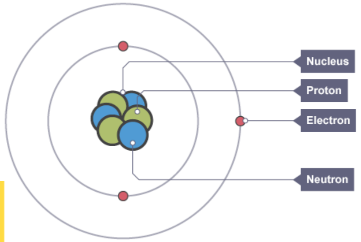
science physics

GCSE P4 – Atomic Structure & Radiation

1. Atomic Structure

Nucleus contains protons and neutrons. Electrons orbit the nucleus in shells.



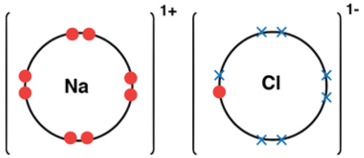
Mass Number = Protons + Neutrons

Atomic Number = Protons

$^{35}_{17}\mathrm{Cl}$

Electron number = Proton number so the overall charge on the atom is neutral.

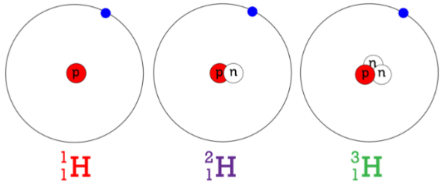
Particle	Charge	Mass
Proton	+1	1
Neutron	0	1
Electron	-1	0



A **negative ion** is an atom that has **gained** electrons

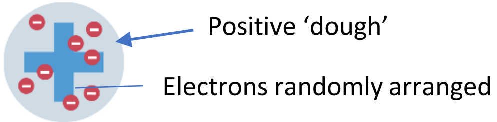
A **positive ion** is an atom that has **lost** electrons

Isotopes of the same element have the same number of protons and electrons but different numbers of neutrons



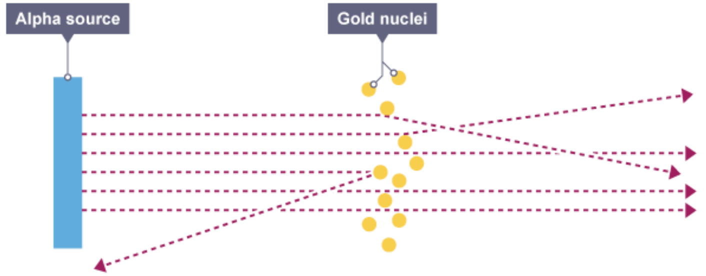
2. Development of the Atomic Model

- **Dalton** → atoms are indivisible spheres
- **Thompson** → discovered the electron and proposed the Plum Pudding Model



- **Rutherford** → alpha scattering experiment evidence for the Nuclear Model
- **Bohr** → concluded electrons orbit in fixed energy levels (shells)
- **Chadwick** → discovered the neutron

3. Evidence for the Nuclear Model



Observation	*Explanation*
Most of the alpha particles went straight through	The atom is mostly empty space (mass in one place – nucleus)
Some of the alpha deflected	Went near something positive (protons in the nucleus)
A few bounced back	Hit something heavy (concentrated mass in the nucleus)

Plum Pudding vs	*Nuclear Model*
Positive charge spread out	Positive charge concentrated in the nucleus
Electrons randomly arranged	Electrons in energy shells
No neutrons	Neutrons
Mass spread out	Mass concentrated in nucleus
No nucleus	Nucleus

4. Nuclear Decay

Isotopes of some elements are unstable because they contain too many or too few neutrons.

The nuclei of these unstable atoms will decay, emitting radiation, to become more stable.

Radiation type	Symbol	Structure	Penetrating power	Ionising power
ALPHA α	$^4_2\mathrm{He}$	2 protons & 2 neutrons	Stopped by few cm of air or thin paper	High
BETA β	$^{0}_{-1}\mathrm{e}$	High energy electron	Stopped by 3mm Aluminium	Low
GAMMA γ	$^0_0\gamma$	EM wave of energy	Reduced by thick lead and metres of concrete	Very low

5. Nuclear decay equations

An unstable nucleus changes into a new element by emitting **alpha particles** or **beta particles**. It is a random and spontaneous process unaffected by any chemical or physical changes. Nuclear decay equations show these changes:

- **Alpha decay:** The nucleus loses 2 protons and 2 neutrons. This changes the mass number by -4 and the atomic number by -2.

$$^{238}_{92}\mathrm{U} \longrightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

- **Beta decay:** Caused by too many neutrons. A neutron splits into a proton and an electron. This changes the mass number by 0 and the atomic number by +1 .

$$^{234}_{90}\mathrm{Th} \longrightarrow {}^{234}_{91}\mathrm{Pa} + {}^{0}_{-1}\mathrm{e}$$

- **Gamma decay** is a release of pure energy and will not change the structure of the nucleus in any way.

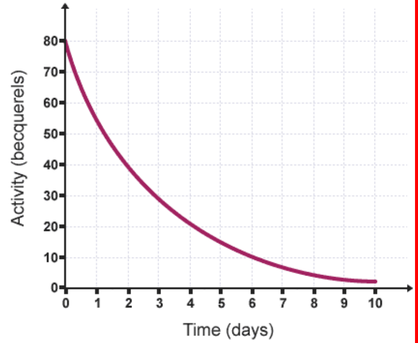
$$^{3}_{2}\mathrm{He} \longrightarrow {}^{3}_{2}\mathrm{He} + {}^{0}_{0}\gamma$$

6. Half Life

Nuclear decay happens **randomly**

Half life = the **time** it takes for half of the unstable nuclei in a sample to decay.

Count-rate = the number of decays recorded each second by a detector (eg. Geiger-Muller tube)



The graph shows it takes 2 days for the count to halve from 80 to 40. After a further 2 days, the count rate halves again, from 40 to 20. Therefore, the half life of this element is 2 days.

7. Irradiation & Contamination

Irradiation is the process of exposing an object to nuclear radiation. The object is sterilised but does not become radioactive.

Contamination is the unwanted presence of radioactive materials. The hazard comes from the decay of the contaminating atoms emitting harmful alpha, beta and gamma radiation.

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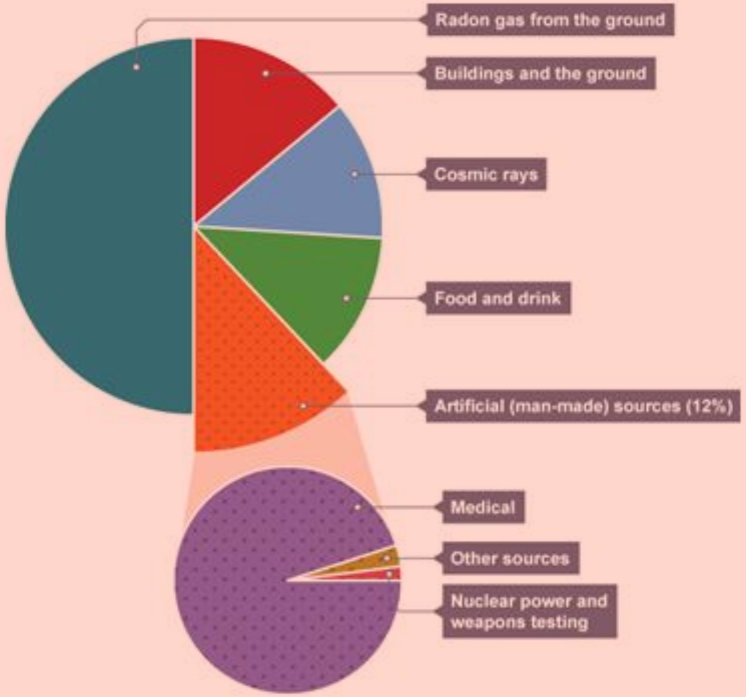
8. Background Radiation

Radioactive materials occur naturally and, as a result, everyone is exposed to a low-level of radiation every day. This exposure comes from a mixture of natural (rocks, cosmic rays) and man-made sources.



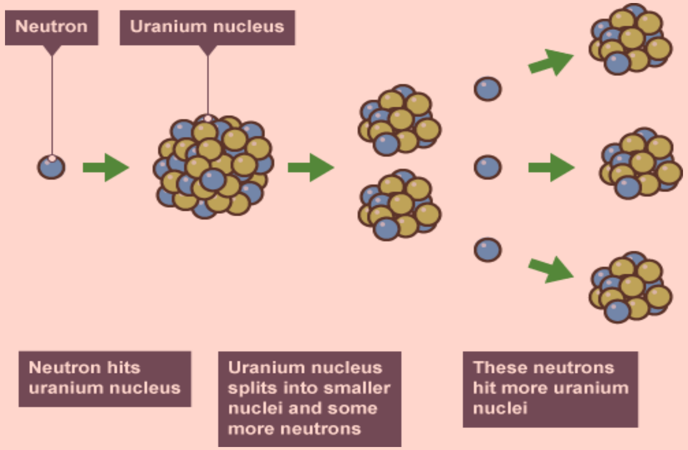
Background radiation affects everyone mainly by irradiation, but a small amount is from being contaminated by radioisotopes in the food and drink that is consumed.

The Becquerel (Bq) is a measure of the activity of the nucleus

The Sievert (Sv) is the unit to measure radiation dose and is the amount of damage that would be caused by the absorption of 1 joule of energy in each kilogram of body mass.

9. Nuclear Fission

The splitting of a large unstable nucleus into smaller nuclei.



In a nuclear reactor, a neutron is absorbed into a uranium nucleus creating violent instability.

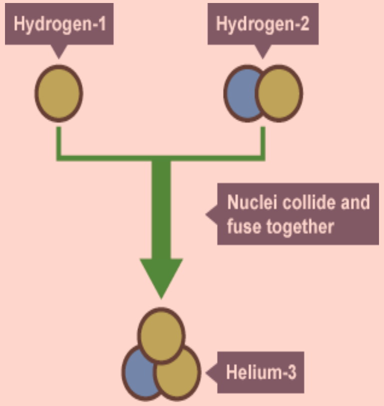
The entire nucleus splits into two large fragments called 'daughter nuclei' and additional neutrons also explode out which can collide with other uranium nuclei to cause further fission reactions.

This is known as a **chain reaction.**

The energy from the fast moving neutrons can be harnessed and used to heat water to drive the turbines that turn the generators.

10. Nuclear Fusion

Two small, light nuclei join together to make a heavier nucleus, releasing energy in the process.



Fusion reactions occur in stars where hydrogen nuclei fuse together to form a nucleus of a helium **isotope** eg:

$$4\,^1_1H \rightarrow \,^4_2He$$

In all nuclear reactions a small amount of the mass changes to energy.