Answers to exam-style questions

Topic 7

Where appropriate, 1 ✓ = 1 mark

1 B

2 B

3 C

4 A

5 B

6 D

7 C

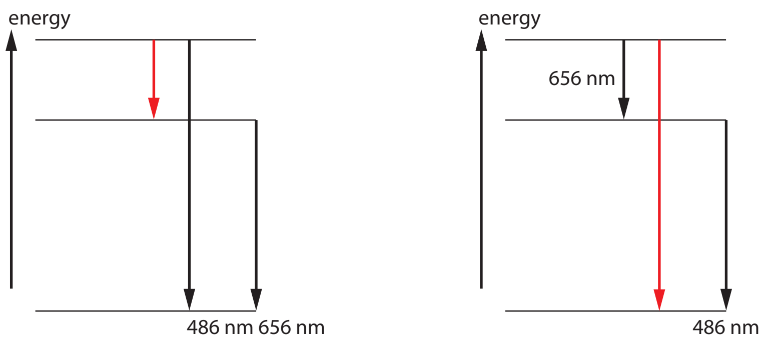
8 D

9 C

10 C

11 **a** The wavelength of a photon is determined by its wavelength (frequency). ✓
Emission spectra show lines at specific wavelengths. ✓
This is consistent with transitions between energy levels of specific energies. ✓

b There are two possibilities as shown in the diagram below. The red line represents the transition with unknown wavelength.



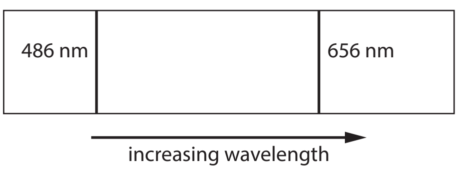
c In the first case the third transition corresponds to an energy difference of

$$\frac{hc}{486\times10^{-9}}-\frac{hc}{656\times10^{-9}}\left(=\frac{6.63\times10^{-34}\times3.0\times10^{8}}{486\times10^{-9}}-\frac{6.63\times10^{-34}\times3.0\times10^{8}}{656\times10^{-9}}=1.06\times10^{-19}\text{ J}\right). ✓$$

The third transition has wavelength $\frac{hc}{\lambda}=\frac{hc}{486\times10^{-9}}-\frac{hc}{656\times10^{-9}}\Rightarrow\lambda=1.88\times10^{-6}$ m. ✓

In the second case $\frac{hc}{\lambda}=\frac{hc}{486\times10^{-9}}+\frac{hc}{656\times10^{-9}}\Rightarrow\lambda=2.79\times10^{-7}$ m. ✓

d Only 2 lines shown. ✓
With right wavelengths and in the right order. ✓



12 **a** **i** In order to avoid collisions of the alpha particles with air molecules which would have scattered the alpha particles. ✓

ii To avoid multiple scatterings of alpha particles within the foil. ✓

iii In order to have well defined scattering angles. ✓

b The electrostatic force. ✓

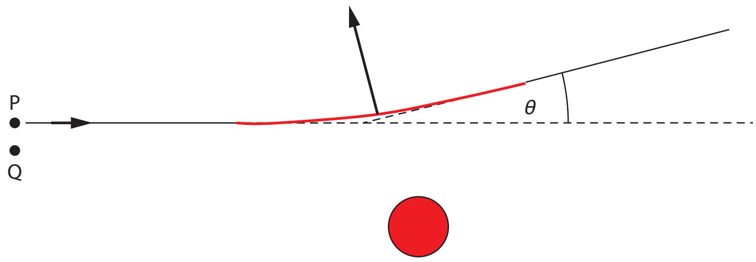
c **i** A very small fraction of the incident alpha particles were scattered at very large scattering angles. ✓

ii This required a very large electric force. ✓
This force could be provided if the positive charge of the atom was concentrated in a very small volume so that the alpha particle could come very close to it. ✓
So most of the atomic volume is empty and most of the mass and all the positive charge is concentrated in the tiny nucleus. ✓

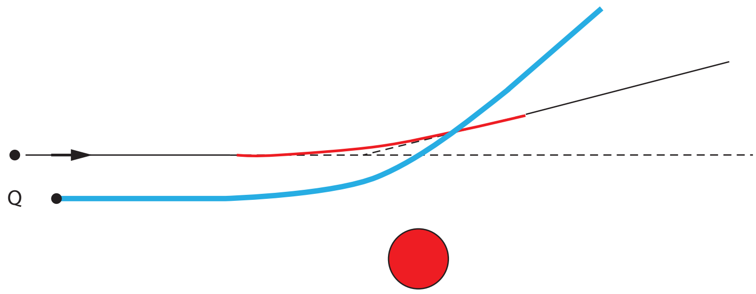
d **i** Smooth curve joining incident and scattered path. ✓

ii Extensions of incident and scattered paths. ✓
Angle delineated as shown. ✓

iii Arrow as shown passing through centre of nucleus. ✓



e **i** Comes closer to the nucleus. ✓
Has a larger scattering angle. ✓



ii The new nucleus would have the same nuclear charge. ✓
So there would be no difference. ✓

13 **a** **Random**: It is not possible to predict which nucleus will decay. ✓
Or when it will decay. ✓
Spontaneous: A nucleus cannot be prevented from decaying. ✓
The rate of decay cannot be modified in any way. ✓

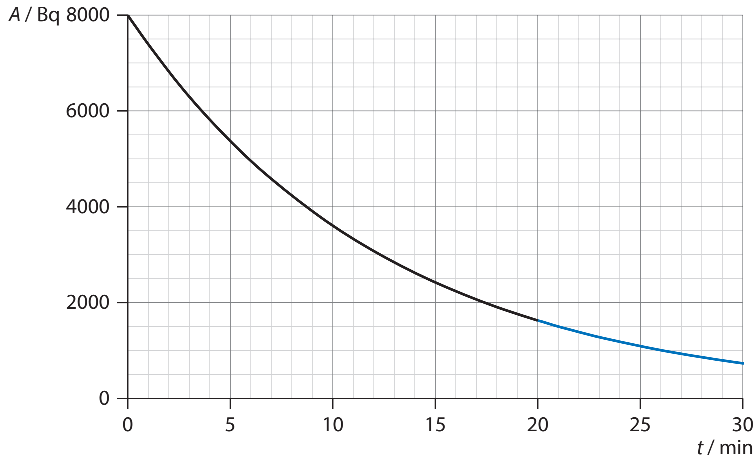
b **i** A nucleus of a specific element (so with a specific atomic number) but with a different number of neutrons (so a different mass number). ✓

ii Locating the point with activity 4000 Bq. ✓
8.7/8.8 min. ✓

iii That the background radiation is negligible. ✓

iv Smooth joining. ✓

To correct value within 1 square at 30 min. ✓



c **i** $^{225}_{90}\text{Th} \rightarrow {}^{221}_{88}\text{Ra} + {}^{4}_{2}\alpha$

Correct numbers for alpha. ✓

Correct numbers for radium. ✓

ii $\Delta m = 226.024903 - (221.013917 + 4.0026603) = 1.0083$ u ✓

$Q = 1.0083 \times 931.5 = 939$ MeV ✓

d The alpha and the radium nucleus have equal and opposite momenta, each of magnitude p. ✓

The energies are $E_{\text{Ra}} = \dfrac{p^2}{2 \times 221}$ and $E_{\alpha} = \dfrac{p^2}{2 \times 4.0}$. ✓

Hence the alpha to radium energy ratio is energy is $\dfrac{221}{4.0} = 55$. ✓

14 **a** **i** $x = 236 - 90 - 143 = 3$ ✓

ii $Q = BE_{\text{right}} - BE_{\text{left}}$ ✓

$BE_{\text{right}} \approx 143 \times 8.4 + 90 \times 8.7 = 1984$ MeV and $BE_{\text{left}} \approx 235 \times 7.6 = 1786$ MeV ✓

$Q = 1984 - 1768 = 198 \approx 200$ MeV ✓

b Because the nuclear force is short range only the immediate neighbours of any given nucleon prevent the nucleon from being ejected from a nucleus. ✓

Nuclei with $A > 20$ are large nuclei with many protons and neutrons so any one nucleon is surrounded by roughly the same number of nucleons. ✓

Since the binding energy per nucleon is a measure of the energy needed to eject one nucleons, this energy is roughly constant. ✓

c In fusion we start with light nuclei and produce heavier nuclei. ✓

According to the binding energy curve this increases the binding energy than the reactants and hence energy is released. ✓

15 **a** A baryon is a particle made of 3 quarks. ✓

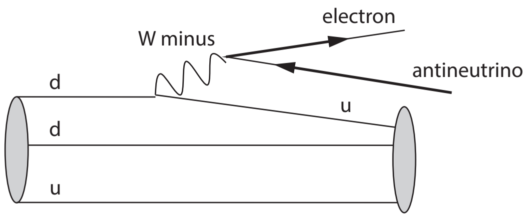
Whereas a meson is made of a quark and an antiquark. ✓

b Hadrons correct. ✓

Leptons correct. ✓

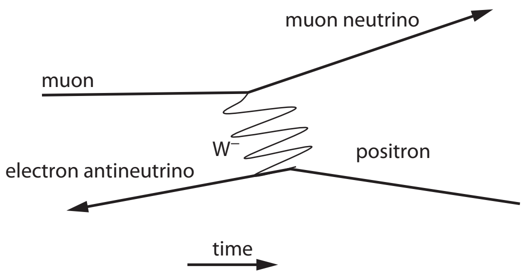
	strong	weak
hadrons	✓	✓
leptons		✓

c ddu for neutron. ✓
d to u. ✓
W minus. ✓
Electron. ✓
Antineutrino. ✓



d i K and π are mesons so $B = 0$ and p is a baryon so $B = 1$. ✓
To conserve baryon number Σ^- must have B = 1 and so is baryon. ✓
ii The reaction violates strangeness conservation. ✓
And so must happen via the weak interaction since the other interactions conserve strangeness. ✓
iii In order to conserve family lepton number. ✓
It has to be an electron antineutrino. ✓

16 a i Similarities: both are leptons/both have charge − 1. ✓
Differences: have different mass/belong to different families. ✓
ii It violates electron lepton number conservation. ✓
It violates muon lepton number conservation. ✓
b i Top line: muon neutrino. ✓
Middle line: electron. ✓
Lower line: electron antineutrino. ✓
ii Top vertex correct. ✓
Lower vertex correct. ✓



iii Positron. ✓
Correct neutrinos. ✓
$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$
c It has very large mass. ✓