Radiation MS2

Question Number	Answer		Mark
1(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> $\lambda = \frac{0.693}{5700\text{ yr}} = 1.22 \times 10^{-4}\text{ yr}^{-1}$ $14.7\text{ s}^{-1} = 16.5\text{ s}^{-1} \times e^{-1.22\times10^{-4}\text{ yr}^{-1}\times t}$ $t = \frac{\ln\left(\frac{14.7\text{ s}^{-1}}{16.5\text{ s}^{-1}}\right)}{-1.22\times10^{-4}\text{ yr}^{-1}} = 947\text{ yr}$	**(1)** **(1)** **(1)** **(1)**	**4**
1 (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 1		**6**

Question Number	Answer		Mark
2 (a)(i)	$\text{N} + \alpha \rightarrow {}^{17}_{8}\text{O} + {}_{1}\text{p}$ All values correct	(1)	1
2(a)(ii)	In nuclear fission a chain reaction can be set up **Or** in a chain reaction the (total) energy released can be very large **Or** heavier/larger nuclei release much more energy **Or** a very high reaction rate releases much more energy	(1)	1
2 (b)	Attempt at mass deficit calculation Use of $\Delta E = c^2 \Delta m$ (Allow use of 1 u = 1.66 x 10^{-27} kg) Use of 1 MeV = 1.6 × 10^{-13} J (Allow use of 1u = 931.5 MeV/c^2) ΔE = 174 MeV <u>Example of calculation</u> $\Delta m = (390.29989 - 233.99404 - 152.64708 - (2 \times 1.67493)) \times 10^{-27}\ \text{kg}$ $\Delta m = 3.0891 \times 10^{-28}\ \text{kg}$ $\Delta E = (3.00 \times 10^{8}\ \text{m s}^{-1})^2 \times 3.0891 \times 10^{-28}\ \text{kg} = 2.780 \times 10^{-11}\ \text{J}$ $\Delta E = \frac{2.780 \times 10^{-11}\ \text{J}}{1.60 \times 10^{-13}\ \text{J MeV}^{-1}} = 173.8\ \text{MeV}$	(1) (1) (1) (1)	4
2 (c)(i)	Same number of protons [do not accept atomic/proton number], Different numbers of neutrons [do not accept mass/nucleon/neutron number]	(1) (1)	2
2(c)(ii)	Correct calculation for ω [see 6283 or 2000π or $\frac{60\ 000 \times 2\pi}{60}$] a = (-) 5.9 × 10^{6} m s^{-2} <u>Example of calculation</u> $a = -\left(\frac{60000 \times 2\pi}{60\ \text{s}}\right)^2 \times 15 \times 10^{-2}\ \text{m} = 5.92 \times 10^{6}\ \text{m s}^{-2}$	(1) (1)	2
2(c)(iii)	**Max 2** Stiff/stiffness Strong/strength Low density	(1) (1) (1)	2
2(d)	Use of ΔE = mcΔθ Rate at which energy is removed = 3.1 × 10^{9} (W) Use of the efficiency equation [must have 2.2 × 10^{9} (W) on top line] Efficiency = 42% [accept 0.42] <u>Example of calculation</u> $\Delta E = 70000\ \text{kg} \times 3990\ \text{J kg}^{-1}\ \text{K}^{-1} \times 11\text{K} = 3.07 \times 10^{9}\ \text{J}$ $\%\ \text{efficiency} = \frac{\text{useful power output}}{\text{total power input}} \times 100 = \frac{2.2 \times 10^{9}\ \text{W}}{(2.2 + 3.1) \times 10^{9}\ \text{W}} \times 100 = 41.5\%$	(1) (1) (1) (1)	4
	Total for question 2		16

Question Number	Answer		Mark
3 (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**
3(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**
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**
3 (c)(i)	$^{210}_{84}Po \rightarrow ^{206}_{82}Pb + ^{4}_{2}\alpha$ Top line correct Bottom line correct	(1) (1)	**2**
3 (c)(ii)	So that momentum is conserved	(1)	**1**
3 (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**

3(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 3	**16**

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

Question Number	Answer		Mark
5 (a)	**QWC – Work must be clear and organised in a logical manner using technical wording where appropriate** (Nuclear fission is) the splitting of a large nucleus into smaller nuclei The mass of the (fission) fragments is less than the mass of the original nucleus Reference to $\Delta E = c^2\Delta m$ **Or** the binding energy <u>per nucleon</u> is greater in the fragments than in the original nucleus	 **(1)** **(1)** **(1)**	**3**
(b)	Use of $\frac{\Delta N}{\Delta t} = -\lambda N$ $\frac{\Delta N}{\Delta t} = 1.6 \times 10^8 \text{ Bq}$ <u>Example of calculation</u> $\frac{\Delta N}{\Delta t} = -\lambda N = 1.3 \times 10^{-5} \text{ s}^{-1} \times 1.2 \times 10^{13} = 1.56 \times 10^8 \text{ Bq}$	**(1)** **(1)**	**2**
(c)	Material must have a high density Concrete	**(1)** **(1)**	**2**
(d)	Idea that fission reactors produce more radioactive waste Fuel for fission is a limited resource, whereas fuel for fusion is (virtually) unlimited. (accept specific examples uranium, hydrogen and deuterium) (do not accept "renewable"/"non-renewable" for "limited"/"unlimited")	**(1)** **(1)**	**2**
	Total for Question 16		**9**

Question Number	Answer	Mark
6(a)(i)	Can't say when a nucleus will decay **Or** which nucleus will decay next **(1)**	**1**
(a)(ii)	Cannot influence when a nucleus will decay **(1)**	**1**
(b)(i)	Top line correct **(1)** Bottom line correct **(1)** $^{210}\text{Po} \rightarrow {}_{82}\text{Pb} + {}_{2}\alpha$	**2**
(b)(ii)	Use of $\frac{1}{2}mv^2$ **(1)** $v = 1.6 \times 10^7$ (m s^{-1}) **(1)** <u>Example of calculation</u> $\frac{1}{2}mv^2 = 8.5 \times 10^{-13}\text{ J}$ $v = \sqrt{\frac{2 \times 8.5 \times 10^{-13}\text{ J}}{6.64 \times 10^{-27}\text{ kg}}} = 1.60 \times 10^7\text{ m s}^{-1}$	**2**
(b)(iii)(1)	momentum is conserved **Or** total momentum is constant **(1)** Polonium/Final /initial momentum is zero **(1)**	**2**
(b)(iii)(2)	Use of $m_{Pb}v_{Pb} = m_\alpha v_\alpha$ **(1)** $v_{Pb} = 3.9 \times 10^5$ m s^{-1} **(1)** (use of $v_\alpha = 1.6 \times 10^7$ gives $v_{Pb} = 3.1 \times 10^5$ m s^{-1} scores both marks) <u>Example of calculation</u> $v_{Pb} = \frac{m_\alpha}{m_{Pb}} \times v_{Pb} = \frac{4\text{u}}{206\text{u}} \times 2 \times 10^7\text{ m s}^{-1} = 3.88 \times 10^5\text{ m s}^{-1}$	**2**

(b)(iv)	Although the alpha has a smaller mass it has a bigger velocity/speed And velocity/speed is squared in the energy expression **Or** Both particles have the same momentum $E_k = p^2/2m$ so alpha has more energy, since it has a smaller mass	**(1)** **(1)** **(1)** **(1)**	**2**
(c)(i)	Use of $P = E \times \frac{\Delta N}{\Delta t}$ P = 69 (W) <u>Example of calculation</u> $P = E \times \frac{\Delta N}{\Delta t} = 8.5 \times 10^{-13}\,\text{J} \times 8.1 \times 10^{13}\,\text{s}^{-1} = 68.9\,\text{W}$	**(1)** **(1)**	**2**
(c)(ii)	Use of $t_{1/2} = \frac{\ln 2}{\lambda}$ $t_{1/2}$ = 139 days links (short) half life to activity/ power (dependent mark) **Or** use exponential equation to find activity/power after at least one year Decay constant and time in complementary units The idea that the activity/power is too small (dependent mark) <u>Example of calculation</u> $t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{5.0 \times 10^{-3}\,\text{day}^{-1}} = 138.6\,\text{day}$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
	Total for Question 18		**17**