Mark scheme for Support Worksheet – Topic 6, Worksheet 4

1 **a** The product of the uncertainties in energy and time is never less than Planck's constant divided by 4π. [1]

b Since $\Delta t : 10^{-8}$ s (this is an order of magnitude calculation you may choose $\Delta t : \frac{1}{2}\times 10^{-8}$ s if you wish); $\Delta E \approx \frac{h}{4\pi\times\Delta t} = \frac{6.63\times 10^{-34}}{4\pi\times 10^{-8}} = 5.3\times 10^{-27} \approx 10^{-26}$ J [2]

2 **a** A wavefunction is a quantity $\Psi(x,t)$ associated with an electron such that $|\Psi(x,t)|^2\,\delta V$ is the probability for finding the electron within a volume δV around position x at time t. [1]

b Boundary conditions have to be imposed on the wavefunction and these result in conditions on the allowed energy of the system. [1]

3 Similarities: both predict energy levels; both predict the wavelengths of the photons emitted in transitions between energy levels; Differences: the Schrödinger theory can be applied to any atom, the Bohr cannot; the Schrödinger theory predicts the intensity of the lines in the emission spectrum the Bohr theory cannot. [4]

4 **a** The difference in energy between the levels is $-\frac{13.6}{4^2}-(-\frac{13.6}{2^2}) = 2.55$ eV;

therefore $\frac{hc}{\lambda} = 2.55\times 1.6\times 10^{-19}$; and so

$\lambda = \frac{6.63\times 10^{-34}\times 3\times 10^{8}}{2.55\times 1.6\times 10^{-19}} = 4.875\times 10^{-7} \approx 4.9\times 10^{-7}$ m [3]

b Visible. [1]

5 **a** At the point of closest approach, $k\frac{(2\text{e})(28\text{e})}{d} = 4.8$ MeV; hence

$d = k\frac{(2\text{e})(28\text{e})}{4.8\times 10^{6}\times 1.6\times 10^{-19}}$

$d = 8.99\times 10^{9}\times\frac{(2\times 1.6\times 10^{-19})(28\times 1.6\times 10^{-19})}{4.8\times 10^{6}\times 1.6\times 10^{-19}} = 1.67\times 10^{-14} \approx 1.7\times 10^{-14}$ m [3]

b Alpha particles of known kinetic energy are directed at nuclei and the distance of closest approach is calculated; the kinetic energy of the alpha particles is increased until few alpha particles are observed to be back scattered from the nuclei; at this distance of closest approach the alpha particles reach the surface of the nuclei and are attracted to the nuclei by the nuclear force – this distance of closest approach is roughly the nuclear radius. [3]

6 **a** The electron energies are continuous whereas alpha and gamma rays are discrete. [1]

b If we have nuclear energy levels the transitions between these levels result in emissions of energy that have specific values; this is precisely what is being observed in alpha and gamma decays. [2]

7 The difference is mainly one of scale, atomic energy levels involve eV or keV whereas nuclear energy levels involve MeV/atomic energy levels involve electrons, nuclear energy levels involve nucleons. [1]

8 The nucleus after the alpha decay is an excited energy state and when it makes a transition to the ground state a photon is emitted. [1]

9 The total energy released in beta decay is fixed; if only a nucleus and an electron were produced, the electron would have a fixed fraction of this energy; the fact that the electron has a range of energies implies the existence of a third particle that shares in the taking up the energy produced. [3]

10 **a** The decay constant is the probability per unit time that a particular nucleus will decay. [1]

b λN [1]

11 Substitute $N = \frac{N_0}{2}$ and $t = T_{1/2}$ in $N = N_0 e^{-\lambda t}$ to get $\frac{1}{2} = e^{-\lambda T_{1/2}}$; take logs of both answers to get the answer $\lambda T_{1/2} = \ln 2$ [2]

