Question Number	Answer	Mark
1(a)(i)	Alpha particles are very ionising **(1)** So alpha particles have very low penetrating power **Or** so alpha particles will be absorbed/stopped by the skin **(1)**	**2**
1(a)(ii)	Gamma rays are very penetrating **Or** Gamma rays will pass through the skin **(1)**	**1**
1(a)(iii)	Handled using (long) tongs **Or** never handled directly **Or** (closed source) pointed away from people **(1)** Kept in a <u>lead</u>-lined box (when not being used) **(1)**	**2**
1(b)	We cannot be sure which nuclei will decay **next/when** **(1)** **Or** All nuclei will (eventually) decay We know that the activity halves in a fixed period of time **(1)** **Or** We can calculate the activity using $A = A_0 e^{-\lambda t}$ **Or** We know that the activity decreases exponentially **Or** Probability of decay is constant for a source	**2**
	Total for Question	**7**

Question Number	Answer	Mark
2(a)	$^{14}_{7}\text{N}+^{1}_{0}\text{n}\rightarrow^{12}_{6}\text{C}+^{3}_{1}\text{H}$ Top line correct **(1)** Bottom line correct **(1)**	**2**
2(b)(i)	Background radiation would increase the count rate (by a constant amount) **Or** Background count rate has to be subtracted (from the activity) **(1)**	**1**
2(b)(ii)	Record the count for a long period of time **Or** Record the count more than once and find an average value **(1)**	**1**
2(b)(iii)	Use of $\lambda t_{1/2} = \ln 2$ **(1)** Use of $A = A_0 e^{-\lambda t}$ **(1)** Correct time identified (65 years) **(1)** A_0 = 42 Bq **(1)** **Or** Use of $A = \frac{A_0}{2^x}$ **(1)** Correct time identified (65 years) **(1)** Use of $x = \frac{t}{t_{1/2}}$ **(1)** A_0 = 42 Bq **(1)** <u>Example of calculation</u> $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{12.3\,\text{year}} = 0.0563\,\text{year}^{-1}$ $A = A_0 e^{-\lambda t}$ $\therefore 1.08\,\text{Bq} = A_0 \text{e}^{-0\ 0563\text{year}^{-1}\times 65\text{year}}$ $A_0 = \frac{1.08\,\text{Bq}}{0.0257} = 42.1\,\text{Bq}$	**4**
2(c)(i)	Mass difference calculation **(1)** Conversion to kg **(1)** Use of $\Delta E = c^2 \Delta m$ **(1)** $\Delta E = 2.8 \times 10^{-12}$ (J) **(1)** <u>Example of calculation</u> Δm = (3.0155 + 2.0136) u – (4.0015 + 1.0087) u = 0.0189 u $\Delta m = 0.0189\text{ u} \times 1.66 \times 10^{-27}\text{ kg u}^{-1} = 3.14 \times 10^{-29}$ kg $\Delta E = c^2\Delta m = (3 \times 10^8\text{ m s}^{-1}) \times 3.14 \times 10^{-29}\text{ kg} = 2.82\times 10^{-12}$ J	**4**

2(c)(ii)	**MAX 2** Very high temperatures [accept $T \sim 10^7$ K] **(1)** so that nuclei have sufficient energy to come close enough to overcome electrostatic repulsion [accept reference to strong interaction] **(1)** A collision rate large enough to sustain fusion (from a very high density) **(1)**	**2**
	Total for Question	**14**

Question Number	Answer		Mark
3(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**
3(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**
3(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**
3(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> $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{8.0\,\text{d}} = 0.0866\,\text{d}^{-1}$ $A = A_0 e^{-\lambda t} = 6.38 \times \text{e}^{-0.0866\,\text{d}^{-1} \times 30\,\text{d}} = 6.38\,\text{Bq} \times 0.074 = 0.47\,\text{Bq}$	**(1)** **(1)** **(1)**	**3**
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**

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>4(a)(i)</td><td>Ionising radiation removes electrons from atoms/molecules</td><td>(1)</td><td>1</td></tr>
<tr><td>4(a)(ii)</td><td><table><tr><td colspan="3">Least ionising → most ionising</td></tr><tr><td>γ</td><td>β</td><td>α</td></tr></table></td><td>(1)</td><td>1</td></tr>
<tr><td>4(b)(i)</td><td><table>
<tr><th></th><th>Paper</th><th>0.5 cm aluminium</th><th>0.5 cm lead</th></tr>
<tr><td>α radiation</td><td>stopped</td><td>stopped</td><td>stopped</td></tr>
<tr><td>β radiation</td><td>passes through</td><td>stopped</td><td>stopped</td></tr>
<tr><td>γ radiation</td><td>passes through</td><td>passes through</td><td>passes through</td></tr>
</table></td><td>(1)
(1)
(1)</td><td>3</td></tr>
<tr><td>4(b)(ii)</td><td>(There is the possibility of) exposure to neutrons

Uncharged particles are not (directly) ionising</td><td>(1)

(1)</td><td>2</td></tr>
<tr><td></td><td>Total for question</td><td></td><td>7</td></tr>
</table>

Question Number	Answer		Mark
5(a)(i)	Top line correct Bottom line correct $^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$	**(1)** **(1)**	**2**
5(a)(ii)	Attempt at mass deficit calculation ΔE = 0.0175 GeV (accept 2.8 × 10^{-12} J) <u>Example of calculation:</u> Δm = (3.7274 + 0.939566 – 2.8089 – 1.8756) GeV/c^2 = 0.0175 GeV/c^2 ΔE = 0.0175 GeV	**(1)** **(1)**	**2**
5(a)(iii)	Momentum is conserved Mass of neutron is smaller, so speed is greater $E_k = ½ mv^2$, so E_k is larger **Or** Momentum is conserved $E_k = p^2/2m$ m of neutron is smaller, so E_k is larger	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
5(b)	Use of $\lambda = \frac{\ln 2}{t_{½}}$ Use of $A = A_0 e^{-\lambda t}$ t = 41 (years) <u>Example of calculation:</u> $\lambda = \frac{\ln 2}{t_{½}} = \frac{0.693}{12.3 \text{ year}} = 0.0563 \text{ year}^{-1}$ $A = A_0 e^{-\lambda t} \quad \therefore t = \frac{\ln\left(A/A_0\right)}{-\lambda} = \frac{\ln(0.1)}{-0.0563 \text{ year}^{-1}} = 40.9 \text{ years}$	**(1)** **(1)** **(1)**	**3**

*5(c)	**QWC – Work must be clear and organised in a logical manner using technical wording where appropriate** There is little possibility of a runaway fusion reaction (unlike fission) **(1)** There would not be any radioactive waste produced in the <u>fusion</u> process **Or** the flux of neutrons would produce radioactive isotopes when absorbed by materials in the reactor **(1)** A very/extremely high temperature (plasma) is required **(1)** Plasma must not touch reactor walls, so strong magnetic fields are required **(1)** If plasma touches the walls of the reactor its temperature falls (and fusion stops) **(1)**	**5**
	Total for question	**15**