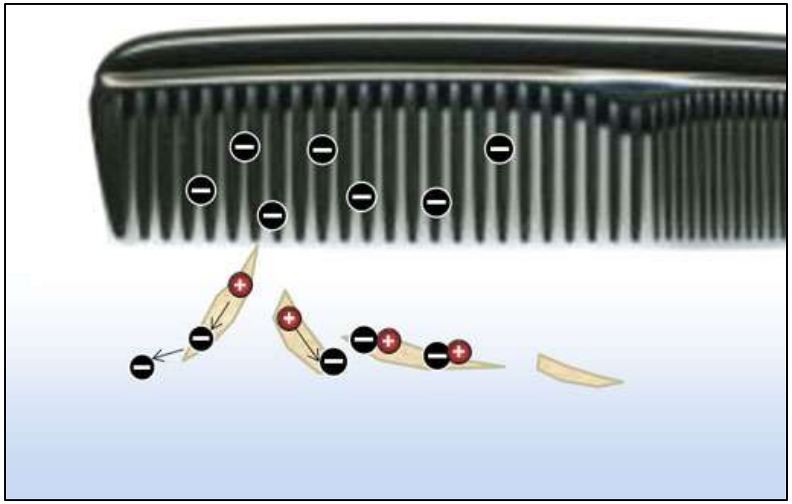
If the charges are opposite - **they attract**

P2.1 Electrostatic Phenomena

The negatively charged balloon repels the electrons in the wall and they move away. The positive charge left behind attracts the balloon.



The negatively charged comb repels the electrons in the paper. The positive charge left behind is attracted to the comb which is why it picks up the paper.



P2.2 Uses and Dangers of static

How lightning is caused:

- Static electricity can build up in clouds. This can cause a huge spark to form between the ground and the cloud.
- A flow of charge through the atmosphere.

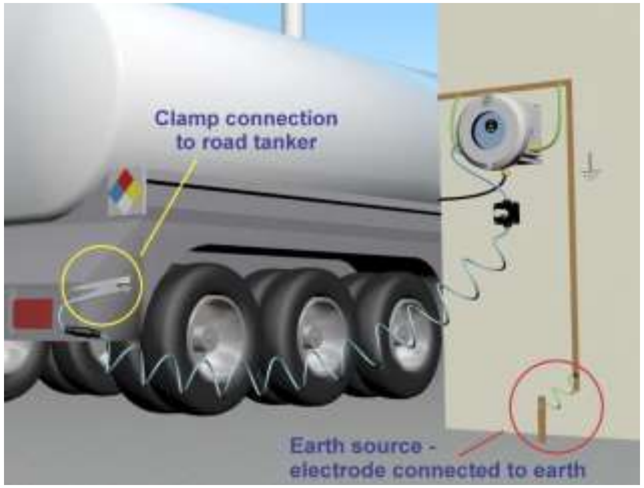
Static is dangerous when:

- There are inflammable gases or vapours or a high concentration of oxygen. A spark could **ignite** the gases and cause an explosion.
- You touch something with a large electric charge on it. The charge will flow through your body causing an **electric shock**.

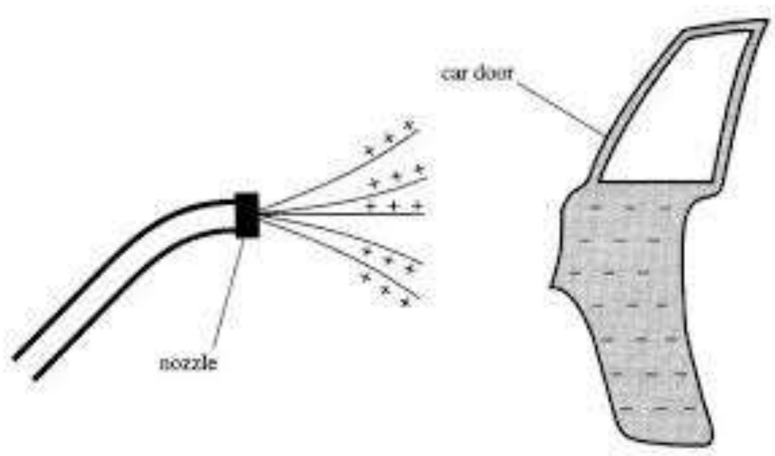
Static electricity builds up on everyday objects. It can be dangerous if it can create a spark. A conducting path can be used to prevent sparking.

Earthing removes excess charge by movement of electrons.

The electrons flow through the earthing cable to earth rather than there being a discharge and spark.



P2.2 Uses and Dangers of static



Paint Spraying

1) The car is negatively charged.
2) The paint is positively charged. The positively charged paint spreads out as the repel each other.
3) The negative attracted to the positive and stick.
4) The metal spray nozzle is connected to the positive terminal of the power pack and the paint picks up a positive charge.

Air craft can build up a static charge when flying through the air and refuelling can also build a charge. To stop explosions the aircraft has a bonding line which is used to connect the air craft to the earth before it has been refuelled.

Insecticide sprays

Insecticide use static electricity.
Sprayed from aircraft so that they cover a large area.
Risk that some of the spray will blow away or fall unevenly. To prevent this, the insecticide is given a static charge as it leaves the aircraft.
The static drops spread evenly as they all have the same charge and are attracted to the earth.

P2.3 Electric Currents

Materials contain electrons.

Insulating materials the electrons cannot move but in a metal they move and this can and this creates a current.

Key terms

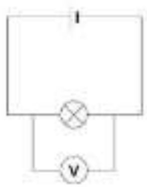
- Current is the flow of charge
- Current in metals is the flow of electrons
- Cells and batteries supply direct current (d.c.)
- Direct current is the movement of charge in one direction.

Be able to use the equation:

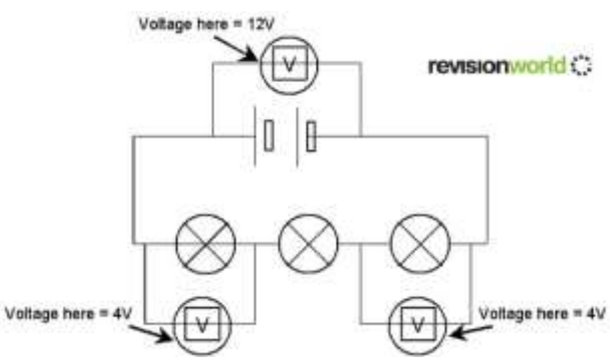
charge (coulomb, **C**) = **current** (ampere, **A**) **x time** (second, **s**)

$$Q = I \times t$$

P2.4 Current and Voltage.

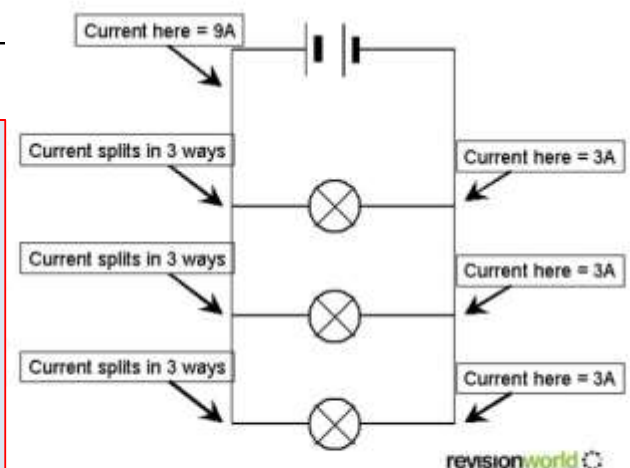


Voltmeter	Ammeter
Measures voltage in Volts	Measures current in Amps
Measures the energy difference between the electrons going into the component and back.	Electrons not used up out the output is the same as the input back to the cell.
Parallel	Series
No junctions	Current splits up at a junction
Potential difference measured.	Current size measured.



Potential difference is the energy transferred per unit charge.

1 Volt is 1 Joule per Coulomb



P2.6 Changing resistances

- Resistance measures how hard it is for the electricity to flow through a circuit.
- Measured in Ohms
- Dependant on how many components are in the circuit.
- The higher the resistance the lower the current.
- Variable resistor = can change the resistance of a wire.

Be able to use the equation:

potential difference (volt, V) **= current** (ampere, **A**) **x resistance** (ohm, **Ω**)

V = I x R

Component	**Resistance**
Filament lamp.	As they get hot the resistance decreases. They get hot as they have a higher potential difference.
Diodes	Electricity flows in one direction. If a potential difference is applied in the other direct no current will flow.
Light dependant resistor	Resistance is high in the dark and low in the day time
Thermistor	High resistance when cold, low resistance when hot.

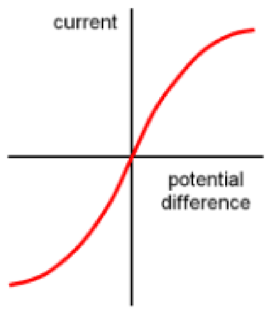
P2.6 Changing Resistances

The filament lamp

The filament lamp is a common type of light bulb. It contains a thin coil of wire called the filament. This heats up when an electric current passes through it and produces light as a result.

Lamp

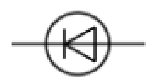
The filament lamp does not follow Ohm's Law. Its resistance increases as the temperature of its filament increases. So the current flowing through a filament lamp is not directly proportional to the voltage across it. This is the graph of current against voltage for a filament lamp.



The diode

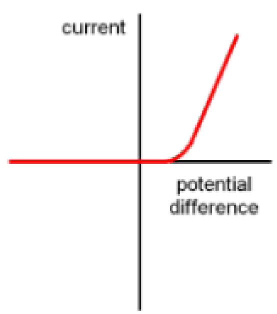
You should be able to recognise the graph of current against voltage for a diode.

Diodes are electronic components that can be used to regulate the potential difference in circuits and to make logic gates. Light-emitting diodes (LEDs) give off light and are often used for indicator lights in electrical equipment such as computers and television sets.



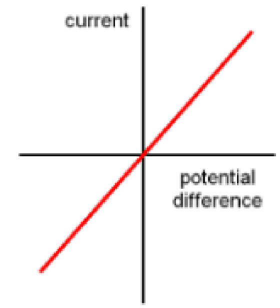
Diode

The diode has a very high resistance in one direction. This means that current can only flow in the other direction. This is the graph of current against potential difference for a diode.



Resistor at constant temperature

The current flowing through a resistor at a constant temperature is directly proportional to the potential difference across it. A component that gives a graph like the one to the right is said to follow *Ohm's Law*.



A graph with current on the y axis and voltage on the x axis. A diagonal line goes through the graph at 45 degrees

AQA P2 Topic 5

Mains electricity

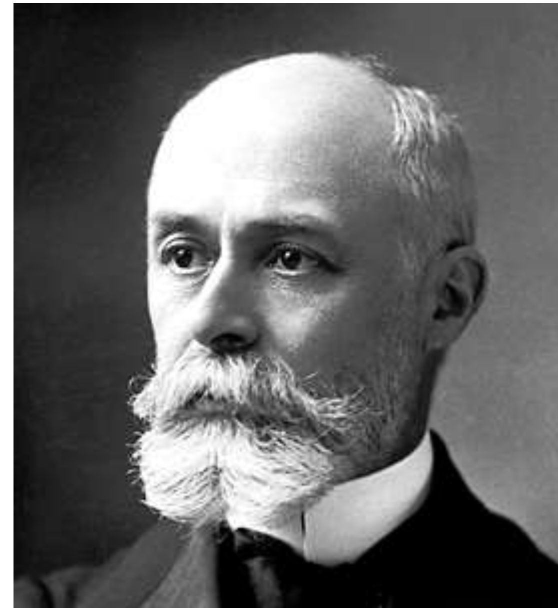
AQA P2 Topic 6

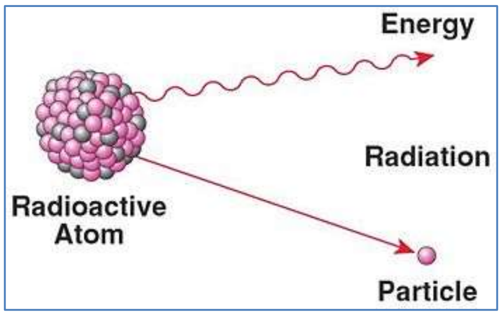
Radioactivity

P2 6.1 Observing nuclear radiation

Radioactivity was discovered by accident by Henri Becquerel. An image of a key appeared on a photographic film when the key was left between the film and a packet of uranium salts. Becquerel concluded that something must have passed from the uranium salts through the paper that the film was wrapped, but that it must have been blocked by the metal keys.

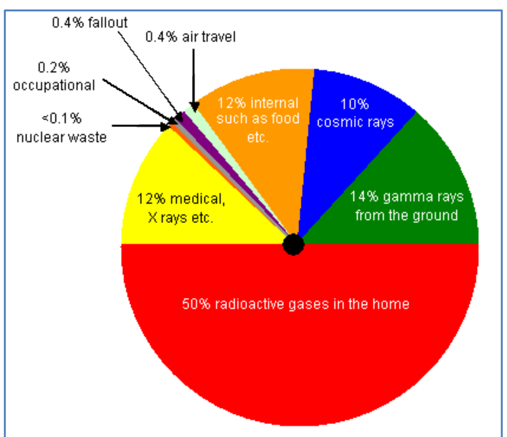
Becquerel asked his young research assistant, Marie Curie, to investigate. It was she who coined the word radioactivity.





Radioactive emissions happen because the nuclei of an element are unstable. The nuclei become stable by emitting radiation.

There are three types of radiation: alpha, beta and gamma. Alpha and beta are particles. Gamma is a form of energy.



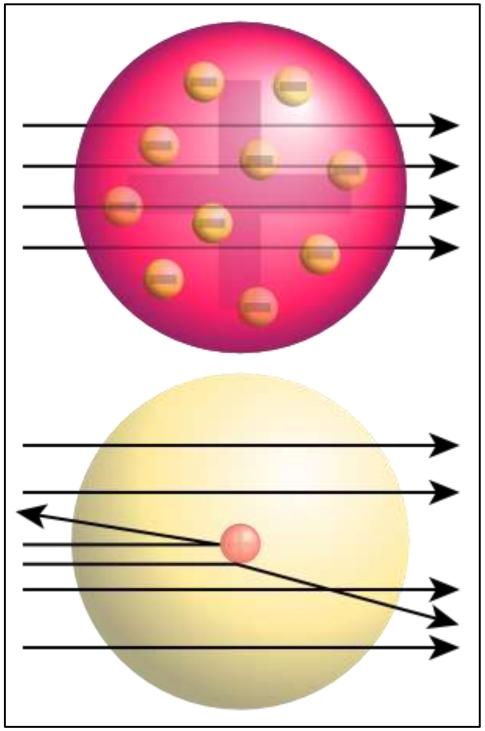
Background radiation is everywhere all the time. Most of it comes from natural sources, including radon gas in the air (50%), radioactive rocks in the ground (14%) and cosmic rays (10%). 12% is in our food! Only about 13% comes from man-made sources, mostly medical, including X-rays. Less than 1% comes from nuclear power and fallout from nuclear explosions and accidents.

P2 6.2 The discovery of the nucleus

Until 1911, the accepted model of the atom was known as the plum pudding model (top diagram). It was believed that the atom was a ball of positive charge with negatively-charged electrons (discovered in 1897) buried inside.

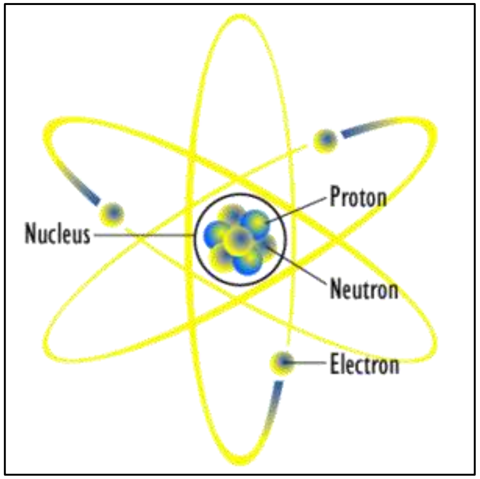
Then Ernest Rutherford, together with his research assistants Ernest Marsden and Hans Geiger (after whom the Geiger counter radio detector is named) conducted an experiment. They fired alpha particles at a thin sheet of metal foil.

They expected the alpha particles to pass straight through, as shown by the arrows on the top diagram. To their surprise, some of the alpha particles changed direction and some even bounced back! Rutherford was so astonished he likened it to firing artillery shells at tissue paper and having them rebound!



Their results could not be explained by the plum pudding model. Rutherford deduced that there was a positively-charged nucleus at the centre of the atom. The nucleus must be positively-charged because it repelled positively-charged alpha particles. (Remember, like charges repel.) And the nucleus must be much smaller than the atom because most alpha particles passed straight through (as shown on the middle diagram. Consequently, most of the atom is empty space.

Rutherford's nuclear model of the atom was improved with discovery of the neutron in 1932. This story demonstrates how new evidence can cause an accepted theory to be re-evaluated if experimental evidence does not fit.



Did you know? The nucleus is 100,000 times smaller than the whole atom. If the nucleus was 1cm across, the electrons would be 1km away. The rest is empty space.

P2 6.3 Nuclear reactions

Isotopes are atoms of an element with the **same number of protons and electrons** but with **different numbers of neutrons**. To describe isotopes, we use an expanded version of the familiar chemical element symbols.

This is the mass number. It is the **total number of protons and neutrons.** Isotopes have **different mass numbers** but the **same atomic number**.

Maths tip: to work out the number of neutrons in an isotope, take away the atomic number from the mass number

$$^{4}_{2}\mathrm{He}$$

This is the chemical symbol from the periodic table.

This is the atomic number (or proton number). It is the number of protons in the nucleus. All atoms of an element have the same number of protons.

Sub-atomic particle	Relative mass	Relative charge
proton	1	+1
neutron	1	0
electron	almost zero	-1

The sub-atomic particles

	Alpha (α) radiation	Beta (β) radiation	Gamma (γ) radiation
Particle emitted	2 protons and 2 neutrons	a fast-moving electron	not a particle
Change to mass number	-4	no change	no change
Change to proton number	-2	+1 (a neutron changes into a proton)	no change

Radiation facts

Fact: the number of electrons in an atom equals the number of electrons in the nucleus

P2 6.4 Ionising radiation

An ion is an atom with an electrical charge, either because it has lost or gained one or more electrons. The three types of ionising radiation can all ionise atoms to different degrees by knocking an electron off the atom.

Type of radiation (symbol)	What is it?	Charge	Ionising power	Penetrating power	Range in air	Affected by electric fields?	Affected by magnetic fields?
Alpha (α) particle	2 protons, 2 neutrons (a helium nucleus)	+2	Strong	Weak – stopped by a thin sheet of paper	~ 5 cm	Yes (because it has a positive charge, it is **repelled** from the positive plate)	Yes
Beta (β) particle	A fast-moving electron	-1	Weak	Average – stopped by 5mm of aluminium	~ 1 m	Yes (because it has a negative charge, it is **attracted** to the positive plate)	Yes
Gamma (γ) wave	An electro-magnetic wave	None (because it's a wave)	Very weak	Strong – requires several cm of lead sheet	unlimited	No (because it's an electromagnetic wave)	No

Ionising radiation facts

Did you know: X-rays can also cause ionisation. This is why X-ray operators have to take precautions to avoid over-exposure to X-rays. Ionisation in a living cell can damage or kill the cell. If the cell's DNA is damaged, the damage can be passed to new cells, which can cause cancer.

P2 6.3 Nuclear reactions: ionising radiation

Keywords

- **Unstable** – an unstable nucleus is one that will decay and give out ionising radiation
- **Radioactive Decay** – when an unstable nucleus changes by giving out ionising radiation to become more stable
- **Ion** - An atom with an electrical charge (through loss or gain of electrons)

Ionising radiation

Alpha	Beta	Gamma
• Particles containing **2 protons** and **2 neutrons** (Helium atom nucleus) • No electrons = **2+ charge** • Emitted from nucleus at **high speed** • **Lose energy** as they **ionise** an atom • Produce many ions quickly so have **short penetration** distance • Stopped by a few **cm of air** of **mm of paper**	• **Electrons** that are emitted from an unstable nucleus • Much **less ionising** that **alpha** • Can **penetrate** much **further** into matter • Stopped by a few **mm or aluminium** or **even thinner lead.**	• **High-frequency electromagnetic waves** emmited by unstable nuclei • Travel at the **speed of light** • **Ten times less ionising** that beta • **Penetrate** matter **easily** • Stopped by a few **cm of lead** or **many metres of concrete.**

P2.28 Changing ideas

Keywords

Hazards – causes of harm

Risk – likelihood of harm

Mutation – a change in the base sequence of DNA.

Henri Becquerel and Marie Curie

- Accidental discovery was made that Uranium exposed photographic plates = discovery of **radioactivity**
- Showed how radiation could **ionise gases**
- Skin **burns** visible from handling Radium
- By 1920s links made with **cancer** (Marie Curie died of lukaemia)
- Large amount of **ionising radiation** = tissue damage (radiation burns)

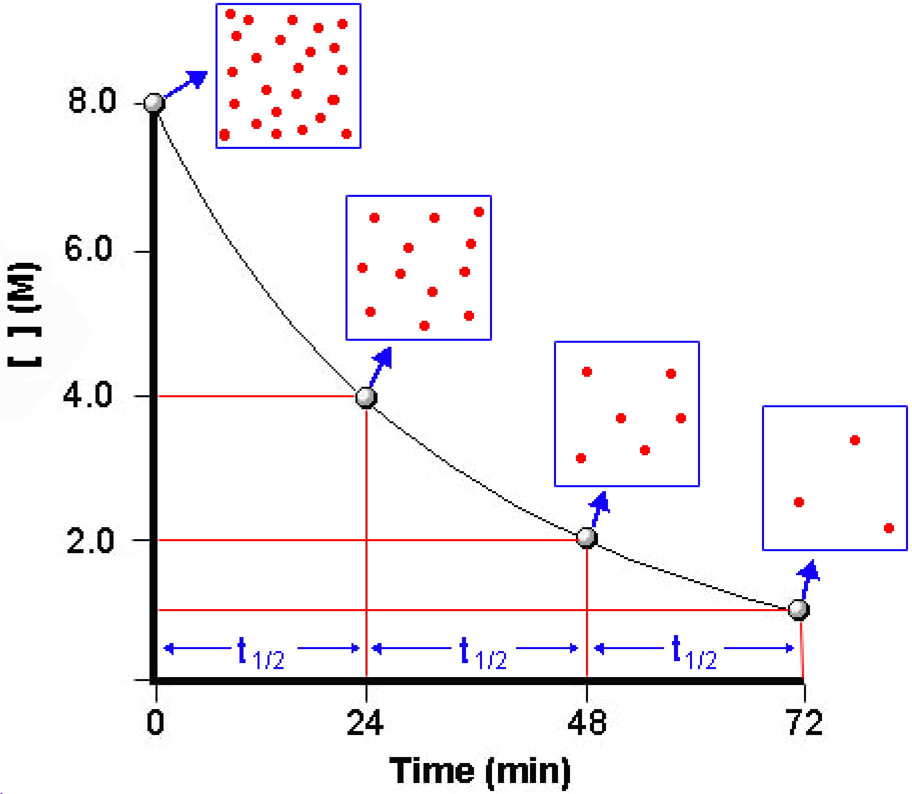
Handling radioactive sources

- Risk of **harm decreases** with **distance** from the source
- Sources always handled with **tongs**
- Risk reduced by **not pointing** sources at people
- Keep sources in **lead** lined containers

P2.30 Half-life

Radioactive decay

- **Unstable** nucleus undergoes **radioactive decay** to become more stable
- Activity of a substance is the number of nuclear **decays per second**
- Measure in **becquerel** (Bq)
- 1Bq is one nuclear decay each second
- Radioactive decay is a **random** process (cannot predict it)
- **Half life** = the time taken for half the unstable nuclei in a sample of a radioactive isotope to decay.
- Half life **does not change** as the sample gets smaller
- After decaying = **more stable nucleus**
- More stable nucleus = **lower activity**
- Half life found by recording activity over a period of time.



Geiger-Muller tube

- Used to **measure** radioactivity
- Can be connected to a **counter** or may give a **click** when radiation detected
- **Count rate** = number of clicks per second or minute

P2.33 and P2.34 Uses of radiation

Diagnosis of Cancer

- Gamma rays used
- A **tracer** solution **injected** into body that collects in cancers
- **Gamma camera** used to detect rays
- Pass through the body so easily detected

Treatment of Cancer

- Radiotherapy = ionising radiation to treat cancer.
- Gamma rays used as beams to target and kill cancer cells.

Irradiating food

- Bacteria will cause food to decay or make us ill
- Gamma rays **kill bacteria**
- Makes food safer and longer lasting
- Does not make food radioactive
- Foods like Fruit, cereals and shellfish are irradiated.

Tracers in the environment

- Added to water to **monitor pollution** or **leaking pipes** underground
- GM tube follows the pipe to detect leaks.

Sterilisation of equipment

- To **kill microorganisms** surgical instruments need to be sterilised
- Heat usually used but cannot be used on some things e.g. plastics
- They are **irradiated** with Gamma rays instead.

Smoke Alarms

- Contains a source of **alpha particles**
- There is an electrical circuit with a gap between 2 charged plates.
- **Air** in gap is **constantly ionised** therefore **constant electric current**.
- When smoke get in the alpha particles are absorbed and stops the **current drops = alarm sounds**

Checking thickness

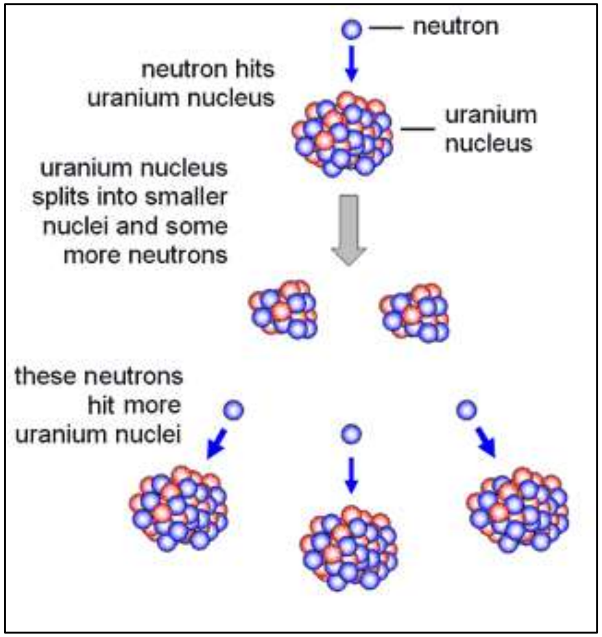
- Use a **detector** to measure the rate Beta passes through paper
- **Thinner paper = higher beta count**.

AQA P2 Topic 7

Energy from the nucleus

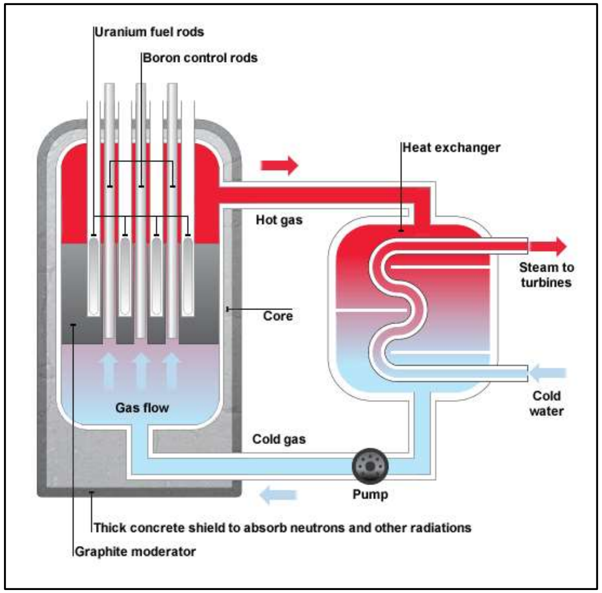
P2 7.1 Nuclear fission

During nuclear fission, atomic nuclei split. This releases energy. In a nuclear power station, the energy heats water and turns it into steam. The steam turns a turbine, which turns a generator, which generates electricity. The two fissionable elements commonly used in nuclear reactors are uranium-235 (U_{235}) and plutonium-239 (Pu_{239}). Most nuclear reactors use uranium-235.



The top diagram shows what happens during nuclear fission of uranium-235. Fission occurs when a neutron hits a uranium nucleus. The nucleus splits into smaller nuclei (so they are different elements) and more neutrons. The neutrons hit more uranium nuclei causing them to split, producing smaller nuclei and more neutrons. Thus the reaction continues, getting bigger and bigger. This is called a chain reaction.

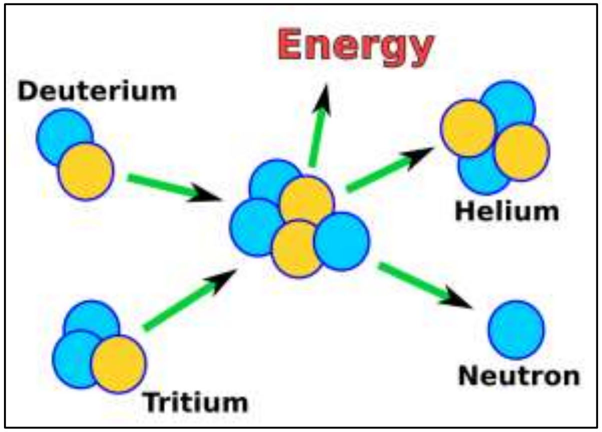
Exam tip: you need to be able to sketch or complete a **labelled** diagram to illustrate how a chain reaction occurs, so remember this diagram.



The bottom diagram shows a nuclear reactor which uses gas to take heat energy from the reactor vessel to a heat exchanger where it turns water into steam. Other reactors designs use pressurised water instead of gas. The purpose of the moderator is to slow down the neutrons, which is necessary because fast neutrons do not cause further fission. The control rods absorb neutrons so that, on average, only one neutron per fission reaction goes on to produce further fission, preventing a chain reaction.

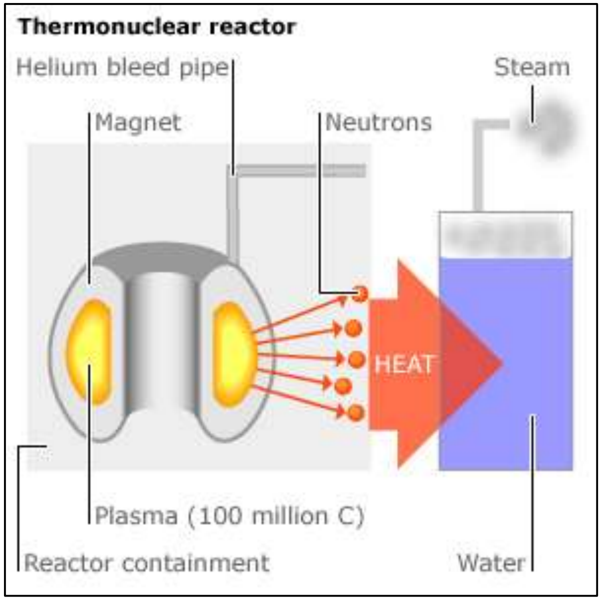
P2 7.2 Nuclear fusion

During nuclear fusion, two atomic nuclei join together to form a larger one. Energy is released when to light nuclei fuse together. Nuclear fusion is the process by which energy is released in stars.



The top diagram shows what happens in stars like the Sun. The Sun is about 75% hydrogen. Deuterium and tritium are isotopes of hydrogen with additional neutrons. Most hydrogen nuclei consist of only one proton with no neutrons, but because the Sun is so hot, there are lots of these 'heavy' hydrogen isotopes. When they collide, they fuse to produce helium, which makes up the other 25% of the Sun.

Fusion reactors could meet all our energy needs, but there are enormous practical difficulties. As shown in the bottom diagram, a fusion reactor needs to be at an extremely high temperature before nuclear fusion can occur, and the plasma needs to be contained by a powerful magnetic field.



Did you know? In March 2014, 13 year-old Jamie Edwards from Preston in Lancashire became the youngest person ever to carry out atomic fusion. He built a fusion reactor in school, smashing two hydrogen atoms together to make helium. This is not yet a standard school practical!

P2 7.3 Radioactivity all around us

Keywords

- **Background radiation** – ionising radiation that is around us all the time from a number of sources. Some is naturally occurring.
- **Background count** – the average number of counts recorded by a GM tube in a certain time from background radiation
- **Radon gas** – naturally occurring radioactive gas that is emitted from rocks as a result of the decay of radioactive uranium

- We are constantly exposed to **ionising radiation** – from **space** and naturally occurring = **background radiation**
- Needs to be considered when measuring a source
- Background count is **subtracted** from the **source count**

Background Radiation

- Main source = **radon** gas
- Released from **decaying uranium** in rocks
- Diffuses into the air from **rocks** and **soil**
- **Medical sources** = x-rays; gamma rays (scans) and cancer treatments
- Some **food** are naturally radioactive
- **Cosmic rays** = high energy charged particles from the stars (like the Sun) and supernovae, neutron stars and black holes.
- Many cosmic rays are stopped by the atmosphere but some reach Earth.

P2 7.4 The early universe

The Big Bang that created the Universe was about 13 billion years ago. The first galaxies and stars formed a few billion years later.

Before the galaxies and stars formed, the universe was a dark, patchy cloud of hydrogen and helium, which are the two most abundant elements in the Universe.

The force of gravity pulled dust and gas into stars and galaxies. A galaxy is a collection of billions of stars held together by the force of their own gravity.

Smaller masses may also form and be attracted by a larger mass to become planets.

Did you know? The early Universe contained only hydrogen. All the other elements were formed in stars. We and everything around us are made from the remains of stars!

P2 7.5 The life history of a star

Stars go through a lifecycle. There are two paths through the lifecyle. Which path a star takes depends on its size.

1. All stars start as a protostar, a cloud of dust and gas drawn together by gravity in which fusion has not yet started.

2. As a protostar gets bigger, gravity makes it get denser and hotter. If it becomes hot enough, fusion starts. This is called a main sequence star because this is the main stage in the lifecycle of a star.

A star can stay in this stage for billions of years. During this stage, the forces in it are balanced: the inward force of gravity is balanced by the outward force of the radiation from the core.

What happens next depends on the size of the star.

3a. Low mass stars (like the Sun) expand, cool down and turn red. The star is now a red giant. Helium and other light elements in the core fuse to form heavier elements up to iron.

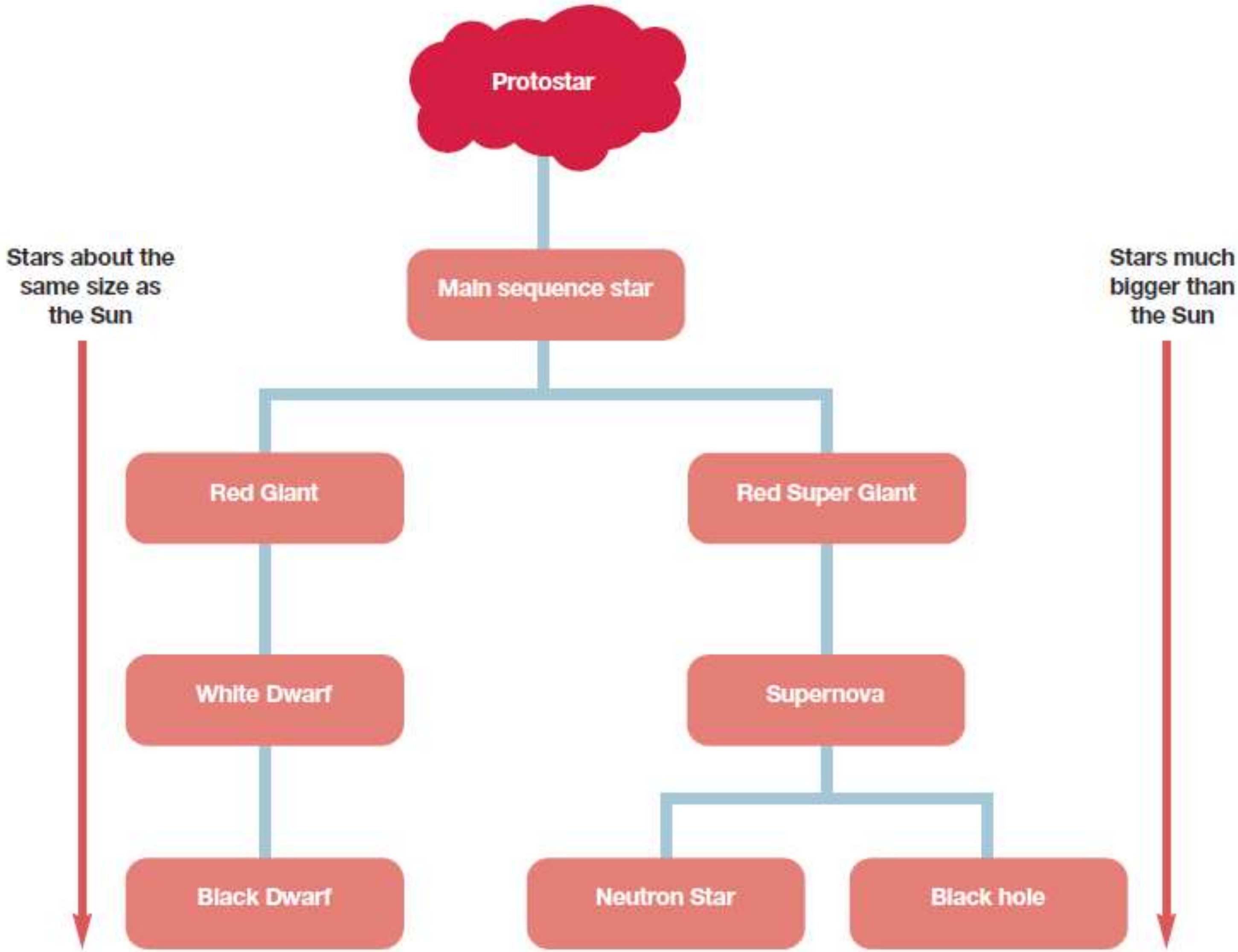
When there are no more light elements left in the core, fusion stops. Due to gravity, it collapses and heats up becoming a white dwarf. As it cools, it becomes a black dwarf.

3b. Stars much bigger than the Sun expand even more to become a red supergiant. This collapses , compressing the core more and more until there is a massive explosion called a supernova.

The explosion compresses the remaining core of the star into a neutron star or, if it is really big, a black hole. The gravity of a black hole is so strong that not even light can escape.

P2 7.5 The life history of a star (continued)

Exam tip: you need to be able to sketch or complete a **labelled** diagram to illustrate the lifecycle of a star, so remember this diagram, the reason why a star goes ‘left’ or ‘right’ (its size/mass) and what happens at each stage.

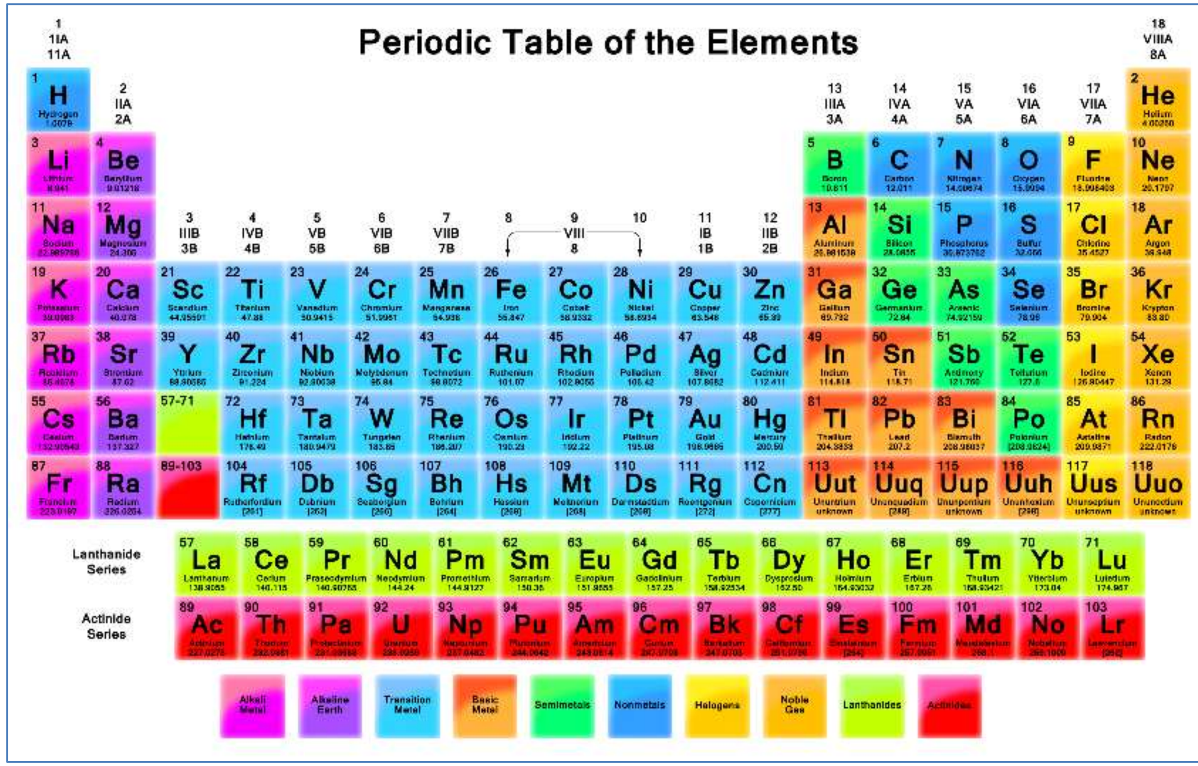


P2 7.6 How the chemical elements formed

Main sequence stars fuse hydrogen nuclei into helium and other small nuclei, including carbon.

When stars like the Sun become red giants, they fuse helium and other light elements to form heavier elements up to iron.

But nuclei larger than iron cannot be formed this way because too much energy is needed.



All the elements heavier than iron were formed when red supergiants collapsed then exploded in a supernova. The enormous force fuses small nuclei into the larger nuclei of heavier elements.

The debris from a supernova contains all the elements. Planets form from that debris. Hence the Sun and the rest of the Solar System were formed from the debris of a supernova.

Remember:

- Elements up to iron were formed in stars by nuclear fusion
- Elements heavier than iron were formed in supernova explosions