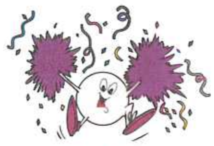
Half-Life

How quickly unstable nuclei decay is measured using activity and half-life — two very important terms.

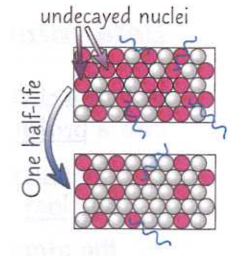
Radioactivity is a Totally Random Process

1) Radioactive sources contain radioactive isotopes that give out radiation from the nuclei of their atoms.
2) This process is entirely random. This means that if you have 1000 unstable nuclei, you can't say when any one of them is going to decay, or which one will decay next.



3) If there are lots of nuclei though, you can predict how many will have decayed in a given time based on the half-life of the source (see below). The rate at which a source decays is called its ACTIVITY. Activity is measured in becquerels, Bq. 1 Bq is 1 decay per second.
4) Activity can be measured with a Geiger-Müller tube, which clicks each time it detects radiation. The tube can be attached to a counter, which displays the number of clicks per second (the count-rate).
5) You can also detect radiation using photographic film. The more radiation the film's exposed to, the darker it becomes (just like when you expose it to light).

The Radioactivity of a Source Decreases Over Time



1) Each time a radioactive nucleus decays, one more radioactive nucleus disappears. As the unstable nuclei all steadily disappear, the activity as a whole will decrease.
2) For some isotopes it takes just a few hours before nearly all the unstable nuclei have decayed, whilst others last for millions of years.
3) The problem with trying to measure this is that the activity never reaches zero, so we have to use the idea of half-life to measure how quickly the activity drops off.

The half-life is the average time taken for the number of radioactive nuclei in an isotope to halve.

4) A short half-life means the activity falls quickly, because the nuclei are very unstable and rapidly decay. Sources with a short half-life are dangerous because of the high amount of radiation they emit at the start, but they quickly become safe. (Half-life can also be described as the time taken for the activity to halve.)
5) A long half-life means the activity falls more slowly because most of the nuclei don't decay for a long time — the source just sits there, releasing small amounts of radiation for a long time. This can be dangerous because nearby areas are exposed to radiation for (millions of) years.

EXAMPLE: The activity of a radioactive sample is measured as 640 Bq. Two hours later it has fallen to 40 Bq. Find its half-life.

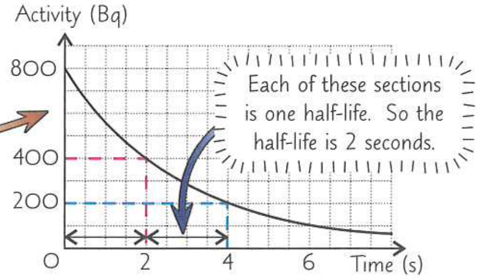
1) Count how many half-lives it took to fall to 40 Bq.

Initial activity:		after 1 half-life:		after 2 half-lives:		after 3 half-lives:		after 4 half-lives:
640	(÷2) →	320	(÷2) →	160	(÷2) →	80	(÷2) →	40

2) Calculate the half-life of the sample. Two hours is four half-lives — so the half-life is 2 hours ÷ 4 = 30 min

You Can Measure Half-Life Using a Graph

1) If you plot a graph of activity against time (taking into account background radiation, p.177), it will always be shaped like the one to the right.
2) The half-life is found from the graph by finding the time interval on the bottom axis corresponding to a halving of the activity on the vertical axis. Easy.



The half-life of a box of chocolates is about five minutes...

Half-life — the average time for the number of radioactive nuclei or the activity to halve. Simple.

Q1 A radioactive source has a half-life of 60 h and an activity of 480 Bq. Find its activity after 240 h. [2 marks]

Half-life

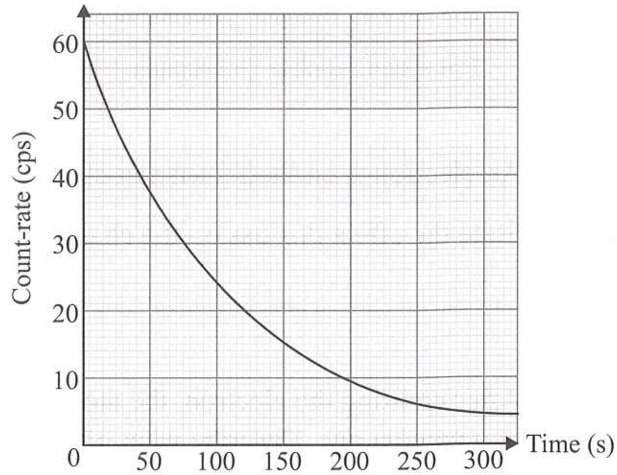
1 Each time an unstable nuclei in a sample decays, a 'count' is registered by a radiation detector. **Figure 1** shows how the count-rate of a radioactive sample changes over time, after background radiation has been taken into account. Grade 4-6

a) State what is meant by half-life. Your answer should refer to the number of undecayed nuclei.

....

.... *[1]*

Figure 1



b) Determine, using **Figure 1**, the half-life of the sample.

Half-life = ... s *[1]*

c) Initially, the sample contains approximately 800 undecayed nuclei. Predict how many of these nuclei will have decayed after two half-lives.

Number of decayed nuclei = ... *[2]*

d) After two half-lives, what is the ratio of the number of undecayed nuclei left to the initial number of undecayed nuclei?

☐ **A** 1:2 ☐ **B** 2:1 ☐ **C** 1:4 ☐ **D** 4:1

[1]

[Total 5 marks]

2 **Figure 2** shows data about two radioactive sources. Grade 6-7

Figure 2

	Isotope 1	Isotope 2	Isotope 3
Number of undecayed nuclei	20 000	20 000	20 000
Half-life	4 minutes	72 years	5 years

a) State the isotope that is the most unstable.

.... *[1]*

b) Explain which isotope will have the highest activity initially.

....

.... *[2]*

[Total 3 marks]

3 The activity of a radioisotope is 8800 Bq. Six hours later, the activity has fallen to 1100 Bq. Grade 6-7

a) Calculate how many half-lives have passed during the six hours.

Number of half-lives = ...

[3]

b) Calculate the radioisotope's half-life.

Half-life = ... hour(s)

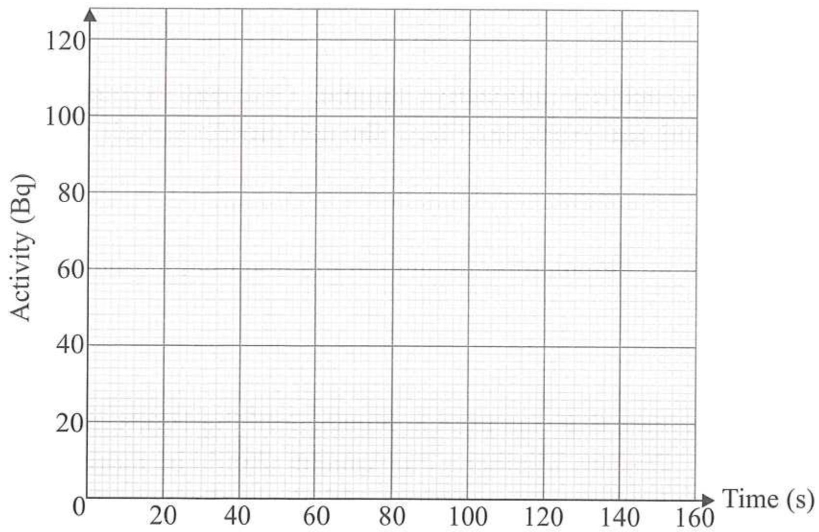
[1]

[Total 4 marks]

4 A radioactive sample has a 50 second half-life. The initial activity of the sample is 120 Bq. Grade 7-9

a) Complete the graph in **Figure 3** to show how the activity will change in the first 150 seconds.

Figure 3



[2]

b) Predict, using your graph in **Figure 3**, the activity of the sample after 40 seconds.

Activity = ... Bq

[1]

c) Estimate the activity after 200 s. Give your answer to one significant figure.
Explain why this estimate is less likely to be correct than your prediction in part b).

....

....

....

[4]

[Total 7 marks]

Exam Practice Tip

Half-life and activity are really important things to get your head around — they're a key thing to mention when talking about any radioactive substance. Remember that every activity-time graph showing radioactive decay has the same shape — radioactive decay is a random process, but by looking at lots of nuclei you can make fairly accurate estimates.