

# Ionising Radiation and Nuclear Reactions

## Set 6: Half Life

Time for Activity to 'Half' is the half life time.

$A_0$  = Initial Activity

$A_T$  = Activity after a period of time

$t_{1/2}$  = Half life time

Number of nuclei is directly related to the Activity (Bq)

6.1

- a. 22 hrs
- b.  $\frac{1}{2}$
- c. After 44 hours 2 half-life would have gone by.  
 $\frac{1}{2} \times \frac{1}{2}$  (2 half-lives) =  $\frac{1}{4}$  of original radioisotope remaining.

6.2

In a graph use the Activity on the y axis. If the  $A_0$  = Initial Activity (Bq) = 500 MBq and at an  $A_T$  = 250 MBq then one half-life would have gone by. Record the time on the x axis.

- a.  $t_{1/2}$  = 6 hrs
- b. From 500 MBq to 'about 2' MBq would require around 8 half-lives to have gone by.

6.3

$t_{1/2}$  = 30 years

1 Half-life	2 Half-life's	3 Half-life's	4 Half-life's	4 half life's
$1/2$	$\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$	$\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = 1/8$	$\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = 1/16$	

$$\begin{aligned}
 t &= n \times t_{1/2} \\
 &= 4 \times 30 \\
 &= 120 \text{ years}
 \end{aligned}$$

6.4

$t_{1/2}$  = 14.3 days  
 $A_0$  = 2.40 MBq

1 Half-life	2 Half-life's	3 Half-life's
14.3	28.6	42.9

$$\begin{aligned}
 A_T &= A_0 \times \frac{1}{2}^n \\
 &= 2.4 \times \frac{1}{2}^3 \\
 &= 0.3 \text{ MBq}
 \end{aligned}$$

6.5

$t_{1/2}$  = ?  
 $A_0$  = 2048 Bq  
 $A_T$  = 128 counts / min = 2.133 Bq  
 $t$  = 150 mins

Half live n	1	2	3	4	5	6	7	8	9	10
$A_0$ = 2048 Bq	1024	512	256	128	64	32	16	8	4	2

or

$$\begin{aligned}
 A_T &= A_0 \times \frac{1}{2}^n \\
 2.1333 &= 2048 \times \frac{1}{2}^n \\
 n &= 9.907
 \end{aligned}$$

$$\begin{aligned}
 \text{Half-life} &= T/n \\
 &= 150/9.907 \\
 &= 15.1 \text{ mins (3sf)}
 \end{aligned}$$

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6.6

$$t_{1/2} = 12 \text{ hrs}$$

$$A_0 = ? \text{ Bq}$$

$$A_T = 800000 \text{ Bq}$$

a.  $t = 24 \text{ hrs before}$   
 $n = 2$

$$A_T = A_0 \times \frac{1}{2}^n$$

$$A_0 = A_T / \frac{1}{2}^2$$

$$A_0 = 800000 / \frac{1}{4}$$

$$= 3.20 \times 10^6 \text{ Bq (3sf)}$$

b.  $t = 24 \text{ hrs after}$   
 $n = 2$

$$A_T = A_0 \times \frac{1}{2}^2$$

$$A_T = 800000 \times \frac{1}{4}$$

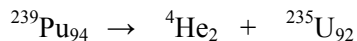
$$= 2.00 \times 10^6 \text{ Bq (3sf)}$$

6.7

$$\text{Number of atoms} = 1.00 \times 10^{24}$$

$$t_{1/2} = 2.41 \times 10^4 \text{ yrs}$$

- a. After 1 half-life  $0.5^1 \times 1.00 \times 10^{24} = 5.00 \times 10^{23}$  atoms  
 b. With Alpha decay ensure the sum of nucleons are conserved and that the number of protons remains the same.



6.8

$$t_{1/2} = 5.30 \text{ yrs}$$

$$A_0 = 800 \text{ GBq}$$

$$A_T = 128 \text{ counts / min} = 2.133 \text{ Bq}$$

a.  $t = 26.0 \text{ yrs}$   
 $n = 26/5.3 = 4.90 \text{ half-lives}$

Half live n	1	2	3	4	5
$A_0 = 800$ GBq	800	400	200	100	50

b.  $t_{1/2} = 5.3 \text{ yrs}$   
 $A_0 = 800 \text{ GBq}$   
 $A_T = 0.001 \times 800 \text{ GBq} = 0.8 \text{ GBq}$

Half live n	1	2	3	4	5	6	7	8	9	10	11
$A_0 = 800$ GBq	800	400	200	100	50	25	12.5	6.25	3.125	1.56	0.78

After 10 half-lives

$$t = n \times t_{1/2}$$

$$= 10 \times 5.3 \text{ yrs}$$

$$= 5 \text{ decades (1sf)}$$

or

$$A_T = A_0 \times \frac{1}{2}^n$$

$$0.8 = 800 \times \frac{1}{2}^n$$

$$n = 9.965$$

$$\text{Half-life} = T/n$$

$$= 5.3/9.965$$

$$= 52.8 \text{ (3sf)}$$

$$= 5 \text{ decades (1sf)}$$

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6.9

Given that there is the same number of nuclei, Sample X will have the higher activity as it has the lowest half-life. After 8 seconds half of the nuclei should have decayed thus more particles should be emitted and then detected.

6.10

$$\begin{aligned}
 t_{1/2} &= 2.70 \text{ days} \\
 A_0 &= 8.00 \text{ MBq} \\
 A_T &=? \\
 t &= 7.00 \text{ days}
 \end{aligned}$$

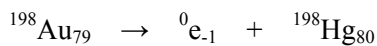
Half live n	1	2	3
A <sub>0</sub> = 8.00 MBq	4.00	2.00	1.00

$$\begin{aligned}
 n &= 7 / 2.7 \\
 &= 2.60 \text{ half-lives} \\
 A_T &= 1.5 \text{ MBq (2sf)}
 \end{aligned}$$

or

$$\begin{aligned}
 A_T &= A_0 \times \frac{1}{2}^n \\
 A_0 &= 8.00 \times \frac{1}{2}^{2.6} \\
 A_0 &= 1.32 \text{ MBq (3sf)}
 \end{aligned}$$

With Beta the number of protons will increase by 1 proton. The number of nucleons will still remain the same. Remember 1 neutron is changing into a proton and emitting an electron.



6.11

There is less C-14 in old bone compared to new bone due to the fact the animal has long dies and as such stopped absorbing C-14 from the atmosphere.

6.12

$$A_T / A_0 = 12.5 \% = 0.125$$

Half live n	1	2	3	4
%	50	25	12.5	6.25

$$\begin{aligned}
 n &= 3 \\
 t &= 3 \times t_{1/2} \\
 &= 3 \times 5730 \text{ yrs} \\
 &= 1.72 \times 10^4 \text{ yrs}
 \end{aligned}$$

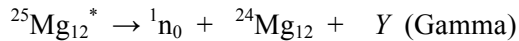
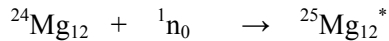
6.13

- a. Use an Activity vs Time graph to determine half-life. Use the activity decrease to determine 3 half-life times. Average these times.  
 $t_{1/2} = 20\text{-}21 \text{ mins}$
- b. Likely to be Alpha. Beta and Gamma will still move through the Al foil.

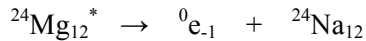
# Ionising Radiation and Nuclear Reactions

6.14

a. With neutron bombardment add one nucleon on. Ensure remains same element.



With Beta the number of protons will increase by 1 proton. The number of nucleons will still remain the same. Remember 1 neutron is changing into a proton and emitting an electron.



b. 90% remaining means  $A_T / A_0 = 0.9$

$$A_T = A_0 \times \frac{1}{2}^n$$

$$A_T / A_0 = 0.9 \times \frac{1}{2}^n$$

$$n = 0.152$$

$$\begin{aligned} t &= 0.152 \times t_{1/2} \\ &= 0.152 \times 15.0 \text{ hrs} \\ &= 2.28 \text{ hrs (3sf)} \end{aligned}$$

6.15

a.  $n = 20 \text{ days} / 4 \text{ days}$   
 $= 5 \text{ half-lives}$

$$\begin{aligned} A_T &= A_0 \times \frac{1}{2}^n \\ &= 3.80 \text{ kBq} \times \frac{1}{2}^5 \\ &= 119 \text{ Bq (3sf)} \\ &= 100 \text{ Bq (1sf)} \end{aligned}$$

b.

More harmful?

Both are Alpha which is bad.

With higher activity Polonium would be worse if present in the body. A lot of energy released in a short period of time.

Radon is a gas so it can easily enter the lungs.

6.16

$$A_T = A_0 \times \frac{1}{2}^n$$

$$A_T / A_0 = 0.95 \times \frac{1}{2}^n$$

$$n = 0.07400$$

$$\begin{aligned} t &= 0.07400 \times t_{1/2} \\ &= 0.07400 \times 28.9 \text{ yrs} \\ &= 2.13 \text{ yrs} \end{aligned}$$

# Ionising Radiation and Nuclear Reactions

6.17

$$A_T / A_0 = 15 / 200$$

$$A_T = A_0 \times \frac{1}{2}^n$$

$$A_T / A_0 = 0.075 \times \frac{1}{2}^n$$

$$n = 3.74$$

$$t = 3.74 \times t_{1/2}$$

$$= 3.74 \times 5730 \text{ yrs}$$

$$= 21413 \text{ yrs}$$

$$= 2.41 \times 10^4 \text{ yrs (3sf)}$$

6.18

- Because of the short half-lives, they will decay from the natural environment. May be present in extremely small amounts.
- Because they are naturally occurring and are usually part of a common decay sequence with the environment. Amount is continually being 'produced' from the decay of other naturally occurring isotopes.