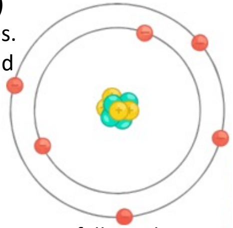
Atomic Structure: Physics

1. The Structure of the Atom (common content with Chemistry)



- Atoms are very small, they have a radius of about $1x10^{-10}$ metres.
- Atoms have a positively charged nucleus made from protons and neutrons surrounded by negatively charged electrons.
- The radius of the nucleus is less than 1/10,000 of the radius of the atom, so most of the atom is empty space.
- The electrons are arranged in energy levels. If electrons absorb electromagnetic radiation they may move to a higher energy level, further from the nucleus. If they emit electromagnetic radiation, they may fall to a lower energy level closer to the nucleus.

2. Mass number, Atomic Number and Isotopes (common content with Chemistry)

- In an atom, the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge.
- All atoms of a particular element have the same number of protons (called the atomic number).
- The sum of the protons and neutrons in an atom is its mass number

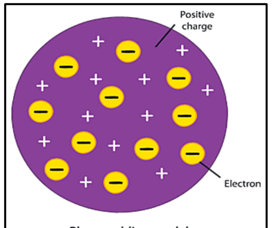
Mass number, M_r → 23
Atomic number, A_r → 11
Na
Sodium

- Atoms of the same element have the same number of protons but can have a different number of neutrons; these atoms are called **isotopes** of that element.
- Atoms turn into positive ions if they lose electrons.

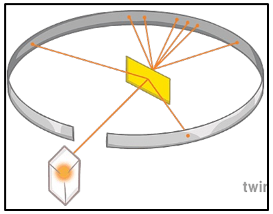
3. Development of the model of the atom (common content with Chemistry)

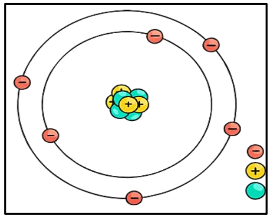
Note: you only need to know the names of **Bohr and Chadwick (in bold).**

Scientist	Discovery
1800's and before	Atoms were thought to be tiny spheres that could not be divided.
JJ Thomson, 1897	The discovery of the **electron** led to the **plum pudding model** of the atom where the atom is a ball of positive charge with negative electrons embedded in it.
Ernest Rutherford, 1909	The results from the alpha particle scattering experiment led to the conclusion that the mass of an atom was concentrated at the centre (**nucleus**) and that the nucleus was charged.
Niels Bohr, 1911	Niels Bohr adapted the nuclear model by suggesting that **electrons orbit the nucleus** at specific distances.
Ernest Rutherford, 1920	Later experiments led to the idea that the positive charge of any nucleus could be subdivided into **protons.**
James Chadwick, 1940	Provided the evidence to show the existence of **neutrons** within the nucleus. This was about 20 years after the nucleus became an accepted scientific idea.



Plum pudding model





4. Atoms & Nuclear Radiation

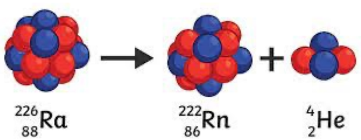
- Some atomic nuclei are **unstable**. This means they give out radiation as it changes to become more stable. This **random** process is called **radioactive decay**.
- Activity is the rate at which a source of unstable nuclei decays it is measured in **becquerel (Bq).**
- **Count-rate** is the number of decays recorded per second by a detector (e.g. a Geiger-Muller tube).

Radiation	Symbol	Made from	Penetrating Power	Ionising power	Range in air
Alpha	**α**	2 protons & 2 neutrons (same as a He nucleus)	Stopped by paper/skin	High	<5cm
Beta	**β**	A high speed electron ejected from the nucleus as a neutron turns into a proton	Stopped by 3mm aluminium foil	Low	Approx. 1 m
Gamma	**γ**	Electromagnetic radiation from the nucleus	Stopped by lead/concrete	Very low	> 1km

5. Nuclear Equations

- Nuclear equations can be used to represent radioactive decay.
- The emission of the different types of radiation may cause a change in the mass and/or charge of the nucleus, for example:

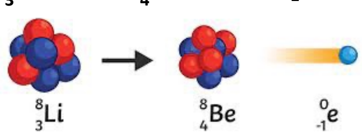
$^{226}_{88}$radium → $^{222}_{86}$radon + $^{4}_{2}\alpha$



An alpha particle may be represented as: $^{4}_{2}He$

- So alpha decay causes both the mass and the charge of the nucleus to decrease.

$^{8}_{3}$lithium → $^{8}_{4}$beryllium + $^{0}_{-1}\beta$



A beta particle may be represented as: $^{0}_{-1}e$

- So beta decay not cause the mass of the nucleus to change, but does cause the charge of the nucleus to increase.
- The emission of a gamma ray does not cause the nucleus to change.

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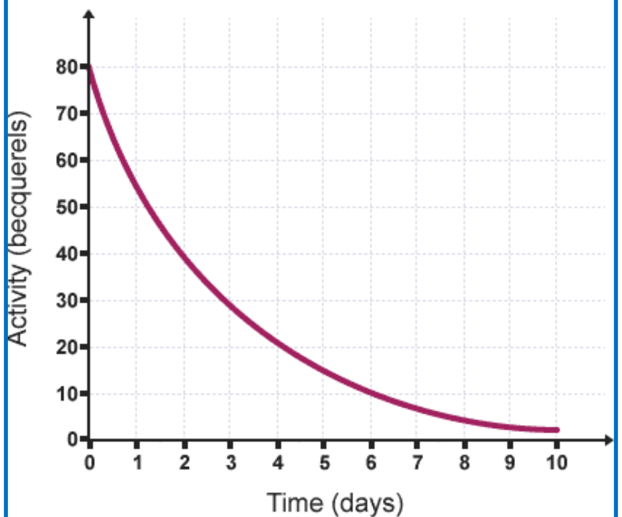
6. Half-lives

- Radioactive decay is random.
- The half-life of a radioactive isotope is the time it takes for the number of nuclei of the isotope in a sample to halve, or the time it takes for the count rate to fall to half of its initial level.



You can calculate half lives from graphs such as the one here. Read off how long it takes the activity to half,
e.g. to go from 80 to 40 Bq takes 2 days.

7. Radioactive Contamination and Irradiation

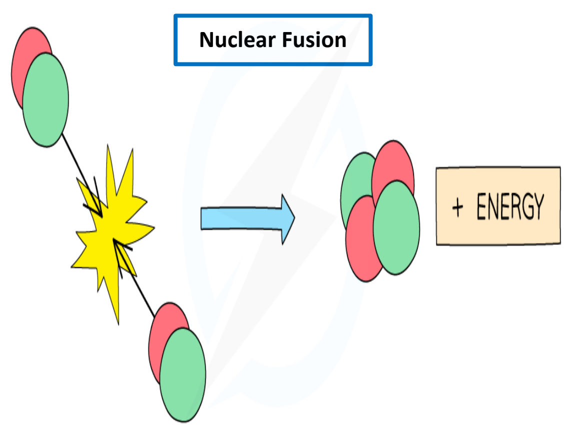
- Radioactive contamination is the unwanted presence of materials containing radioactive atoms on other materials.
- The hazard from contamination is due to the decay of the contaminating atoms. The type of radiation emitted affects the level of hazard.
- Irradiation is the process of exposing an object to nuclear radiation. The irradiated object does not become radioactive.
- Suitable precautions must be taken to protect against any hazard that the radioactive source used in the process of irradiation may present.

8. Background Radiation: *(Separate Physics Only)*

- Background radiation is around us all the time, it comes from:
  - ➢ Natural sources e.g. rocks, cosmic rays
  - ➢ Artificial sources e.g. medical uses, nuclear weapons fallout and nuclear accidents.
- The level of background radiation dose may be affected by occupation and location.
- Radiation dose is measured in sieverts (Sv). 1,000 millisieverts (mSv) = 1 sievert (Sv)
- Radioactive isotopes have a very wide range of half-lives. The use of them depends on the half-life, e.g. a short half-life would be used for a medical tracer so it is not in the body for long.

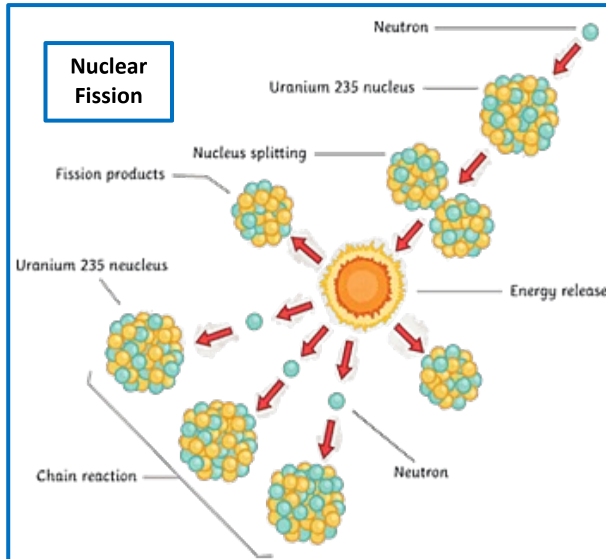
9. Uses of Nuclear Radiation: *(Separate Physics Only)*

- Medicinal uses:
  - ➢ Exploration of internal organs, e.g. tracers
  - ➢ Control and destruction of unwanted tissue (e.g. cancer). Gamma rays can be used in radiotherapy to kill cancer cells when they are targeted directly at the unwanted cells.



10. Nuclear Fission: *(Separate Physics Only)*

- Nuclear fission is the splitting of a large and unstable nucleus (e.g. uranium or plutonium).
- Spontaneous fission is rare.
- For fission to occur the unstable nuclei must absorb a neutron.
- The nuclei undergoing fission splits into two smaller, equal sized nuclei and emits neutrons, gamma rays and energy.
- All the fission products have kinetic energy.
- The neutrons may go on to start a chain reaction.
- The chain reaction is controlled in a nuclear reactor to control the energy released. The explosion caused by a nuclear weapon is caused by an uncontrolled chain reaction.



11. Nuclear Fusion: *(Separate Physics Only)*

- Nuclear fusion is the joining of two light nuclei to form a heavier nucleus. In this process some of the mass may be converted into the energy of radiation.