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.

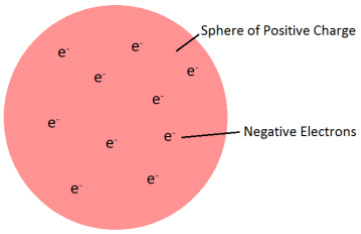
Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	0.0005	-1

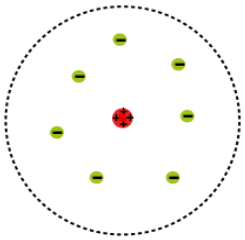
Atoms of the same element have the same number of protons. Isotopes are forms of an element's atom with the same number of protons but a different number of neutrons.
For a given nuclide ${}^{A}_{Z}X$:

- 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:** $^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$
  - 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:** $^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e^{-}$
  - 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.**

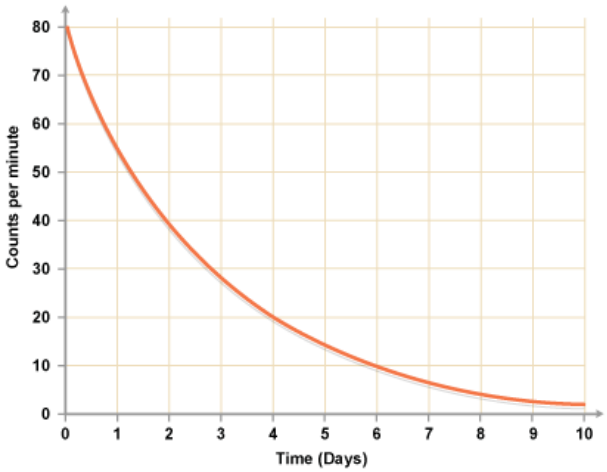
Some ways of detecting radiation include:

- 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.