

Radiation and Half-life

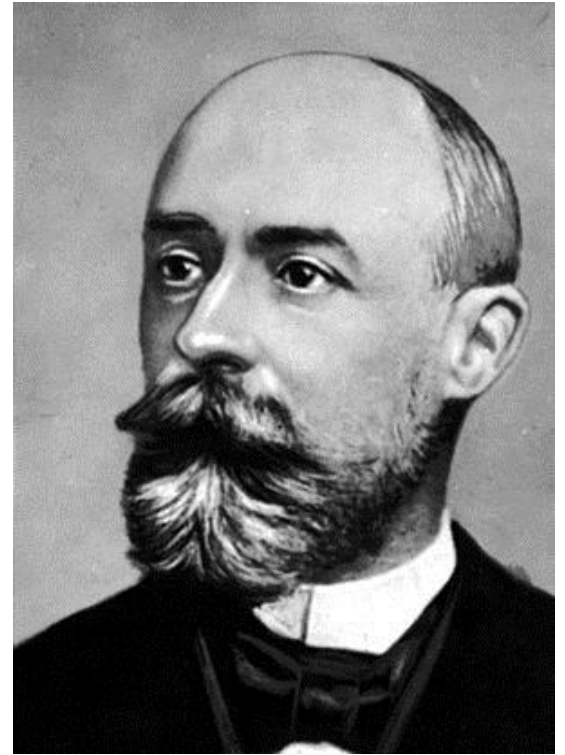
Physics Year 11 Term 2 Week 9

Activity

The activity of a radioactive source is equal to the number of decays per second.

Activity is measured in **becquerels (Bq)**

1 becquerel
= 1 decay per second



Henri Becquerel
discovered
radioactivity in 1896

Question 1

A radioactive source undergoes 72 000 decays over a ten minute period.

What is its average activity in becquerels?

Activity in becquerels equals decays per second.

72 000 per 10 minutes

= 72 000 / 10 per minute

= 72 000 / (10 x 60) per second

= 72 000 / 600

= 120 per second

Activity = 120 becquerel

Question 2

A radioactive source has an activity of 25 Bq.

How many decays would be expected over a 3 hour period?

Activity is 25 Bq

= 25 decays per second

= $(25 \times 60) = 1500$ decays in one minute

= $(1500 \times 60) = 90\,000$ decays in one hour

= $(90\,000 \times 3)$ decays in 3 hours

Number of decays in 3 hours = 270 000

Half-life

The activity of a radioactive sample decreases over time.

The **half-life** of a radioactive sample is the average time taken for half of the original mass of the sample to decay.

Half-lives of some radioactive isotopes

Uranium 238 = 4500 million years

Uranium 235 = 704 million years

Plutonium 239 = 24 100 years

Carbon 14 = 5600 years

Strontium 90 = 29 years

Hydrogen 3 (Tritium) = 12 years

Cobalt 60 = 5.2 years

Technetium 99m = 6 hours

Radon 224 = 60 seconds

Helium 5 = 1×10^{-20} seconds

Example 1 - The decay of a sample of strontium 90

Strontium 90 has a half-life of 29 years.

In 2012 a sample contains 19.2g of strontium 90

The mass of strontium 90 in the sample halves every 29 years.

Year	Mass of strontium 90 (g)
2012	18.2
2041	9.6
2070	4.8
2099	2.4
2128	1.2
2157	0.60

When will the mass have fall to **0.15 g**?

2215

Question 1

At 10am in the morning a radioactive sample contains 80g of a radioactive isotope. If the isotope has a half-life of 20 minutes calculate the mass of the isotope remaining at 11am.

10am to 11am = 60 minutes

= 3 x 20 minutes

= 3 half-lives

mass of isotope = $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times 80\text{g}$

mass at 11 am = 10g

Question 2

Calculate the half-life of the radioactive isotope in a source if its mass decreases from 24g to 6g over a period of 60 days.

$$24\text{g} \times \frac{1}{2} = 12\text{g}$$

$$12\text{g} \times \frac{1}{2} = 6\text{g}$$

therefore **TWO** half-lives occur in 60 days

half-life = 30 days

Other ways of defining half-life

In terms of activity of a source:

The **half-life** of a radioactive source is the average time taken for the activity of the source to decrease to half of its initial value.

In terms of the number of nuclei:

The **half-life** of a radioactive isotope is the average time it takes for half of the nuclei of the isotope to decay into some other isotope.

Example 2 – The decay of source Z

Source Z decays with a half-life of three hours.

At 9 am the source has an activity of 16000 Bq

The activity halves every three hours.

<i>Time</i>	<i>Activity (Bq)</i>
9 am	16000
12 noon	8000
3 pm	4000
6 pm	2000
9 pm	1000
midnight	500

When will the activity have fallen to **125 Bq**? **6 am**

Example 3 – The decay of isotope X

Isotope X decays to Isotope Y with a half-life of 2 hours.

At 2 pm there are 6400 nuclei of isotope X.

<i>Time</i>	<i>Nuclei of X</i>	<i>Nuclei of Y</i>
2 pm	6400	0
4 pm	3200	3200
6 pm	1600	4800
8 pm	800	5600
10 pm	400	6000
midnight	200	6200

When will the nuclei of isotope X fallen to 25?

6 am

Question 3

A radioactive source has a half-life of 3 hours.

At 8 am it has an activity of 600 Bq.

What will be its activity at 2 pm?

at 8 am activity = 600 Bq

2 pm is 6 hours later

this is 2 half-lives later

therefore the activity will halve twice

that is: $600 \Rightarrow 300 \Rightarrow 150$

activity at 2 pm = 150 Bq

Question 1 – The decay of substance P

Substance P decays to **substance Q** with a half-life of 15 minutes. At 9 am there are 1280 nuclei of **substance P**. Complete the table.

<i>Time</i>	<i>Nuclei of X</i>	<i>Nuclei of Y</i>
9 am	1280	0
9:15	640	640
9:30	320	960
9:45	160	1120
10 am	80	1200
10:15	40	1240

How many nuclei of **substance X** will be left at 11 am? **5**

Question 4

A sample contains 8 billion nuclei of hydrogen 3 atoms. Hydrogen 3 has a half-life of 12 years. How many nuclei should remain after a period 48 years?

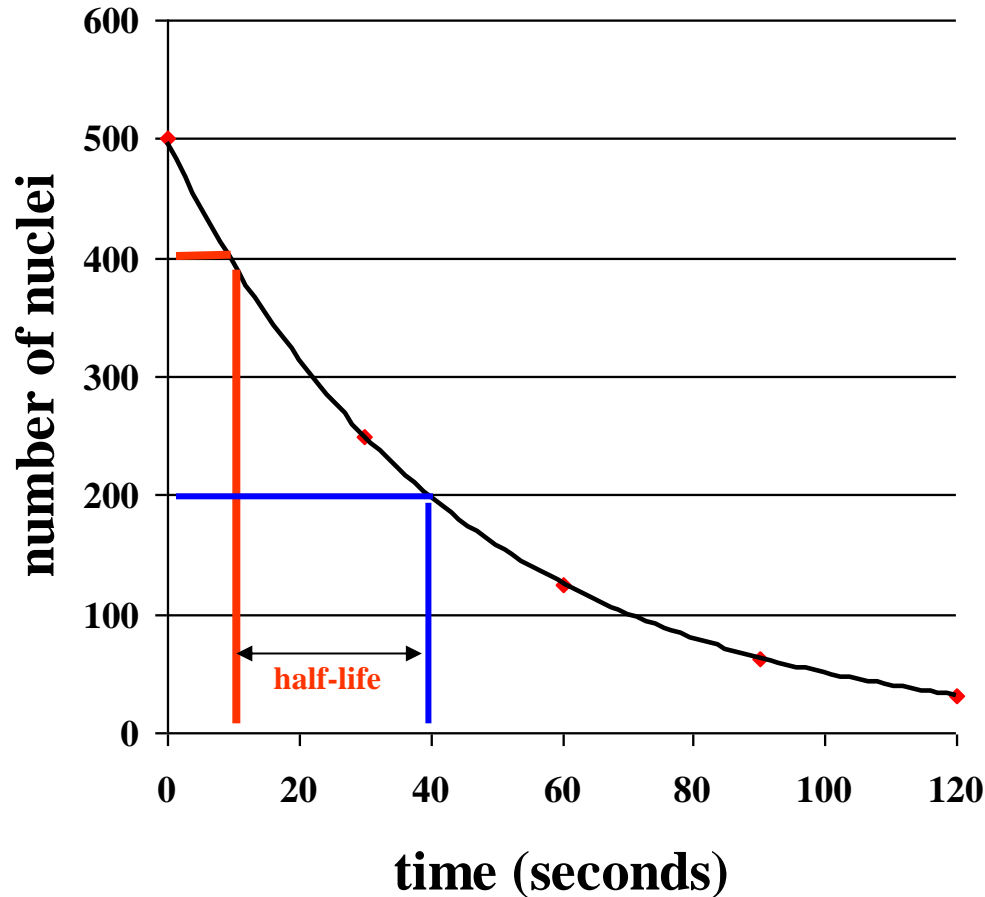
48 years = 4 x 12 years

= FOUR half-lives

nuclei left = $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times 8$ billion

nuclei left = 500 million

Finding half-life from a graph



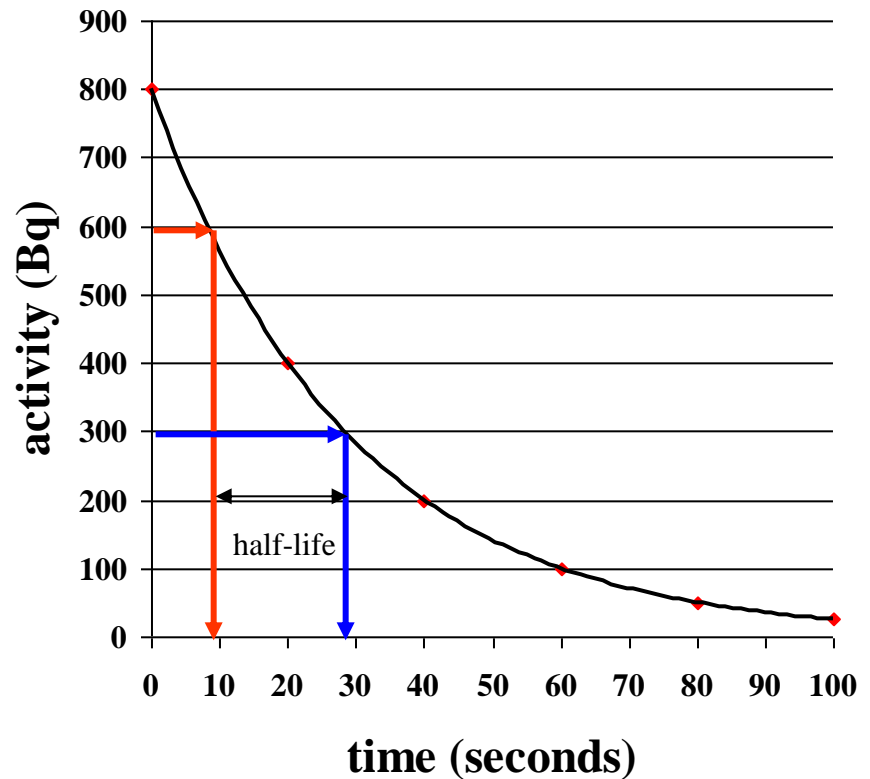
The half-life in this example is about 30 seconds.

A more accurate value can be obtained by repeating this method for a other initial nuclei numbers and then taking an average.

Question 1

Estimate the half-life of the substance whose decay graph is shown opposite.

The half-life is approximately 20 seconds



Choose appropriate words or numbers to fill in the gaps below:

The half-life of a radioactive substance is the average time taken for half of the nuclei of the substance to decay. It is also equal to the average time taken for the activity of the substance to halve.

The half-life of carbon 14 is about 5600 years. If today a sample of carbon 14 has an activity of 3400 Bq then in 5600 years time this should have fallen to 1700 Bq. 11200 years later the activity should have fallen to 425 Bq.

The number of carbon 14 nuclei would have also decreased by eight times.

WORD & NUMBER SELECTION:

5600 nuclei eight half-life 425 1700 activity