Question Number	Answer		Mark
19(a)(i)	Use of $\lambda = \frac{\ln 2}{t_{½}}$	**(1)**	**2**
	$\lambda = 7.31 \times 10^{-10}$ (s^{-1}) [Minimum 3 sig fig]	**(1)**	
	Example of calculation $\lambda = \frac{\ln 2}{30.1 \times 3.15 \times 10^{7}\ s} = 7.31 \times 10^{-10}\ s^{-1}$		
19(a)(ii)	Use of $\frac{dN}{dt} = -\lambda N$	**(1)**	**3**
	Use of $u = 1.66 \times 10^{-27}$ kg with 137 [Allow use of 1.67×10^{-27} kg with 137]	**(1)**	
	$m = 5.9 \times 10^{-6}$ (kg) (Allow ecf from (a)(i))	**(1)**	
	Example of calculation $N = \frac{19 \times 10^{9}\ s^{-1}}{7.31 \times 10^{-1}\ \ s^{-1}} = 2.60 \times 10^{19}$		
	$m = 2.60 \times 10^{19} \times 137 \times 1.66 \times 10^{-27}\text{kg} = 5.91 \times 10^{-6}$ kg		
19(a)(iii)	Use of $A = A_0 e^{-\lambda t}$	**(1)**	**2**
	A = 18.1 GBq (Allow ecf from (a)(i))	**(1)**	
	Example of calculation		
	$A = 19 \times 10^{9}\text{Bq} \times \text{e}^{-7.31 \times 10^{-10}\ s^{-1} \times 2 \times 3.15 \times 10^{7}\ s}$		
	$A = 1.81 \times 10^{10}$ Bq		
	[2 years = 6.3×10^{7} s]		
19(b)	Use of total energy released $= \left(\frac{\Delta N}{\Delta t}\right) \times \Delta t \times E$ **Or** Use of total energy released $= \Delta N \times E$	**(1)**	**3**
	Use of 1 eV $= 1.6 \times 10^{-19}$ J	**(1)**	
	Total energy released = 4.3×10^{3} (J)	**(1)**	
	[If $\left(\frac{\Delta N}{\Delta t}\right) \times \Delta t$ determined by using exponential decay equation to calculate number of undecayed nuclei after 14 days; final answer should round to 4300 (J)]		
	Example of calculation $E = 19 \times 10^{9}\ s^{-1} \times 14 \times 86\,400\ s \times 1.17\ \text{MeV} = 2.69 \times 10^{16}\ \text{MeV}$ $E = 2.69 \times 10^{16}\ \text{MeV} \times 10^{6} \times 1.6 \times 10^{-19}\ \text{J eV}^{-1} = 4.30 \times 10^{3}\ \text{J}$		
	Total for question 19		**10**