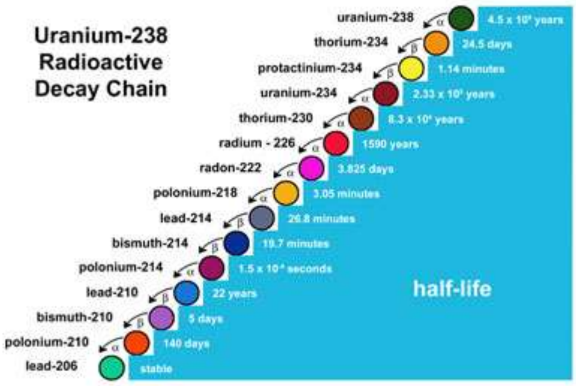
Topic 6 Half Life



Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the random nature of radioactive decay and to model the decay of a collection of atoms using a constant probability of decay, e.g. using a large collection of dice, coins or a suitably programmed spreadsheet

(b) how to plot or sketch decay curves for radioactive materials, understand that a given radioactive material has a characteristic half-life and determine the half-life of a material from the decay curve

(c) how to perform simple calculations involving the activity and half-life of radioactive materials in a variety of contexts, e.g. carbon dating

(d) the different uses of radioactive materials, relating to the half-life, penetrating power and biological effects of the radiation e.g. radioactive tracers and cancer treatment

SPECIFIED PRACTICAL WORK

Determination of the half-life of a model radioactive source, e.g. using dice

Modelling radioactive decay

A nucleus of an unstable atom has a fixed probability of decay. We can model its behaviour using a cube with a dot painted on one side. If you throw the cube and it lands with the dot facing up it has decayed. Its probability of decay is 1 in 6.

We use a large sample size to get more valid results – this smoothes out the random fluctuations in the data.

Half Life

The Half Life of a radioactive element is the time taken for half of the nuclei in a sample to decay

It is also the time taken for the activity of a radioactive substance to halve.

It is also the time taken for the mass of the sample to halve.

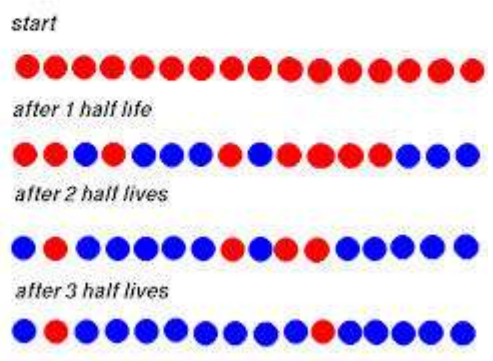
This value is fixed for each radioactive element and could be anything from fractions of a second to millions of years

The ACTIVITY is the number of decays occurring every second and it is measured in Becquerel's

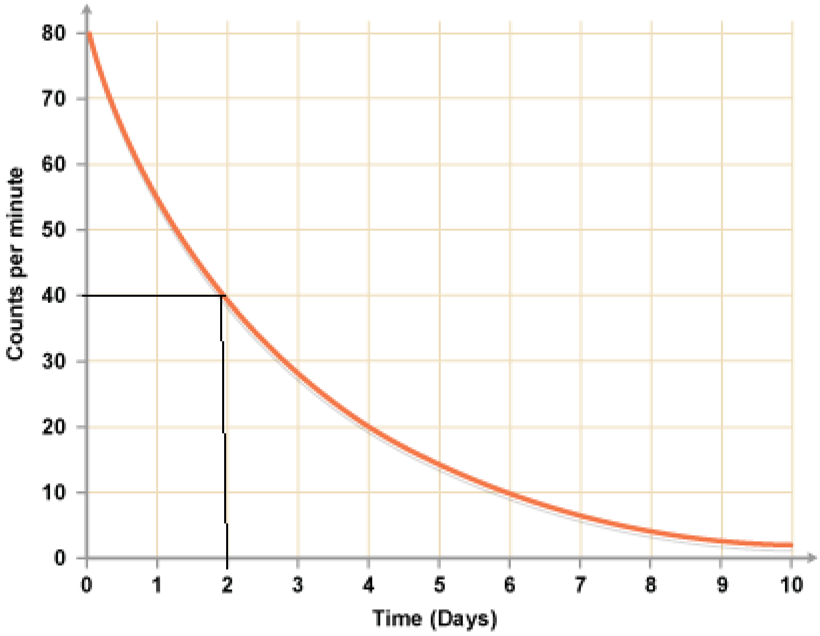
1Bq = 1 decay per second

After 1 half-life half of the original nuclei will have decayed forming a new nucleus. After 2 half-lives half of the remaining nuclei will now have decayed.

The red dots in the diagram below are the original nuclei and the blue dots represent the newly formed daughter nuclei.



Half-life is often represented on a graph



1. A substance has an initial activity of 1000Bq and a half-life of 8 days

a) Sketch a half-life graph for this substance

b) Calculate the activity after 5 half lives

c) After how many half-lives will the activity have fallen to 1/32 of its initial value?

2. A substance has a half-life of 10 minutes. It has an initial activity of 800 Bq. After how long will it's measured activity be 100 Bq?

Radioactive materials have a variety of uses and they are chosen because of their half-life and their penetrating properties (e.g. if they emit alpha, beta or gamma).

Radiotherapy

A long half-life gamma emitter is used to target tumours from the outside of the body (the source is not put into the patient). It has to be gamma so it can get to the tumour as it is the most penetrating. It also causes the least harm to healthy tissue as it is the least ionising. We use a long half-life so that the source does not have to be regularly changed.

Smoke Alarms

The source is a long half-life alpha emitter. If smoke enters the alarm it absorbs the alpha and stops it reaching a detector setting off the alarm. (Long half-life so we don't have to keep replacing the source). Alpha is used as it is the least penetrating and so is easily absorbed by smoke.

Tracers in medicine

These are short half-life gamma emitters. The source is injected into the patient so we want it to decay quickly to minimise harm. Gamma is used to be able to be easily detected outside the body. It also causes the least harm to healthy tissue as it is the least ionising. The tracer reveals, for example blood flow around the body.

Industrial Tracers

Used for detecting leaks in pipes. Short half-life gamma emitters are used so that they decay quickly to minimise any harm and gamma is the most penetrating so it can be easily detected at the surface. At the position of the leak more radioactivity is detected at the surface.

Thickness detectors

This is used in industry to control the thickness of a product e.g. paper or aluminium foil. A radioactive source is held above the material and a detector is placed the other side. A source is chosen that will be partly absorbed so if the thickness increases the count goes down and vice versa. This then sends a message to a computer to alter the thickness. A long half-life emitter is chosen so it doesn't need replacing often. For paper alpha emitters would be used and aluminium beta would be used.

Carbon dating

Carbon 14 is a radioactive form of carbon. It exists in a fixed proportion in the air compared to carbon 12. When plants are living they continually take in Carbon 14 so the percentage of Carbon 14 in the wood in a living tree is constant. When it dies the % of Carbon 14 it contains decays over time. As the half-life of carbon 14 is 5700 years, measuring the activity of carbon 14 in old wood can help age it (as long as it is old enough). The aging is done using a half-life curve.