Mark scheme for Extension Worksheet – Topic 6, Worksheet 3

1 **a** Atoms of a given chemical element come in many isotopes; and these have different mass. [2]

b The work done to accelerate the ions goes to kinetic energy i.e. $qV = \frac{1}{2}mv^2$; and so $v^2 = \frac{2qV}{m}$; the force bending the ions in a circle is the magnetic force so $qvB = \frac{mv^2}{r} \Rightarrow qB = \frac{mv}{r}$; substituting for the speed: $qB = \frac{m}{r} \times \sqrt{\frac{2qV}{m}}$; squaring gives the given answer. [4]

c Using $m = \frac{qB^2r^2}{2V}$ we get

$$m_1 = \frac{1.6\times10^{-19}\times(0.150)^2\times(0.0951)^2}{2\times490} = 3.3\times10^{-26}\text{ kg}$$; or

$$m_1 = \frac{3.3\times10^{-26}}{1.661\times10^{-27}} = 20.0\text{ u}$$; the other mass will be

$$m_2 = 20.0\times\left(\frac{0.0996}{0.0951}\right)^2 = 21.9\text{ u}$$ [3]

2 **a** Arrow from the level of Cs to the first excited state of barium. [1]

b The energy released in the decay is shared also by the antineutrino produced in the beta decay; and so the electron energy varies depending on directions of motion. [2]

c The beta decay finds barium in an excited nuclear energy level; and so it will decay to the ground state by emitting a photon. [2]

d The energy of the photon is $1.17 - 0.51 = 0.66\text{ MeV}$; hence

$$\frac{hc}{\lambda} = 0.66\text{ MeV} \Rightarrow \lambda = \frac{6.63\times10^{-34}\times3.0\times10^8}{0.66\times10^6\times1.6\times10^{-19}} = 1.9\times10^{-12}\text{ m}$$ [2]

3 **a** After the tree dies it will not longer be able to absorb any C-14 from the air; and what it already has will decrease due to the radioactive decay of C-14. [2]

b Since the concentration of C-14 is so tiny we may safely assume that the molar mass of the charcoal is just 12 g and so is equal to $\frac{15}{12} = 1.25$ moles; hence

$$N_{\text{C}-12} = 1.25\times6.02\times10^{23} = 7.5\times10^{23}$$ [2]

c The activity of the charcoal is $A = \lambda N_{\text{C}-14}$; and so

$$1.40 = \frac{\ln 2}{5730\times365\times24\times3600}N_{\text{C}-14} \Rightarrow N_{\text{C}-14} = 3.650\times10^{11}$$; so the ratio is

$$1.40 = \frac{\ln 2}{5730\times365\times24\times3600}N_{\text{C}-14} \Rightarrow \frac{N_{\text{C}-14}}{N_{\text{C}-12}} = \frac{3.650\times10^{11}}{7.525\times10^{23}} = 4.85\times10^{-13}$$ [3]

d $4.8\times10^{-13} = 1.3\times10^{-12}\times e^{-\lambda t}$; $-\lambda t = \ln\dfrac{4.8\times10^{-13}}{1.3\times10^{-12}} = -0.99$; so

$t = \dfrac{0.99}{\ln 2/5730} = 8184 \approx 8200$ yr [3]

