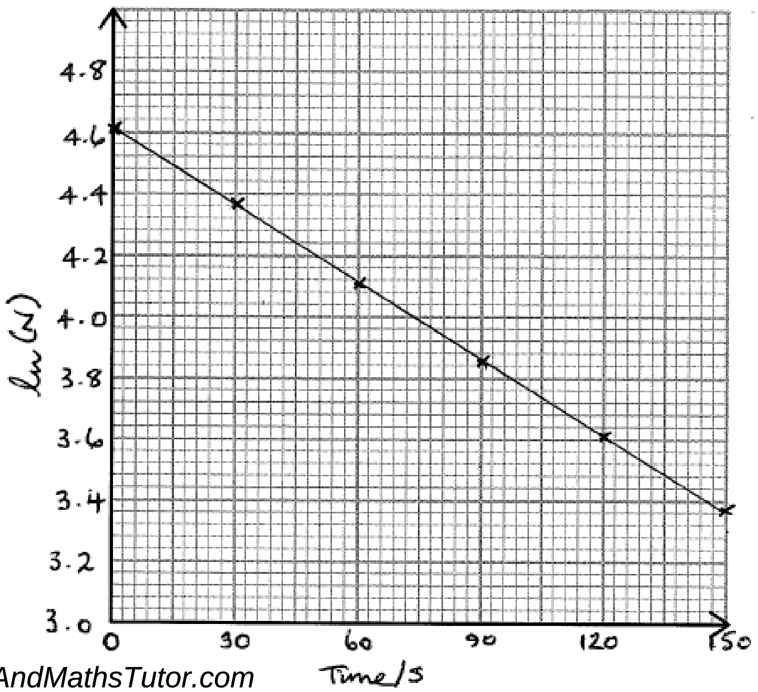
Question Number	Answer	Mark
1 (a)(i)	Use of $\lambda . t_{1/2} = \ln 2$ (1) $\lambda = 5.8 \times 10^{-8}$ (s^{-1}) (1) Use of $\frac{\Delta N}{\Delta t} = -\lambda$ N (1) $\frac{\Delta N}{\Delta t} = (-)1.5 \times 10^{8}$ Bq [accept s^{-1} **Or** counts s^{-1}] (1) <u>Example of calculation</u> $\lambda = \frac{0.693}{(138 \times 24 \times 3600)s} = 5.81 \times 10^{-8} s^{-1}$ $\frac{\Delta N}{\Delta t} = -5.81 \times 10^{-8} \text{s}^{-1} \times 2.54 \times 10^{15} = -1.48 \times 10^{8}$ Bq	**4**
1(a)(ii)	Use of $N = N_0 e^{-\lambda t}$ (1) Fraction of nuclei remaining = 0.90 (1) 10% of nuclei have decayed [accept 0.1 **Or** 1/10] (1) <u>Example of calculation</u> t = 21 × 24 × 3600 s = 1 814 400 s $\frac{N}{N_0} = e^{-5\ 81 \times 10^{-8} s^{-1} \times 1\ 81 \times 10^{6} s}$ $\frac{N}{N_0} = e^{-0\ 105} = 0.900$ Fraction decayed = 1- 0.9 = 0.1	**3**
1(b)	Idea that α-particles are not able to penetrate the (dead layer of) skin (from outside the body) (1) Damage/danger if energy is transferred to cells/DNA **Or** damage/danger to cells/DNA due to ionisation (1)	**2**
1 (c)(i)	$^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}\alpha$ Top line correct (1) Bottom line correct (1)	**2**
1 (c)(ii)	So that momentum is conserved (1)	**1**
1 (d)	Spontaneous means that the decay cannot be influenced by any external factors. (1) Random means that we cannot identify which atom/nucleus will (be the next to) decay **Or** we cannot identify when an individual atom/nucleus will decay **Or** we cannot state exactly how many atoms/nuclei will decay in a set time (1) **Or** we can only estimate the fraction of the total number that will decay in the next time interval	**2**

1(e)	Idea that traces of the isotope will be excreted from the body (and deposited in the surroundings) (1) Idea that the half life is long enough for the activity to be detectable for a long time (1)	**2**
	Total for question	**16**

Question Number	Answer		Mark
2(a)	**Max 4 with at least ONE similarity and ONE difference** **Similarities**:		
	• Radioactive decay and corn popping are both random events **Or** the time at which any given nucleus will decay **and** any kernel will pop cannot be predicted **Or** can't tell which nucleus will decay **nor** which kernel will pop next	**(1)**	
	• (With a large number) the rate of decay / popping for both depends upon the number of unchanged nuclei / kernels	**(1)**	
	• Both have a decreasing rate of decay	**(1)**	
	• The rate of decay / popping depends upon the type of nucleus (isotope) / size of kernel	**(1)**	
	• Radioactive decay is an irreversible change, as is corn popping	**(1)**	
	Differences:		
	• Not all the kernels are identical, whereas (for a given isotope) all the nuclei are identical	**(1)**	
	• Popping of corn depends on external factors and radioactive decay does not. (examples such as heating acceptable)	**(1)**	
	• The kernels do not emit standard fragments when they decay whereas radioactive nuclei emit radiation.	**(1)**	**4**
2(b)(i)	Log graph drawn	**(1)**	
	Suitable scales [not starting from 0 on y-axis]	**(1)**	
	Correct plotting of 6 points	**(1)**	
	Valid attempt at gradient calculation	**(1)**	
	Use of $t_{1/2}$ = ln 2/gradient	**(1)**	
	$t_{1/2}$ = 82 ± 3 s	**(1)**	**6**
	<u>Example of Calculation</u>  		

$$gradient = \frac{(4.4-3.4)}{(26-145)\,s} = 8.4\times10^{-3}\,s^{-1}$$

$$t_{1/2} = \frac{0.693}{8.4\times10^{-3}\,s^{-1}} = 82\ s$$

Or [Max 4]

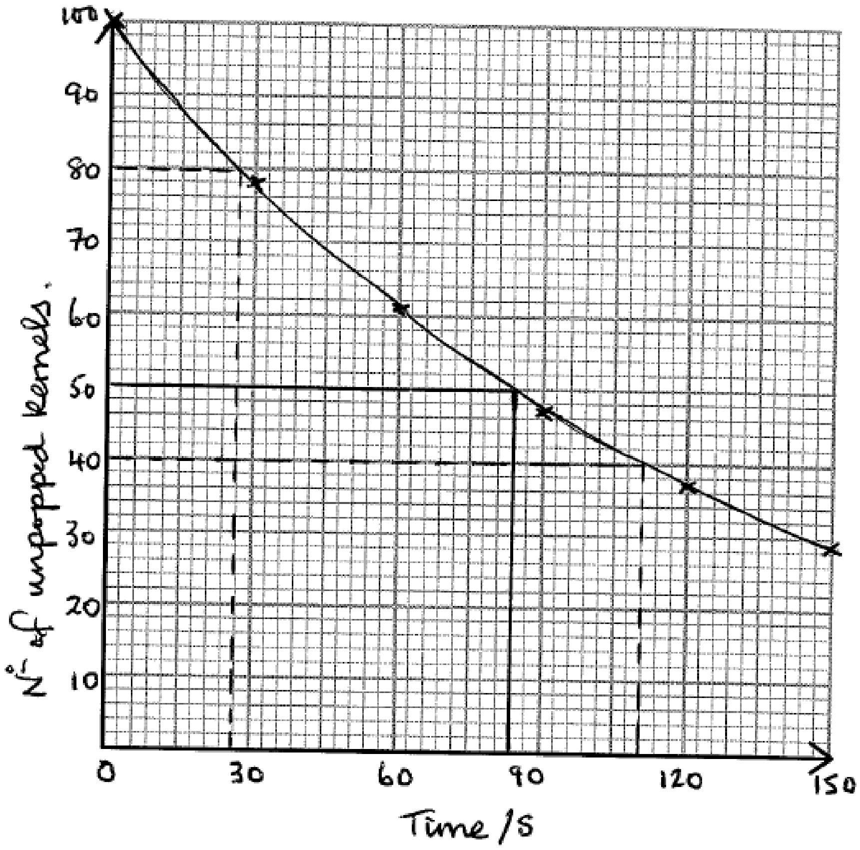
Suitable scales **(1)**

Correct plotting **(1)**

$t_{1/2}$ = 82 ± 3 s accurate from their graph **(1)**

Half life found from curve for at least two initial values of N **(1)**

<u>Example of calculation</u>



$t_{½}$ = (84 – 0) s = 84 s
$t_{½}$ = (111 – 27) s = 84 s

2(b)(ii)	(Identify that ¼ of kernels **or** 25 kernels are left, so 2 half lives have elapsed) 2 × answer in (i) **Or** read from graph **Or** 160 s <u>Example of calculation</u> $N = 100 - 75 = 25 \therefore \frac{N}{N_0} = \frac{25}{100} = \frac{1}{4}$ t = 2 × 82 s = 164 s	**(1)**
	Total for question	**11**

Question Number	Answer		Mark
3(a)(i)	Use of $\lambda = \ln 2/t_{½}$ Use of $dN/dt = -\lambda N$ $dN/dt = 7.6 \times 10^{13}$ (Bq) (no ue) <u>Example of calculation</u> $\lambda = \frac{\ln 2}{138 \times 24 \times 60 \times 60\ s} = 5.81 \times 10^{-8}\ s^{-1}$ $\frac{dN}{dt} = -\lambda N = -5.81 \times 10^{-8}\ s^{-1} \times 1.3 \times 10^{21} = 7.55 \times 10^{13}\ s^{-1}$	**(1)** **(1)** **(1)**	**3**
3(a)(ii)	Conversion from MeV to J Use of $P = \Delta W/\Delta t$ $P = 64$ (W) (no ue) <u>Example of calculation</u> $P = 7.55 \times 10^{13}\ s^{-1} \times 5.3 \times 1.6 \times 10^{-13} = 64$ W	**(1)** **(1)** **(1)**	**3**
3(b)(i)	5% factor seen Use of $P = 4\pi r^2 \sigma T^4$ $T = 970$ K <u>Example of calculation</u> $T = \sqrt[4]{\frac{3.2\ W}{4\pi(2.25 \times 10^{-3}\ m)^2 \times 5.67 \times 10^{-8}\ W\ m^{-2} K^{-4}}}$ $T = 971$ K	**(1)** **(1)** **(1)**	**3**
3(b)(ii)	Use of $\lambda_{max} T = 2.898 \times 10^{-3}$ $\lambda_{max} = 3.0 \times 10^{-6}$ m <u>Example of calculation</u> $\lambda_{max} = \frac{2.898 \times 10^{-3}\ m\ K}{971\ K} = 3.0 \times 10^{-6}$ m	**(1)** **(1)**	**2**
3(b)(iii)	Infrared	**(1)**	**1**
3(c)	Alphas are highly ionising (therefore) will not penetrate the skin (and enter the body)	**(1)** **(1)**	**2**
	Total for question		**14**

Question Number	Answer	Mark
4(a)	β-particles can (easily) penetrate the body/skin (1) Since they are not very ionising OR reference to what will stop them (1)	**(2)**
4(b)(i)	Use idea that number of unstable atoms halves every 8 days OR that 24 days represents 3 half-lives (1) Correct answer (1) Example calculation: $N_0 \rightarrow \frac{N_0}{2} \rightarrow \frac{N_0}{4} \rightarrow \frac{N_0}{8}$ $t = 0 \quad t = t_{1/2} \quad t = 2t_{1/2} \quad t = 3t_{1/2}$ Fraction decayed = 100% - 12.5% = 87.5%	**(2)**
4(b)(ii)	Use of $\lambda T_{1/2} = \ln 2$ (1) Use of an appropriate decay equation (1) Correct answer (1) Example of calculation: $\lambda = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{8\,\text{day}} = 0.0866\,\text{day}^{-1}$ $1.50\,\text{MBq} = A_0\,e^{-0\ 0866\ \text{day}^{-1} \times 1\text{day}}$ $A_0 = 1.50\,\text{MBq}\,e^{0\ 0866} = 1.64\,\text{MBq}$	**(3)**
	Total for question	**(7)**

Question Number	Answer		Mark
5(a)	Use of $\lambda = \ln 2/t_{1/2}$ $\lambda = 1.22 \times 10^{-4}$ (yr^{-1}) [$\lambda = 3.86 \times 10^{-12}$ (s^{-1}), $\lambda = 2.31 \times 10^{-10}$ (min^{-1})] Use of $A = A_0 e^{-\lambda t}$ t = 950 (yr) [if $\lambda = 1.2 \times 10^{-4}$, then t = 960 (yr)] [credit answers that use a constant ratio method to find the number of half lives elapsed] <u>Example of calculation</u> $\lambda = \dfrac{0.693}{5700\ \text{yr}} = 1.22 \times 10^{-4}\ \text{yr}^{-1}$ $14.7\,\text{s}^{-1} = 16.5\,\text{s}^{-1} \times e^{-1\,22\times10^{-4}\ \text{yr}^{-1}\times t}$ $t = \dfrac{\ln\left(\dfrac{14.7\,\text{s}^{-1}}{16.5\,\text{s}^{-1}}\right)}{-1.22\times10^{-4}\ \text{yr}^{-1}} = 947\ \text{yr}$	**(1)** **(1)** **(1)** **(1)**	**4**
5 (b)	Initial value of count rate should be bigger than 16.5 min^{-1} **Or** greater count rate from living wood in the past [e.g. A/A_0 smaller] **Or** initial value of count rate underestimated in the calculation **Or** Initial number of undecayed atoms greater [e.g. N/N_0 smaller] Age of sample has been underestimated **Or** ship is older than 950 yr **Or** sample has been decaying for a longer time [If a calculation has been carried out to show that a greater value of initial activity leads to a greater age, then award both marks]	**(1)** **(1)**	**2**
	Total for question		**6**