WJEC (Wales) Physics GCSE

2.8: Half-life

Detailed Notes

(Content in **bold** is for higher tier **only**)

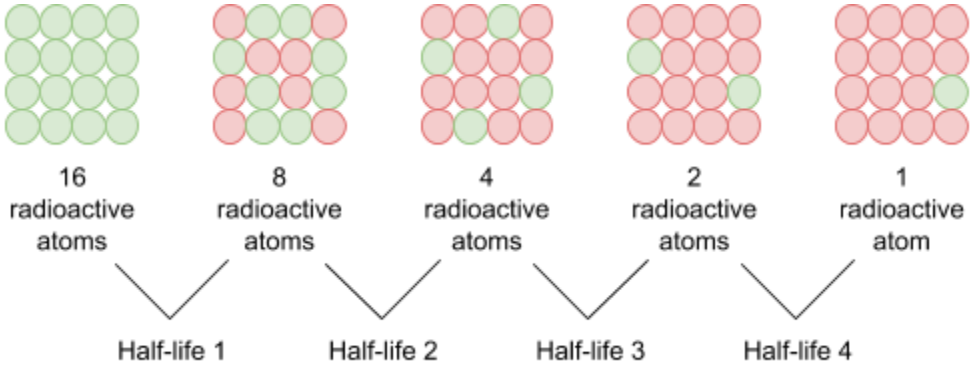
Radioactive Half-life

Random Decay Nature

Radioactive decay is **random** in nature meaning it is not possible to **predict** when a specific individual atom will decay. However, when measured over a longer period of time, an estimation of **half-life** can be made.

Half-life

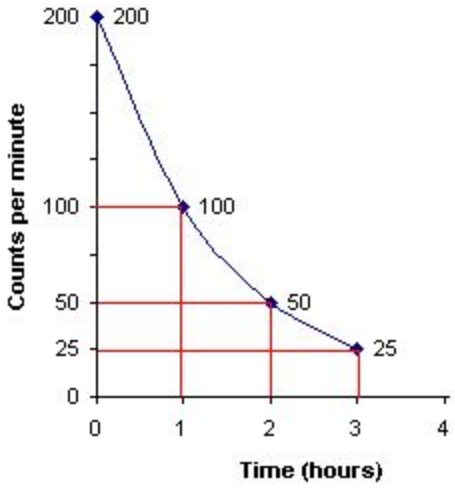
The half-life of a radioactive element is the time it takes for the **number of nuclei** of that element to **halve** or the time it takes for the **count-rate** of radioactive radiation to **halve**.



Half-life is **unique** to each radioactive element and can range from a few minutes to millions of years. It can be found experimentally but **many repeat readings** are required over a **long period** of time to calculate an accurate estimate.

Decay Curves

Graphs of **count-rate against time** can be used to determine the half-life of a radioactive substance. Every time the count-rate **halves**, a **half-life** has passed.



Count-rate - time graph for a radioactive element with a half-life of 1 hour (darvill.clara.net).

Common Radioactive Half-lives

Radioactive Isotope	Half-life
Uranium - 235	704 million years
Plutonium - 239	24,110 years
Carbon - 14	5,730 years
Technetium - 99m	6 hours
Polonium - 218	3 minutes

Uses of Radioactive Materials

Measuring Thickness

Beams of **beta radiation** can be used to monitor **thickness** of things like aluminium foil or paper. If at a **regular thickness**, the detector will pick up a **constant level** of radiation. Any **variation** in thickness will mean the level of radiation picked up will **differ**.

Sterilisation

Gamma radiation can be used to **kill microbes** and **sterilise** medical equipment.

Smoke Alarms

Alpha radiation is used in smoke alarms. The radiation **ionises the air** allowing an electrical current to flow between two **electrodes**. If smoke is present it will **block** this current, break the circuit and set off the alarm. Alpha sources tend to have **long half-lives** meaning they do not have to be constantly replaced in the detector.

Medical Tracers

Radioactive materials can be used **inside the body** to help image organs or monitor fluid flows. **Technetium-99m** (m for medical) is a **gamma source** with a half-life of just **6 hours**. It is injected into blood vessels to check for arterial blocks or internal bleeds by detecting it from outside the body.

The **short half-life** of Technetium-99m means it remains detectable for a reasonable amount of time for surgery but won't continue to emit radiation for long periods of time afterwards. If this were the case, it could be potentially dangerous for the patient.

Cancer Treatment

Gamma radiation is directed towards **cancerous cells** inside the body to kill them and prevent them from spreading. Long half-life sources are used so that they are **powerful** enough and don't need to be regularly changed. Prolonged exposure can be **dangerous** but for treating the disease, the benefits outweigh the risks.

Alpha radiation is used to kill cancerous cells inside the body by directly **injecting** into the tumour. This is **Targeted Alpha Therapy (TAT)**. The strong ionising power of alpha will kill the cell but its weak penetrating power means it **will not transfer** through the body to other healthy cells. This makes it better for certain treatments than gamma, which is highly penetrating.

Carbon Dating

Radioactive **carbon-14** is used to date organic ancient artefacts. Living plants and animals **absorb** carbon-14 when alive, but stop when they die. Therefore **isotope decay** takes place which follows a typical decay curve for carbon-14. As a result we can be used to work out **how many half-lives** have passed since the animal/plant from which the artefact was made died. This provides a reasonable estimate of **how old** the object is. Carbon-14 can be used to effectively date organic objects up to 100,000 years old.

Example:
Carbon-14 has a half-life of 5,730 years. An old bone has 25 % of the carbon-14 a living bone has. How old is the bone?

25% remaining means two half-lives have passed. Therefore two half-lives is 11,460 years, so the bone is this old.