| Question Number | Answer | Mark |
|---|---|---|
| **1(a)** | A radioactive atom has an unstable nucleus **(1)**<br>which emits α, β, or γ radiation [at least one of α β γ named] **(1)** | **2** |
| **1(b)** | $\mathrm{C}\rightarrow{}^{11}_{5}\mathrm{B}+{}^{0}_{1}\mathrm{e}^{+}+\nu_{\mathrm{e}}$<br>Top line correct **(1)**<br>Bottom line correct **(1)** | **2** |
| **1(c)** | Attempt at mass diference calculation **(1)**<br>Attempt at conversion from (M)eV to J **(1)**<br>$\Delta E = 1.4 \times 10^{-13}$ (J) **(1)**<br><br><u>Example of calculation:</u><br>$\Delta E = 10\,253.6 - 10252.2 - 0.5 = 0.889$ MeV<br>$\Delta E = 0.889\text{ MeV} \times 1.6 \times 10^{-13}\text{ J MeV}^{-1} = 1.42 \times 10^{-13}$ J | **3** |
| **1(d)** | The idea that the sample will not produce radiation for very long (because carbon-11 has a relatively short half-life) **(1)**<br><br>β particles are not very ionising **Or** positrons are not very ionising **Or** boron is safe in small amounts **(1)** | **2** |
| **1(e)** | Use of $\lambda t_{1/2} = \ln 2$ **(1)**<br>($\lambda = 5.68 \times 10^{-4}\text{ s}^{-1}$)<br>Use of $A = A_0 e^{-\lambda t}$ **(1)**<br>Use $A = 1.58 \times 10^{6}$ Bq in $A = A_0 e^{-\lambda t}$ **(1)**<br>$A_0 = 1.2 \times 10^{7}$ Bq **(1)**<br><br><u>Example of calculation:</u><br>$\lambda = \frac{0.693}{1220\text{ s}} = 5.68 \times 10^{-4}\text{ s}^{-1}$<br>$1.58 \times 10^{6}\text{ Bq} = \mathrm{A}_0 e^{-5.68\times10^{-4}\text{ s}^{-1}\times 60\times60\text{ s}}$<br>$\mathrm{A}_0 = 1.22 \times 10^{7}$ Bq | **4** |
| | **Total for question** | **13** |

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

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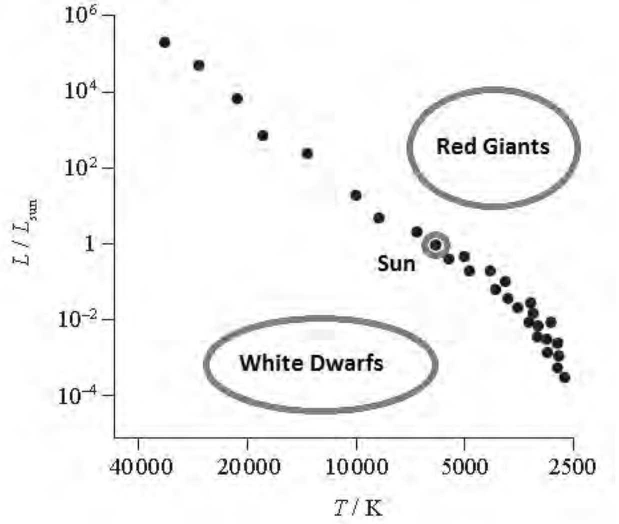
| **2(c)(ii)** | **MAX 2**<br>Very high temperatures [accept T~$10^7$ K] **(1)**<br>so that nuclei have sufficient energy to come close enough to overcome electrostatic repulsion [accept reference to strong interaction] **(1)**<br>A collision rate large enough to sustain fusion (from a very high density)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

| Question Number | Answer | Mark |
|---|---|---|
| **3(a)**<br>**(i)**<br>**(ii)** |  <br>Sun's position identified [single point identified] **(1)**<br>White dwarf region **(1)**<br>Red giant region **(1)** | **3** |
| ***3(a)(iii** | (QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)<br>White dwarf stars have:<br>high temperature $T$ (because $\lambda_{max}$ is small) **(1)**<br>low luminosity $L$ **(1)**<br>$L = \sigma A T^4$ linked to a determination of the surface area **(1)** | **3** |
| **3(b)** | The star cools, so temperature $T$ reduces **(1)**<br>The star contracts (under gravitational forces), so area $A$ reduces **(1)**<br>$L = \sigma A T^4$ hence L is reduced (mark dependent upon either mp1 or mp2) **(1)** | **3** |
| **3(c)(i)** | $^{7}_{3}\mathrm{Li} + {}^{1}_{1}\mathbf{X} \rightarrow 2 \times {}^{4}_{2}\mathrm{He}$ **(1)**<br>X is a proton [Accept X is hydrogen/H] **(1)** | **2** |
| **3(c)(ii)** | Attempt at calculation of mass difference **(1)**<br>Use of 1 MeV = $1.60 \times 10^{-13}$ J **(1)**<br>$\Delta E = 2.77 \times 10^{-12}$ (J) **(1)**<br><u>Example of calculation:</u><br>$\Delta m = 6533.8\mathrm{MeV/c^2} + 938.3\mathrm{MeV/c^2} - \left(2 \times 3727.4\mathrm{MeV/c^2}\right) = 17.3\mathrm{MeV/c^2}$<br>$\Delta E = 17.3\mathrm{MeV}$<br>$\Delta E = 17.3\mathrm{MeV} \times 1.60 \times 10^{-13}\mathrm{J\,MeV^{-1}} = 2.768 \times 10^{-12}\mathrm{J}$ | **3** |

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| **3(d)** | **Max 4**<br>- Extremely high temperature and density needed **(1)**<br>- High temperature because nuclei need high energy to overcome the (electrostatic) repulsive force **(1)**<br>- Since nuclei must come very close for fusion to occur<br>**Or** since nuclei must come close enough for (strong) nuclear force to act **(1)**<br>- Very high density is needed to maintain a sufficient collision rate **(1)**<br>- Reference to extreme conditions leading to containment problems **(1)** | **4** |
| | **Total for Question** | **18** |