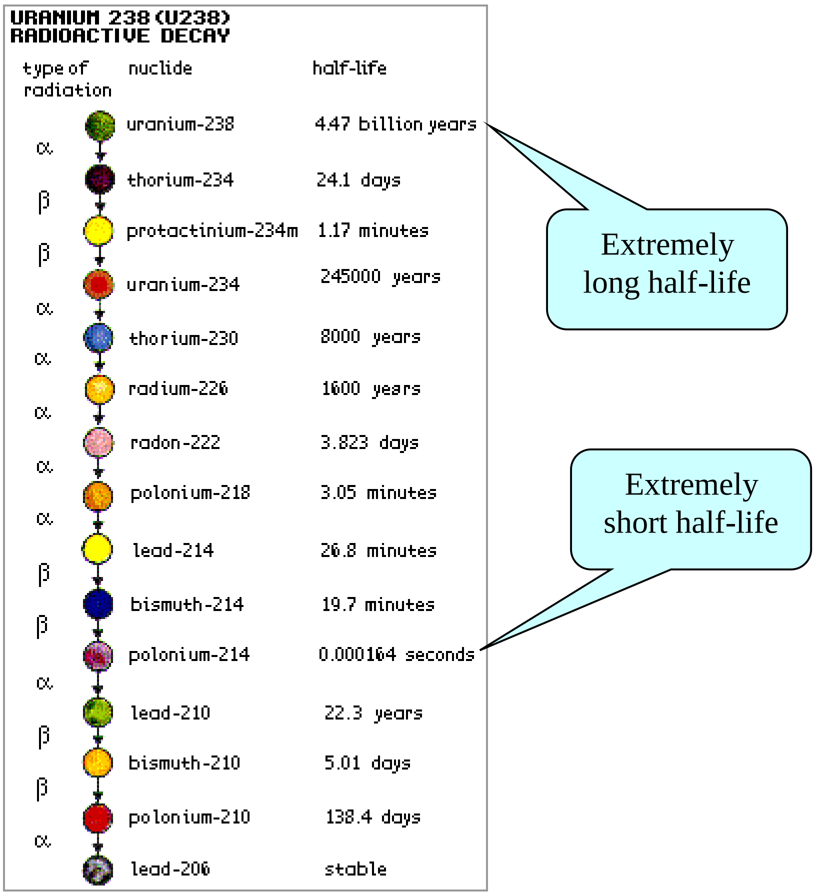
Section 2 – Nuclei Half Life

Half Life

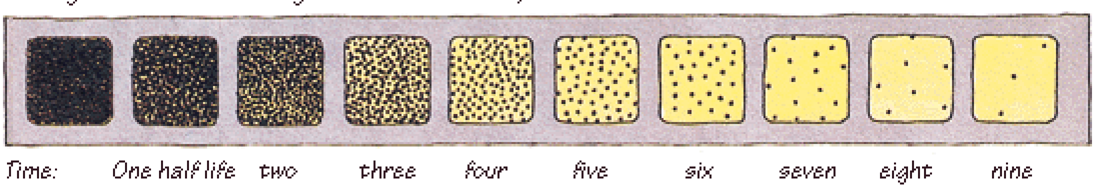
Different radioisotopes emit radiation at different **rates.**

Eg. Polonium – 218, hardly detectable after 30 minutes
Uranium – 234, still detectable after 1000000 years

It is difficult, or rather impossible, to measure a time at which a radioisotope becomes non radioactive. Rather the term **half-life** is used to describe the time taken for **½** a radioactive sample to decay. Consider the following example:



Decay rate of radioactivity: After ten half lives, the level of radiation is reduced to one thousandth



Half Life Calculations

When you project **forwards** in time, the number of radioactive nuclei **decreases.**
When you project **backwards** in time, the number of radioactive nuclei **increases.**

Time	**Backwards**			**Current**	**Forwards**		
	3 Half Lives	2 Half Lives	1 Half Life		1 Half Life	2 Half Lives	3 Half Lives
n(half lives)	**3**	**2**	**1**	**0**	**1**	**2**	**3**
Fraction remaining	x 8	x 4	x 2	x 1	x 1/2	x 1/4	x 1/8
	x (2^3)	x (2^2)	x (2^1)	x(2^0)	x $1/(2^1)$	X $1/(2^2)$	X $1/(2^3)$

Increase the number of radioactive nuclei

Fraction remaining = 2^n

Decrease the number of radioactive nuclei

Fraction remaining = $\frac{1}{2^n}$

Eg.1 Sodium-24 is used as a medical tracer and has a half-life of 15 hours.
i. What fraction remains after 45 hours?
ii. How many grams of the original 20 grams sample with remain after 45 hours?

Fraction Remaining = ?
t = 45 hrs
$t_{1/2}$ = 15 hrs
∴ n = $\frac{45}{15}$ = 3 half lives

Fraction remaining = $\frac{1}{2^n}$
= $\frac{1}{2^3}$
= $\frac{1}{8}$

Amount (A) = ?
Original Amount (A_o) = 20 grams
Fraction Remaining = $\frac{1}{8}$

A = A_o x Frac
= 20 x $\frac{1}{8}$
= **<u>2.5 grams</u>**

Eg.2 Seaborgium-266 is a synthetic element that has a half-life of 30 seconds.
i. What fraction remains after 2 minutes?
ii. Given its original activity was 32 kBq (32000 decays per second), what would be its activity after 2 minutes?

Fraction Remaining = ?
t = 2 min = 120 sec
$t_{1/2}$ = 30 sec
∴ n = $\frac{120}{30}$ = 4 half lifes

Fraction remaining = $\frac{1}{2^n}$
= $\frac{1}{2^4}$
= $\frac{1}{16}$

Activity (A) = ?
Original Activity (A_o) = 32 kBq
Fraction Remaining = $\frac{1}{16}$

A = A_o x Frac
= 32000 x $\frac{1}{16}$
= **<u>2000 Bq</u>**
= **<u>(2 kBq)</u>**

NB: One unit used to measure radioactivity is the **Becquerel**.
1 Becquerel represents 1 decay per second
(1 Bq = 1 decay/sec)

Eg.3 Carbon-11is used for medical treatment. A sample of C-11 has a half-life of 20 minutes and an activity of 1 kBq.

i. What fraction remains after 1 hour <u>prior</u> to this point in time?
ii. What would its activity be 1 hour <u>prior</u> to this point in time?

(**NB**: going "back: in time increases the number of radioactive nuclei & activity)

Fraction Remaining = ?
t = 1 hr = 60 min
$t_{1/2}$ = 20 mins
$\therefore$ n = $\frac{\mathbf{60}}{\mathbf{20}}$ = 3 half lifes

Fraction remaining = $\mathbf{2^n}$
= $\mathbf{2^3}$
= **8**

Activity (A) = ?
Original Activity (A_o) = 1 kBq
Fraction Remaining = 8

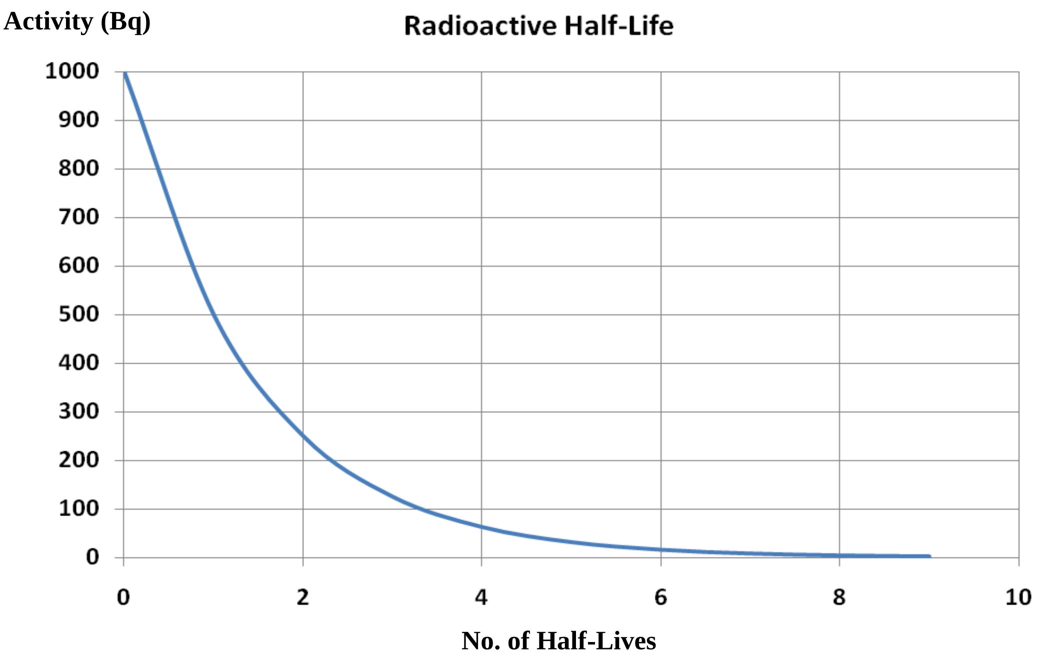
A = A_o x Frac
= 1000 x $\mathbf{8}$
= <u>**8000 Bq**</u>
= <u>**(8 kBq)**</u>

Eg.4 A sample of Thorium-234 contains 8.0 x 10^{12} nuclei. The half-life of Th-234 is 24 days. How many Thorium-234 atoms will remain in the sample after:

i. 24 days
ii. 48 days
iii. 96 days

Ans. i. 4.0 x 10^{12} ii. 2.0 x 10^{12} iii. 5.0 x 10^{11}

Task: Sketch the radioactive decay of a radioactive sample with an original activity of 1000 Bq. Note, the time axis is measured in half-life quantities.



Radioactive Series

It is quite common that the decay of a radioactive isotope produces a daughter nucleus, which is itself also radioactive. When this second isotopes undergoes decay, there is again a strong possibility that it too will produce yet another radioactive isotope. This chain of events can occur several times before finally a stable isotope is formed.

Such a sequence of subsequent decays is known as a **decay series** or a **decay chain**.

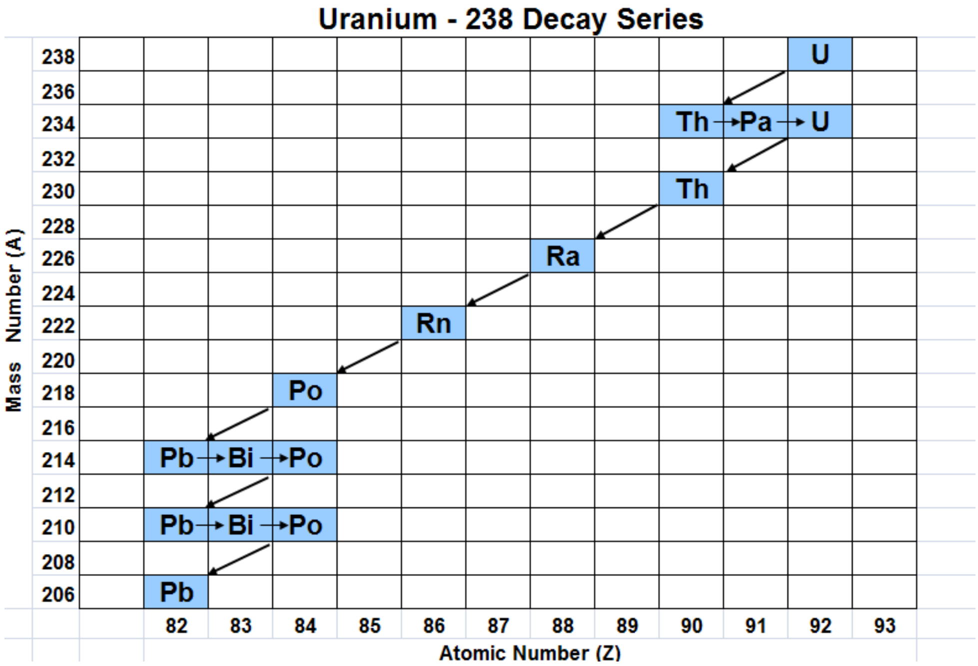
Eg.1 The decay series for Thorium – 232

Decay No.	Isotope	Radiation	Half Life
1	Thorium - 232	α	14 billion years
2	Radium - 228	β	5.8 years
3	Actinium - 228	β	6.1 hours
4	Thorium - 228	α	1.9 years
5	Radium - 224	α	3.7 days
6	Radon - 220	α	56 seconds
7	Polonium - 216	α	0.15 second
8	Lead – 212*	β	11 hours
9	Bismuth – 212*	β	61 minutes
10	Polonium - 212	α	301 nanoseconds
	Lead – 208	Stable	

* Indicates that a significant emission of gamma radiation also occurs.

NB: Thorium – 232 takes 10 individual decays before finally reaching the final stable isotope of Lead -208
At any given time, several different isotopes and radiation forms can be present

Eg.2 Consider the following decay series of Uranium – 238
Identify and annotate the type of radiation emitted (α or β).



Exam Styled Questions

Question 1

If Matilda has 5 kg of a radioactive material that has a half-life of 14 h, how much will be left after 1 week? Write your answer in *grams*.

24 h x 7 days = 168 h

$\frac{168}{14}$ = 12 half-lives

5 x $(\frac{1}{2})^{11}$ = 0.00122kg

= **1.22 g**

Question 2

Angus has also got his hands on some radioactive material. He notices that of the 100 g that he had 6 h ago, he now has only 25 g. What is the half-life of the radioactive material?

100 g $\rightarrow$ 50 g is 1 half-life
50 g $\rightarrow$ 25 g is 2 half-lives
2 half-lives in 6 hours
$\therefore$ 1 half-life is **3 hours**

Question 3

A radioactive material is measured to have 5.12×10^5 decays per second. In 4 half-lives, what will be the activity, in Bq?

$5.12 \times 10^5 \times (\frac{1}{2})^4$
= 32000 Bq
= **32 kBq**