Nuclear Declay - Mark Scheme

Q1.

Question Number	Answer	Mark
	The only correct answer is B *A is not correct because background count affects the accuracy* *C is not correct because increasing the distance reduces the count rate* *D is not correct because background count affects the accuracy*	**(1)**

Q2.

Question Number	Answer	Mark
	The only correct answer is C *A is not correct because the smaller the number of nuclei the lower the activity* *B is not correct because the larger the half-life of the source the lower the activity* *D is not correct because the larger the half-life of the source the lower the activity*	**1**

Q3.

Question Number	Answer	Amplification	Mark
	D	The only correct answer is **D** A is not correct because count rate and count have different dimensions B is not correct because this will not give the corrected count rate C is not correct because count rate and count have different dimensions	**1**

Q4.

Question Number	Answer		Mark
(a)	Top line correct Bottom line correct $^{60}_{28}\text{Ni} + {}^{0}_{-1}\beta^{-}$	**(1)** **(1)**	**2**
(b)	β radiation is quite penetrating as it is moderately ionising γ radiation is very penetrating as it is weakly ionising [idea that γ radiation is more penetrating than β radiation as γ radiation is less ionising than β radiation for max 1] [accept references to materials that would absorb the radiation e.g. 0.5 cm, a few mm of aluminium for β particles, thick lead, thick concrete for γ radiation etc]	**(1)** **(1)**	**2**
(c)	Idea that the radiation (from the source) may damage healthy cells/DNA	**(1)**	**1**
	Total for question		5

Q5.

Question Number	Answer		Mark
(a)(i)	Top line correct Bottom line correct X is a proton $${}_{0}^{1}\text{n} + {}_{7}^{14}\text{N} \rightarrow {}_{6}^{14}\text{C} + {}_{1}^{1}\text{X}$$	(1) (1) (1)	3
(a)(ii)	We cannot know when a given nucleus will decay **Or** We cannot know which nucleus will decay next	(1)	1
(b)	Pairs of activity and times read from graph for at least 2 half lives and find mean **Or** Use $A = A_0 e^{-\lambda t}$ with values from graph and $t_{1/2} = \frac{ln2}{\lambda}$ $t_{1/2}$ matches values from their graph <u>Example of calculation</u> t = 0 year, A_0 = 240 Bq t = 17500 year, A_3 = 30 Bq $t_{1/2}$ = (17500 year)/3 = 5833 year	(1) (1)	2
(c)(i)	The background radiation will increase the recorded count rate **Or** Background count rate has to be subtracted (from the count rate)	(1)	1
(c)(ii)	Record count for a longer time **Or** Repeat count and find an average	(1)	1

(c)(iii)	Use of $\lambda t_{1/2} = \ln 2$ Use of $A = A_0 e^{-\lambda t}$ **Or** $N = N_0 e^{-\lambda t}$ t = 8650 year **Or** Use of $A = \frac{A_0}{2^x}$ Use of $x = \frac{t}{t_{1/2}}$ t = 8650 year [Accept 8600 y – 8700 y] [2.73 $\times 10^{11}$ s] Example of calculation $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{6000\,\text{year}} = 1.16\times10^{-4}\,\text{year}^{-1}$ $A = A_0 e^{-\lambda t}$ $\therefore 10.9\,\text{Bq} = 29.6\,\text{Bq}\times(e^{-1.16\times10^{-4}\,\text{year}^{-1}\times t})$ $t = 8649\,\text{year}$	(1) (1) (1) (1) (1) (1)	3
(d)	The time scale is too long **Or** the half life is too short [accept too many half lives have passed] (So) the activity would be too small to measure (with sufficient accuracy) **Or** (Graph shows) the activity will fall to zero after 50 000 years **Or** (After 68 million years), the skull would not have significant carbon content	(1) (1)	2

* (e)	(QWC Spelling of technical terms must be correct and the answer must be organised in a logical sequence.) Binding energy is the energy released when a nucleus is formed **Or** the energy required to split a nucleus into its constituent particles Binding energy is not a force **Or** We cannot overcome the binding energy [accept idea that it is the strong force that holds the (nucleons in the) nucleus together] Atoms do not undergo fission (nuclei do) Fission is when massive nuclei split into less massive nuclei	(1) (1) (1) (1)	4
	Total for Question		17

Q6.

	Answer		Mark
(a)	Top line correct Bottom line correct $Pb \rightarrow {}^{212}_{83}Bi + {}^{0}_{-1}\beta^-$	(1) (1)	2
(b)(i)	Half life is the average/mean time taken for half of the (unstable) nuclei/atoms to decay **Or** Half life is the average/mean time taken for the rate of decay of (unstable) nuclei/atoms to fall to half of its original value	(1) (1)	1
(b)(ii)	Use of $\lambda t_{1/2} = \ln(2)$ $\lambda = 1.8 \times 10^{-5}$ (s^{-1}) Use of $N = N_0 e^{-\lambda t}$ **Or** a calculation of the number of half-lives and use of the halving rule $N/N_0 = 0.21$ (0.18 if "show that" value used) <u>Example of calculation</u> $\lambda = \frac{0.693}{3.83 \times 10^4 s} = 1.81 \times 10^{-5} s^{-1}$ $\frac{N}{N_0} = e^{-1.8 \times 10^{-5} s^{-1} \times 86400 s} = 0.208$	(1) (1) (1) (1)	4
(b)(iii)	Use of $\Delta E = c^2 \Delta m$ $\Delta m = 1.0 \times 10^{-30}$ kg <u>Example of calculation</u> $\Delta m = \frac{\Delta E}{c^2} = \frac{9.12 \times 10^{-14} J}{(3 \times 10^8 ms^{-1})^2} = 1.01 \times 10^{-30} kg$	(1) (1)	2
(c)	An indication of increased/greater activity (from bismuth) Due to presence of beta particles (as Alpha particles cannot penetrate the bean plant)	(1) (1)	2
(d)	The idea that the material, by absorbing neutrons, reduces the number of neutrons available to cause further fission.	(1)	1

	Answer		Mark
(e)	Fusion reactors use hydrogen as their fuel which is very abundant whereas the fuel for fission reactors is limited	(1)	
	Fusion reactors would produce less radioactive waste than fission reactors **Or** helium produced which isn't radioactive unlike products of fission. (Do not accept references to "greener", "more environmentally friendly" or "safer".	(1)	
	Fusion requires very high temperatures (and densities)	(1)	
	These extreme conditions lead to confinement problems	(1)	
	So very strong magnetic fields are required **Or** contact with container causes temperature to fall and fusion to cease **Or** at the moment input energy would be greater than output energy.	(1)	5
	Total for Question		**17**

Q7.

Question Number	Answer		Mark
(a)(i)	We cannot predict which <u>nucleus</u> will decay next **Or** we cannot know when an individual <u>nucleus</u> will decay **Or** there is a fixed probability of each <u>nucleus</u> decaying within a given time	(1)	1
(a)(ii)	The average/mean time taken for the number of (unstable) nuclei/atoms to halve **Or** the average time taken for the activity (of the source) to halve	(1)	1
(b)(i)	Use of $\lambda t_{1/2} = \ln 2$ Use of $\frac{dN}{dt} = (-)\lambda N$ $\frac{dN}{dt} = 2.34 \times 10^{15}$ (Bq) <u>Example of calculation:</u> $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{2.16 \times 10^4 \text{ s}} = 3.21 \times 10^{-5} \text{ s}^{-1}$ $\frac{dN}{dt} = \lambda N = 3.21 \times 10^{-5} \text{ s}^{-1} \times 7.3 \times 10^{19} = 2.34 \times 10^{15} \text{ s}^{-1}$	(1) (1) (1)	3
(b)(ii)	Use of $A = A_0 e^{-\lambda t}$ **Or** use of $N = N_0 e^{-\lambda t}$ A = 1.5 × 10^{14} Bq [1.4 × 10^{14} Bq if "show that" value used] [Accept candidate's value for λ and check their answer for ecf credit] [Apply ecf for responses that use a value of A_0 that would round to the 'show that' value] [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] <u>Example of calculation:</u> $A = A_0 e^{-\lambda t} = 2.34 \times 10^{15} \text{ Bq} \times e^{-3.2 \times 10^{-5} \text{ s}^{-1} \times 86400 \text{ s}} = 1.46 \times 10^{14} \text{ Bq}$	(1) (1)	2
	Total for question		7

Q8.

Question Number	Answer	Mark
	The only correct answer is B *A is not correct because if the half-life were 2.4 hours the activity would be* 150 Bq *C is not correct because if the half-life were 4.0 hours the activity would be* 600 Bq *D is not correct because if the half-life were 12 hours the activity would be* 2400 Bq	1

Q9.

Question Number	Answer	Mark
	The only correct answer is D ***A** is not correct because this would decrease the activity to 50%* ***B** is not correct because this would decrease the activity to 12.5%* ***C** is not correct because this would decrease the activity to 3.1%*	**1**

Q10.

Question Number	Answer	Mark
	C	**1**

Q11.

Question Number	Answer	Amplification	Mark
	C	The only correct answer is **C** A is not correct because the card and aluminium will block uniformly across the top and bottom third B is not correct because the card and aluminium will block uniformly across the top and bottom third D is not correct because the card will not reduce beta radiation in top third	**1**

Q12.

Question Number	Answer		Mark
(a) **G**	The rate of decay of (unstable) nuclei (accept disintegration for decay and ignore reference to mean/average) [there must be a reference to nucleus/nuclei to get the mark]	(1)	1

* (b)	(QWC Spelling of technical terms must be correct and the answer must be organised in a logical sequence.)		
	(With no source present) record the background count	(1)	
	(Handling the source with tongs) fix one source close to the GM-tube	(1)	
	Introduce a sheet of paper/aluminium between the source and the GM-tube	(1)	
	If paper/aluminium reduces the count rate to background levels it is the americium source	(1)	
	If paper causes no change in the count rate it is the strontium source **Or** If thin aluminium causes a small change in the count rate it is the strontium source	(1)	
	If paper reduces the count rate but the count rate is still above background levels it is the radium source **Or** If thin aluminium causes a large change in the count rate it is the radium source	(1)	6

(c)	Use of $\lambda t_{1/2} = \log_e 2$	(1)	
	Use of $N = N_0 e^{-\lambda t}$ ($A = A_0 e^{-\lambda t}$)	(1)	
	t = 15 years	(1)	3
	<u>Example of calculation</u> $\lambda = \frac{\log_e 2}{t_{1/2}} = \frac{0.693}{5.26\,\text{year}} = 0.132\,\text{years}^{-1}$ $25.7\,\text{kBq} = 185\,\text{kBq} \times (e^{-0.132\text{years}^{-1} \times t})$ $\therefore t = \frac{\log_e\left(\frac{25.7\,\text{kBq}}{185\,\text{kBq}}\right)}{-0.132\,\text{years}^{-1}} = 15.0\,\text{years}$		
	Total for question		**10**