

# **CIE Physics IGCSE**

## Topic 5: Atomic Physics Summary Notes



## The nuclear atom

An atom consists of:

- A **positively charged nucleus** made of:
  - Positive **protons**
  - Neutral **neutrons**
- Surrounded by **negatively charged electrons** which orbit the nucleus

The radius of the nucleus is a lot smaller than the radius of the entire atom. Almost all the mass of the atoms lies in the nucleus.

Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	0.0005	-1

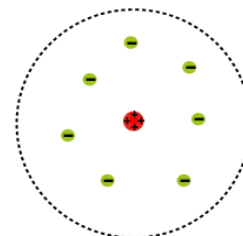
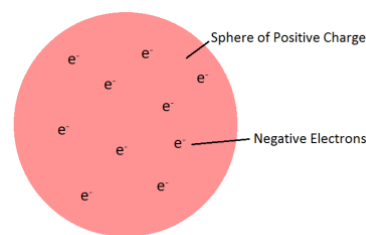
Atoms of the same element have the **same** number of protons. **Isotopes** are forms of an element's atom with the **same number of protons** but a **different number of neutrons**.

For a given nuclide  ${}^A_ZX$  :

- X is the **symbol** of the element
- A is the **nucleon number** (number of neutrons and protons)
- Z is the **proton number** (number of protons)

### Alpha particle scattering:

- An early model of the atom proposed by JJ Thomson was the **plum pudding model** - that the atom consisted of a **cloud of positive charge** with **negatively charged electrons dotted around inside it**.
- In Rutherford's scattering experiment, he aimed a beam of **alpha particles** at a **thin gold foil**. He concluded that:
  - The atom was composed primarily of **empty space** because most alpha particles passed straight through.
  - It had a nucleus which was **massive** and contained most of the mass of the atom because it deflected some alpha particles straight back.
  - The nucleus was **positively charged** because it repelled the positively charged alpha particles.



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### Nuclear fission:

- The process of **splitting a nucleus** is called **nuclear fission**
- **Uranium-235** is a commonly used isotope as the fuel in nuclear reactors
- When a Uranium-235 nucleus **absorbs a neutron**, it splits into **two daughter nuclei** and **2 or 3 neutrons**, releasing **energy** in the process
- The neutrons then can induce further fission events in a **chain reaction**

### Nuclear fusion:

- The process of **fusing two nuclei** to form a larger nucleus is called **nuclear fusion**
- **Energy** is released during this process
- Nuclear fusion is how the sun and other **stars** release energy



## Radioactivity

Radioactive decay is the **spontaneous** transformation of an **unstable** nucleus into a more **stable** one by the release of radiation. It is a **random** process which means one cannot know **what** nucleus will decay and **when** it will decay because it is down to chance.

Decay processes:

- Alpha:
  - A heavy nucleus emits an **alpha particle** (helium nucleus).
  - The nucleus changes to that of a different element **according to the following equation:**

$${}_Z^AX \rightarrow {}_{Z-2}^{A-4}Y + {}_2^4\alpha$$
  - They are **highly ionising** and **weakly penetrating**. **They are stopped by a sheet of paper.**
  - **They are slightly deflected** by electric and magnetic fields.
- Beta:
  - A neutron turns into a proton and emits a **beta particle** (electron)
  - The nucleus changes to that of a different element **according to the following equation:**

$${}_Z^AX \rightarrow {}_{Z+1}^AY + {}_{-1}^0e^{-}$$
  - They are **moderately ionising** and **moderately penetrating**. **They are stopped by a thin sheet of aluminium.**
  - **They are greatly deflected** by electric and magnetic fields.
- Gamma:
  - After a previous decay, a nuclei with excess energy emits a **gamma particle**.
  - Gamma particles are a form of electromagnetic radiation.
  - They are **lowly ionising** and **highly penetrating**. **They are stopped by many centimetres of lead.**
  - **They are not deflected** by electric and magnetic fields.

Some ways of detecting radiation include:

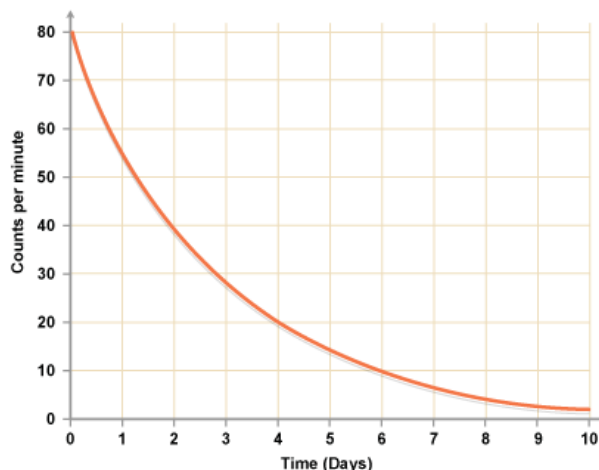
- Photographic film:
  - The more radiation absorbed by the film, the **darker** it gets (the film is initially white).
  - They are worn as **badges** by people who work with radiation, to check how much exposure they have had.
- Geiger-Muller tube:
  - A Geiger-Muller tube is a **tube** which can detect radiation.
  - Each time it absorbs radiation, it transmits an electrical pulse to the machine, which produces a **clicking sound**. The greater the frequency of clicks, the more radiation present.
- Cloud chamber:
  - A cloud chamber is a small **container** full of **water vapour**.
  - Alpha particles create **short, broad** tracks while beta particles produce **long, wispy** tracks.

Weak radiation that can be detected from **external** sources is called **background radiation**. Sources of background radiation include:

- Cosmic rays
- Radiation from underground rocks
- Nuclear fallout
- Medical rays



- The **half-life** of an isotope is the **time taken for half the nuclei to decay**, or the **time taken for the activity to halve**.
- In the graph, the count rate drops from 80 to 40 counts per minute in 2 days, which means the half-life is around 2 days.
- **Background radiation has to be subtracted before attempting to perform half-life calculations**



#### Uses of radioactivity:

- **Smoke detectors**
  - Long half life **alpha** emitters are used in **smoke detectors**.
  - Alpha particles cause a **current** in the alarm.
  - If smoke enters the detector, some of the alpha particles are **absorbed** and the current **drops**, triggering the alarm.
- **Thickness monitoring**
  - Long half life **beta** emitters can be used for **thickness monitoring** of metal sheets.
  - A source and receiver are placed on either side of the sheet during its production. If there is a **drop** or **rise** in the number of beta particles detected, then the thickness of the sheet has changed and needs to be **adjusted**.
- **Sterilisation of equipment**
  - **Gamma** emitters are used to **kill** bacteria or parasites on equipment so it is safe for operations.
- **Diagnosis and treatment**
  - Short half life **gamma** emitters such as technetium-99m are used as **tracers** in medicine as they concentrate in certain parts of the body.
    - The half life must be long enough for diagnostic procedures to be performed, but short enough to not remain radioactive for too long.
  - Other gamma emitters such as cobalt-60 can be used to **destroy** tumours with a **high dose** of radiation.

Exposure to radiation can **destroy living cell membranes** by **ionisation**, causing the cells to **die**, or **damage DNA** which causes **mutations** that could lead to **cancer**.

#### Safety measures include:

- **Minimising the time** of exposure to radiation. For example, radioactive tracers with a short half life should be used.
- Keeping as **big a distance** from the radioactive source as possible. They should be handled using tongs and held far away from people.
- Using **shielding** against radiation, such as the concrete shielding around a nuclear reactor. Radioactive sources must also be kept in a lead-lined box.

