Mark Scheme

Q1.

Question Number	Answer	Mark
	D	**1**

Q2.

Question Number	Answer	Mark
	A	**1**

Q3.

Question Number	Answer	Mark
	B	**1**

Q4.

Question Number	**Acceptable answers**	**Additional guidance**	**Mark**
	The only correct answer is **C** emitting an alpha particle decreases the nucleon number by 4 and decreases the proton number by 2 A is not correct because emitting an alpha particle decreases the nucleon number by 4 and decreases the proton number by 2, but here the nucleon number has been increased by 2 and the proton number has been increased by 4 B is not correct because emitting an alpha particle decreases the nucleon number by 4 and decreases the proton number by 2, but here the nucleon number has been increased by 4 and the proton number has been increased by 2 D is not correct because emitting an alpha particle decreases the nucleon number by 4 and decreases the proton number by 2, but here the nucleon number has been decreased by 2 and the proton number has been decreased by 4		1

Q5.

Question Number	Answer	Mark
	C	**1**

Q6.

Question Number	Answer	Mark
	C	**1**

Q7.

Question Number	Answer	Mark
	D	**1**

Q8.

Question Number	Answer	Mark
	C	**1**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B because alpha is the most ionising and gamma is the most penetrating A is not correct because although alpha is the most ionising, gamma and not alpha is the most penetrating C is not correct because alpha, not gamma, is the most ionising and gamma, not alpha is the most penetrating D is not correct because alpha, not gamma is the most ionising, even though gamma is the most penetrating		1

Q10.

Question Number	Answer	Mark
	D	1

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• (isotopes are atoms/nuclides with the) same number of protons but different numbers of neutrons/nucleons (in the nucleus) **(1)**	Ignore references to the number of electrons in the atoms Do not credit mass number or atomic number	1

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	• so the proportion of unstable nuclei does not change significantly over time **Or** activity does not change significantly over time **(1)**		1

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
	A description that makes reference to the following: • (Remove the source and) record background count for specified time and subtract from equivalent quantity **(1)** • Divide by time to give a count rate. **(1)**	There needs to be two clear steps. Subtract a count from a count, or a count rate from a count rate and divide a count by time to obtain a count rate.	**2**

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• α-particles would only travel a few cm (in air), and so wouldn't reach the GM-tube **(1)** • β-particles would probably not pass through the sides of the GM-tube, and so wouldn't be detected so suggestion is correct. **(1)**	Accept a reference to α-particles not passing through the side of the tube (even if they reached it when d was small) and so not contributing to the count (rate) For 2 marks expect a valid conclusion, as well as a statement of the likelihood of the α-particles and β-particles contributing to the count (rate)	**2**

Q15.

Question Number	Acceptable answers	Additional guidance	Mark
	• top: 40, 0 **(1)** • bottom: 20, -1 **(1)**		**2**

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	• would be of form $Q = Q_0 e^{-kt}$ (1) • plot ln charge against time (1) • if straight line with negative gradient it's exponential (1) **Or** • would be of form $Q = Q_0 e^{-kt}$ (1) • Calculate Q/Q_0 for pairs of values with same time interval t **Or** calculates $t_{1/2}$ at least twice (1) • If equal, then it's exponential (1)	MP3 accept some indication that gradient is negative For both MS options MP3 is dependent on MP2	3

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	**Either** • The GM-tube has a low efficiency for γ-ray detection **Or** there is an increased area exposed to γ-rays (1) • (So) placing the tube side on to the radiation would increase the count rate (1) **Or** • The γ-radiation could be detected anywhere inside the GM-tube (1) • So placing the tube side on to the radiation would reduce the uncertainty in the distance measurement (1)	For low efficiency, accept GM tube poor at detecting γ-rays.	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• Record the count (at least) twice and then determine an average count rate **Or** record the count for a much longer time (1) • This reduces the effect of (random) errors in the measurement of the count rate (1)		2

Q18.

Question Number	Answer		Mark
(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] Example of calculation $\lambda = \frac{0.693}{5700\text{ yr}} = 1.22 \times 10^{-4}\text{ yr}^{-1}$ $14.7\text{ s}^{-1} = 16.5\text{ s}^{-1} \times e^{-1.22\times10^{-4}\text{ yr}^{-1}\times t}$ $t = \frac{\ln\left(\frac{14.7\text{ s}^{-1}}{16.5\text{ s}^{-1}}\right)}{-1.22\times10^{-4}\text{ yr}^{-1}} = 947\text{ yr}$	(1) (1) (1) (1)	4
(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

Q19.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $\lambda t_{½} = \ln 2$ • Use of $dN/dt = -\lambda N$ • $N = 9.5 \times 10^{10}$	(1) (1) (1)	$\lambda \times (1600 \times 365 \times 24 \times 60 \times 60)$ s $= \ln 2$ $\lambda = 1.37 \times 10^{-11}$ s^{-1} 1.3 Bq $= 1.37 \times 10^{-11}$ s$^{-1} \times N$ $N = 9.46 \times 10^{10}$	3
(ii)	• Use of $A = A_0 e^{-\lambda t}$ • Use of $\ln A = \ln A_0 - \lambda t$ or equivalent • $t = 8.58 \times 10^{10}$ s = 2700 years	(1) (1) (1)	ecf λ calculated in (i) $\ln 0.4 = \ln 1.3 - 1.37 \times 10^{-11}$ s$^{-1} \times t$ $t = 8.58 \times 10^{10}$ s = 2721 years	3

Q20.

Question Number	Answer		Mark
(a)(i)	Alpha particles ionise the air **Or** alpha particles strip electrons from air molecules The ions/electrons move (in the electric field between the plates)	 (1) (1)	 2
(a)(ii)	Smoke particles capture electrons (and reduce the free charge able to move) **Or** alpha particles collide with smoke particles and reduce amount of ionisation	 (1)	 1
(b)(i)	Random means 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 **Or** we can only estimate the fraction that will decay in the next time interval Spontaneous means that the decay cannot be influenced by any (external) factors.	 (1) (1)	 2
(b)(ii)	${}_{95}\text{Am} \rightarrow {}^{237}\text{Np} + {}^{4}_{2}\alpha$ Top line correct Bottom line correct	 (1) (1)	 2
	Total for question		7

Q21.

Question Number	Answer		Mark
(a)(i)	Ionising radiation removes electrons from atoms/molecules	(1)	1
(a)(ii)	Least ionising → most ionising γ | β | α	(1)	1
(b)(i)	see table below	(1) (1) (1)	3
(b)(ii)	(There is the possibility of) exposure to neutrons Uncharged particles are not (directly) ionising	(1) (1)	 2
	Total for question		7

Table for (b)(i):

	Paper	0.5 cm aluminium	0.5 cm lead	
α radiation	**stopped**	stopped	**stopped**	(1)
β radiation	**passes through**	**stopped**	stopped	(1)
γ radiation	passes through	**passes through**	**passes through**	(1)

Q22.

Question Number	Answer		Mark
(a)	Activity is the rate of <u>decay</u> (of radioactive nuclei) **Or** the number of <u>decays</u> in a second	(1)	1
(b)	Use of $\lambda\, t_{1/2} = 0.693$ Use of $A = -\lambda N$ $N = 1.9 \times 10^{12}$ <u>Example of calculation:</u> $\lambda = \dfrac{0.693}{3.89 \times 10^{8}\ \text{s}} = 1.78 \times 10^{-9}\ \text{s}^{-1}$ $N = \dfrac{3450\ \text{s}^{-1}}{1.78 \times 10^{-9}\ \text{s}^{-1}} = 1.94 \times 10^{12}$	(1) (1) (1)	3
(c)(i)	Use of $A = A_0 e^{-\lambda t}$ Conversion between seconds and years t = 41 (years) <u>Example of calculation:</u> $0.1 = e^{-(1.78\times10^{-9}\,s^{-1})t}$ $t = 1.29 \times 10^{9}$ s $t = 1.29 \times 10^{9}\ \text{s} / (365 \times 24 \times 3600\ \text{s y}^{-1}) = 41$ y	(1) (1) (1)	3
(c)(ii)	This is a very long time and so: The sample's activity will stay approx. constant for the procedure **Or** tritium may be in the body long enough for damage to be caused **Or** the sample can be prepared well in advance of the procedure	(1) (1) (1)	1
	Total for question		**8**

Q23.

Question Number	Answer		Mark
(a)	Activity is the rate of decay of (unstable) nuclei **Or** activity is the number of (unstable) nuclei that decay in unit time	**(1)**	1

(b)(i)	Background radiation/count will increase the recorded count **Or** background count must be subtracted from the recorded count **Or** background radiation contributes systematic error to the count [Do not accept "to correct for background radiation"]	(1)	1
(b)(ii)	Radioactive decay is a random process (so count for a fixed period will vary) [Ignore references to spontaneous, accurate, reliable] Idea that repeating enables a mean/average value to be calculated	(1) (1)	2
(b)(iii)	Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ Use of $A = A_0 e^{-\lambda t}$ [allow 2.5 Bq for A_0 here; allow use of $N = N_0 e^{-\lambda t}$] $A = 0.47$ Bq [Allow calculation of number of half lives elapsed and use of $A = A_0 \left(\frac{1}{2}\right)^{t/t_{1/2}}$ for mp1 and mp2] <u>Example of calculation:</u> $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{8.0\,\text{d}} = 0.0866\text{d}^{-1}$ $A = A_0 e^{-\lambda t} = 6.38 \times e^{-0.0866\text{d}^{-1} \times 30\text{d}} = 6.38\,\text{Bq} \times 0.074 = 0.47\,\text{Bq}$	(1) (1) (1)	3
(b)(iv)	Idea that people have to be close to or ingest seaweed for any degree of risk **Or** β particles are moderately ionising **Or** β particles can enter body through the skin The half-life is short **Or** after a month the activity has decayed to negligible levels **Or** the radioisotope doesn't remain in the seaweed for very long	(1) (1)	2
	Total for Question		9

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of ratio of atoms and atoms per g (1) • Number of nuclei = 2.9×10^{17} (1)	$N = 0.3\text{ g} \times 8.1 \times 10^{21}\text{ g}^{-1} \times 0.012/100$ $= 2.9 \times 10^{17}$	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• use of $\ln 2 = \lambda t_{1/2}$ (1) • use of activity = λN (ecf from (b)(i)) (1) • activity = 5.1 (Bq) (use of show that value gives 5.3 Bq) (1)	$\ln 2 = \lambda \times 1.25 \times 10^9$ years $= \lambda \times (1.25 \times 10^9 \times 365 \times 24 \times 60 \times 60)$ s $\lambda = 1.76 \times 10^{-17}\text{ s}^{-1}$ $A = 1.76 \times 10^{-17}\text{ s}^{-1} \times 2.9 \times 10^{17}$ $= 5.1$ Bq	3

Question Number	Acceptable answers		Additional guidance	Mark
(iii)	• use of count rate = (counts – background counts) / time • calculates percentage of activity from (b)(ii) **Or** applies 7.5% to activity from (b)(ii) • Comparative statement consistent with their values	(1) (1) (1)	**MP3** can only be awarded if Activity from (ii) is used. A clear comparison with the corresponding value must be made e.g. percentage = 0.8 % which is < 7.5 % so not efficient **Or** detects 176 but should detect 379 counts in 10 min, so not efficient **Or** should detect a rate of at least 0.63 Bq, so not efficient <u>Example of calculation</u> Recorded count rate = (176 - 150) ÷ 600 s = 0.04 Bq 0.04 Bq × 100 ÷ 5.1 Bq = 0.78 % (ecf from (b)(ii) for MP3)	3

Question Number	Acceptable answers		Additional guidance	Mark
(iv)	**Max two from** • emissions are in all directions • some emitted particles may be absorbed by the material in the sample • some emitted particles may be absorbed by the window • some emitted particles pass (right) through detector	 (1) (1) (1) (1)		2

Q25.

Question Number	Answer		Mark
(a)	A radioactive atom has an unstable nucleus which emits α, β, or γ radiation [at least one of α β γ named]	(1) (1)	2
(b)	$C \rightarrow {}^{11}_{5}B + {}^{0}_{1}e^{+} + \nu_e$ Top line correct Bottom line correct	(1) (1)	2
(c)	Attempt at mass diference calculation Attempt at conversion from (M)eV to J $\Delta E = 1.4 \times 10^{-13}$ (J) <u>Example of calculation:</u> ΔE= 10 253.6 – 10252.2-0.5 = 0.889 MeV ΔE= 0.889 MeV × 1.6 × 10^{-13} J MeV^{-1} = 1.42 × 10^{-13} J	(1) (1) (1)	3
(d)	The idea that the sample will not produce radiation for very long (because carbon-11 has a relatively short half-life) β particles are not very ionising **Or** positrons are not very ionising **Or** boron is safe in small amounts	(1) (1)	2
(e)	Use of $\lambda t_{1/2} = \ln 2$ ($\lambda = 5.68 \times 10^{-4}\ s^{-1}$) Use of $A = A_0 e^{-\lambda t}$ Use $A = 1.58 \times 10^6$ Bq in $A = A_0 e^{-\lambda t}$ $A_0 = 1.2 \times 10^7$ Bq <u>Example of calculation:</u> $\lambda = \frac{0.693}{1220\ s} = 5.68 \times 10^{-4}\ s^{-1}$ $1.58 \times 10^6\ Bq = A_0 e^{-5.68 \times 10^{-4}\ s^{-1} \times 60 \times 60\ s}$ $A_0 = 1.22 \times 10^7$ Bq	(1) (1) (1) (1)	4
	Total for question		**13**

Q26.

Question Number	Answer		Mark
(a)(i)	Use of $\lambda t_{1/2} = \ln 2$ $\lambda = 5.8 \times 10^{-8}$ (s^{-1}) Use of $\frac{\Delta N}{\Delta t} = -\lambda N$ $\frac{\Delta N}{\Delta t} = (-)1.5 \times 10^{8}$ Bq [accept s^{-1} **Or** counts s^{-1}] <u>Example of calculation</u> $\lambda = \frac{0.693}{(138 \times 24 \times 3600)s} = 5.81 \times 10^{-8} s^{-1}$ $\frac{\Delta N}{\Delta t} = -5.81 \times 10^{-8} s^{-1} \times 2.54 \times 10^{15} = -1.48 \times 10^{8}$ Bq	(1) (1) (1) (1)	**4**
(a)(ii)	Use of $N = N_0 e^{-\lambda t}$ Fraction of nuclei remaining = 0.90 10% of nuclei have decayed [accept 0.1 **Or** 1/10] <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	(1) (1) (1)	**3**

(b)	Idea that α-particles are not able to penetrate the (dead layer of) skin (from outside the body) Damage/danger if energy is transferred to cells/DNA **Or** damage/danger to cells/DNA due to ionisation	(1) (1)	**2**
(c)(i)	$^{210}_{84}Po \rightarrow ^{206}_{82}Pb + ^{4}_{2}\alpha$ Top line correct Bottom line correct	(1) (1)	**2**
(c)(ii)	So that momentum is conserved	(1)	**1**
(d)	Spontaneous means that the decay cannot be influenced by any external factors. 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 **Or** we can only estimate the fraction of the total number that will decay in the next time interval	(1) (1)	**2**

(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**