Answers to test yourself questions

Topic 12

12.1 The interaction of matter with radiation

1 **a** The emission of electrons from a metallic surface when light or other forms of electromagnetic radiation are incident on the surface.

b From the Einstein formula $E_{\max} = hf - \phi$. At the critical frequency, $E_{\max} = 0$ and so

$$hf_c - \phi = 0 \Rightarrow f_c = \frac{\phi}{h} = \frac{3.00 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 7.24 \times 10^{14}\,\text{HZ}.$$

2 **a** Evidence for photons comes from the photoelectric effect, Compton scattering and others.

b $\phi = hf_c$. Then $E_{\max} = hf - \phi = hf - hf_C = h(f - f_C) = 6.63 \times 10^{-34} \times (3.872.25) \times 10^{14} = 1.074 \times 10^{-19}$ J. The

stopping voltage is $qV_s = E_{\max} \Rightarrow V_s = \dfrac{E_{\max}}{q} = \dfrac{1.0074 \times 10^{-19}}{1.6 \times 10^{-19}} = 0.671V$.

3 **a** Light consists of photons. When light is incident on the metal an electron from within the metal may absorb one photon and so its energy will increase by an amount equal to the photon energy. If this energy is sufficient to overcome the potential well the electron finds itself in, the electron may be free itself from the metal.

b The number of electrons emitted per second is 10^{15} and so the charge that leaves the metal per second, i.e. the current, is $10^{15} \times 1.6 \times 10^{-19} = 1.6 \times 10^{-4}$ A.

c From $E_{\max} = hf - \phi$ we get

$$\begin{aligned}\phi &= hf - E_{\max} = \frac{hc}{\lambda} - E_{\max} \\ &= \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{5.4 \times 10^{-7}} - 2.1 \times 1.6 \times 10^{-19} \\ &= 3.23 \times 10^{-19}\,\text{J} \\ &= \frac{3.23 \times 10^{-20}}{1.6 \times 10^{-19}} \\ &= 0.20\,\text{eV}\end{aligned}$$

d The energy is independent of intensity and so we still have $E_{\max} = 2.1$ eV.

e The current will double since current is proportional to intensity.

4 **a**
- The electrons are emitted without delay. In the photon theory of light the energy is supplied to an electron by a single photon in an instantaneous interaction.
- There is a critical frequency below which no electrons are emitted. The energy of the photon depends on frequency so if the photon energy is less than the work function the electron cannot be emitted.
- The intensity of light has no effect on the energy of the emitted electrons. The intensity of light depends on the number of photons present and so this will affect the number of electrons emitted not their energy.

b **i** Stopping voltage is the voltage that makes the current in the photoelectric experiment zero.

ii $qV_S = \dfrac{hc}{\lambda} - \phi \Rightarrow \phi = \dfrac{hc}{\lambda} - qV_S$

$$\phi = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{2.08 \times 10^{-7}} - 1.6 \times 10^{-19} \times 1.40 = 7.32 \times 10^{-19}\,\text{J}$$

The longest wavelength corresponds to the smallest frequency i.e. the critical frequency:

$$\frac{hc}{\lambda_C} - \phi = 0 \Rightarrow \lambda_C = \frac{hc}{\phi} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{7.32 \times 10^{-19}} = 2.72 \times 10^{-7}\,\text{m}.$$

5 a i As long as the wavelength stays the same, the energy of the emitted will stay the same.

ii Increasing the intensity of light increases the number of electrons emitted i.e. the photocurrent.

b We have that $qV_S = \frac{hc}{2.3 \times 10^{-7}} - \phi$ and $q(2V_S) = \frac{hc}{1.8 \times 10^{-7}} - \phi$.

Subtracting, $qV_S = \frac{hc}{1.8 \times 10^{-7}} - \frac{hc}{2.3 \times 10^{-7}} \Rightarrow V_S = 1.50\,\text{V}$. Hence,

$$\phi = \frac{hc}{2.3 \times 10^{-7}} - qV_S = 6.25 \times 10^{-19}\,\text{J} = \frac{6.25 \times 10^{-19}}{1.6 \times 10^{-19}} = 3.9\,\text{eV}.$$

6 a The work function is $\phi = 3.0 \times 1.6 \times 10^{-19} = 4.8 \times 10^{-19}$ J. The power incident on the given area is $P = 5.0 \times 10^{-4} \times 1.0 \times 10^{-18} = 5.0 \times 10^{-22}$ W. To accumulate the energy equal to the work function we need a time of $5.0 \times 10^{-22} \times t = 4.8 \times 10^{-19}$ i.e. $t = \frac{4.8 \times 10^{-19}}{5.0 \times 10^{-22}} = 960\,\text{s}$ or 16 minutes.

b Since in photoelectric experiments there is no time delay in the emission of electrons, light cannot be treated as a wave as this calculation has.

c In the photon theory of light, the energy carried by a photon is given to the electron in one go, not gradually.

7 a i Extending the graph we find a horizontal intercept of about 5.0×10^{14} Hz.

ii The work function and the critical frequency are related through:

$$hf_C - \phi = 0 \Rightarrow \phi = hf_C = 6.63 \times 10^{-34} \times 5.0 \times 10^{14} = 3.3 \times 10^{-19}\,\text{J} = 2.1\,\text{eV}.$$

b Reading off the graph we find about 2.0×10^{-19} J = 1.25 eV.

c It will be a line parallel to the original with a horizontal intercept at 6.0×10^{14} Hz.

8 The energies, in eV, of the hydrogen atom electron are found from $-\frac{13.6}{n^2}$ and so form the set {−13.6, −3.4, 1.51, 0.85, ...}. The difference between excited levels and the ground state are {10.2, 12.1, 12.8, ...}. Thus an electron with energy 11.5 eV can give 10.2 eV of its energy to a ground state electron that will make a transition to the level $n = 2$ and rebound with a kinetic energy 11.5 − 10.2 = 1.3 eV. Of course the electron may just lose no energy to the atom in which case it will have an elastic collision moving away with the same energy as the original, i.e. 11.5 eV.

9 a The intensity is $I = \frac{P}{A} = \frac{nhf}{A}$ where n is the number of photons incident per second. Then $I = \Phi hf$ where $\Phi = \frac{n}{A}$ is the number of photons per second per unit area.

b $I = \Phi hf = \frac{\Phi hc}{\lambda} = \frac{3.8 \times 10^{18} \times 6.33 \times 10^{-34} \times 3.0 \times 10^{8}}{5.0 \times 10^{-7}} = 1.5\ \text{Wm}^{-2}.$

c $\frac{\Phi hc}{\lambda} = \frac{\Phi' hc}{\lambda'} \Rightarrow \Phi' = \frac{\lambda'}{\lambda}\Phi = \frac{4.0 \times 10^{-7}}{5.0 \times 10^{-7}} = 3.0 \times 10^{18}\ \text{m}^{-2}s^{-1}.$

d Since the intensity is the same, the flux for the shorter wavelength is less and hence fewer electrons will be emitted since fewer photons are incident.

e This assumes that the fraction of photons that eject electrons is the same for both wavelengths. This fraction is called the quantum efficiency, which in general does depend on wavelength in a complex way.

10 a The existence of absorption and emission spectra – the wavelengths of the emitted or absorbed photons are specific to specific elements and correspond to specific energies. This can be understood if we accept that the energy in atoms has specific values so that differences in levels also have specific values.

b We list the energy differences between the ground sate and the excited states: $\Delta E_{12} = 10.2$ eV, $\Delta E_{13} = 12.1$ eV, $\Delta E_{14} = 12.8$ eV, $\Delta E_{15} = 13.1$ eV, $\Delta E_{16} = 13.2$ eV, $\Delta E_{17} = 13.3$ eV. Hence: **i** not enough energy for an excitation, **ii** the electron can reach $n = 4$ and **iii** the electron can reach $n = 6$.

11 a This is the energy that must be supplied to an atom so that an electron can be ejected from the atom.

b The energy in the $n = 3$ level is $E_3 = -\dfrac{13.6}{3^2} = -1.51$ eV and this is the ionization energy for this level.

12 a The smallest wavelength corresponds to the largest energy difference and this theoretically is 13.6 eV. Hence

$$E = hf = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{13.6\times1.6\times10^{-19}} = 9.1\times10^{-8}\ \text{m}.$$

b The kinetic energy of the electron must be at least 13.6 eV, i.e.

$$\frac{1}{2}mv^2 = E_K \Rightarrow v = \sqrt{\frac{2\times13.6\times1.6\times10^{-19}}{9.1\times10^{-31}}} = 2.2\times10^{6}\ \text{m s}^{-1}.$$

13 a $\lambda = \dfrac{h}{p} = \dfrac{6.63\times10^{-34}}{0.250\times10} = 2.7\times10^{-34}\,\text{m}$

b No because to show diffraction effects the brick would have to go through openings of size similar to the wavelength and this is not possible.

14 a The Davisson-Germer experiment – see text.

b $p = \dfrac{h}{\lambda} = \dfrac{6.63\times10^{-34}}{680\times10^{-9}} = 9.75\times10^{-28}$ N s. Hence $v = \dfrac{p}{m} = \dfrac{9.75\times10^{-28}}{9.1\times10^{-31}} = 1.1\times10^{3}\,\text{ms}^{-1}$.

15 a The work done in accelerating the electron will go into kinetic energy and so $E_K = qV$. Then

$$\frac{p^2}{2m} = qV \Rightarrow p = \sqrt{2mqV}.\ \text{Then}\ \lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}.$$

b $$\frac{\lambda_p}{\lambda_\alpha} = \frac{\dfrac{h}{\sqrt{2m_pq_pV}}}{\dfrac{h}{\sqrt{2m_\alpha q_\alpha V}}} = \sqrt{\frac{m_\alpha q_\alpha}{m_pq_p}} \approx \sqrt{4\times2} = \sqrt{8}$$

c From $E_K = \dfrac{p^2}{2m}$ we find $p = \sqrt{2mE_K} = \sqrt{2\times9.1\times10^{31}\times520\times1.6\times10^{-19}} = 1.23\times10^{-23}$ N s. Hence

$$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{1.23\times10^{-23}} = 5.4\times10^{-11}\,\text{m}.$$

16 a From $E_K = \dfrac{p^2}{2m}$ we find $p = \sqrt{2mE_K} = \sqrt{2\times1.67\times10^{-27}\times200\times10^{6}\times1.6\times10^{-19}} = 3.27\times10^{-19}$ N s. Hence

$$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{1.23\times10^{-23}} = 5.4\times10^{-11}\,\text{m}.$$

b The total energy of the electron in the state $n = 2$ is $E = \dfrac{-13.6}{2^2} = -5.44\times10^{-19}$ J. The kinetic energy of the electron is the negative of the total energy and so $E_K = +5.44\times10^{-19}$ J. Since $E_K = \dfrac{p^2}{2m}$ we find $p = \sqrt{2mE_K} = \sqrt{2\times9.1\times10^{-31}\times5.44\times10^{-19}} = 9.95\times10^{-25}$ N s. Hence $\lambda = \dfrac{h}{p} = \dfrac{6.63\times10^{-34}}{9.95\times10^{-25}} = 6.66\times10^{-10} \approx 6.7\times10^{-10}$ m. An alternative way is to use $mvr = \dfrac{nh}{2\pi} \Rightarrow 2\pi r = \dfrac{nh}{p} = n\lambda$ and so $2\pi r = 2\lambda \Rightarrow \lambda = \pi r$. The $n = 2$ state has $r = 4\times0.5\times10^{-10}$ m and so $\lambda = 6.3\times10^{-10}$ m. (The difference with the previous answer is a question of significant figures.)

17 We may take the uncertainty in the electron's position to be $\Delta x \approx 1\times10^{-10}$ m, the "size" of the atom.

Then $\Delta p \geq \frac{h}{4\pi\Delta x} = \frac{6.63\times10^{-34}}{4\pi\times1\times10^{-10}} = 5.27\times10^{-25}$ N s. The corresponding kinetic energy is then of order

$E_K = \frac{p^2}{2m} \approx \frac{\Delta p^2}{2m} = \frac{(5.27\times10^{-25})^2}{2\times9.1\times10^{-31}} = 1.53\times10^{-19}\text{ J} = \frac{1.53\times10^{-19}}{1.6\times10^{-19}} = 0.96 \approx 1\text{ eV}$ which is the correct order of magnitude.

18 **a** There is a wave associated with every moving particle, of wavelength equal to Planck's constant divided by the momentum of the particle.

b The kinetic energy of the electron will be $E_K = qV$ and so $\frac{p^2}{2m} = qV \Rightarrow p = \sqrt{2mqV} = 1.21\times10^{-24}$ N s. Then $\lambda = \frac{6.63\times10^{-34}}{1.21\times10^{-24}} = 5.5\times10^{-10}$ m.

c Precise knowledge of the wavelength implies precise knowledge of the momentum. By the uncertainty principle the uncertainty in position must be large.

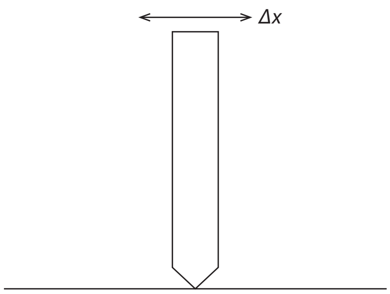
19 **a** As the opening decreases there will be more and more diffraction and so the beam will not be thin – it will spread.

b To reduce diffraction the wavelength must be as small as possible (and smaller than d). This requires fast electrons.

20 The de Broglie wavelength of the tennis ball is $\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{6} \approx 1\times10^{-34}$ m. The tennis ball wave will diffract through the opening. The angle at which the first diffraction minimum occurs is of order

$\theta_D \approx \frac{\lambda}{b} = \frac{1\times10^{-34}}{1} = 1\times10^{-34}$ rad. The angle is insignificantly small. The tennis ball will move on a straight line without any deviation.

21 There will always be an uncertainty Δx in the position of the top of the pencil and so there will be a corresponding uncertainty in momentum. Hence the top of the pencil will have to move and hence the pencil will fall.



22 **a** The top graph allows precise determination of the wavelength and hence the momentum. The uncertainty in momentum will then be small.

b The bottom diagram shows that the probability of finding the particle is large within a small area of space.

23 **a** The wavelength will be given by $\lambda = \frac{2L}{n}$ and for the fundamental (i.e. the first harmonic), $\lambda = 2L = 2\times10^{-15}$ m.

b $\Delta p \geq \frac{h}{4\pi\Delta x} = \frac{6.63\times10^{-34}}{4\pi\times1\times10^{-15}} = 5.27\times10^{-20}$ N s

$E_K = \frac{p^2}{2m} \approx \frac{\Delta p^2}{2m} = \frac{(5.27\times10^{-20})^2}{2\times9.1\times10^{-31}} = 1.53\times10^{-9}\text{ J} = \frac{1.53\times10^{-9}}{1.6\times10^{-19}} \approx 10^{10}\text{ eV} = 10^4\text{ MeV}.$

c This is far larger than the binding energy of a nucleus and so the electron would rip the nucleus apart. The electron cannot be confined within a nucleus.

12.2 Nuclear physics

24 By conservation of energy

$$\frac{1}{2}mv^2 = \frac{k(2e)(79e)}{d} \Rightarrow v = \sqrt{\frac{2k(2e)(79e)}{md}}$$

$$v = \sqrt{\frac{2\times 9\times 10^{9}(2\times 1.6\times 10^{-19})(79\times 1.6\times 10^{-19})}{6.4\times 10^{-27}\times 8.5\times 10^{-15}}}$$

$$v = 3.7\times 10^{7}\ \text{m s}^{-1}$$

25 The idea is that since the nucleus is very massive it will not recoil. Then at the point of closest separation the kinetic energy will be a minimum and will increase as the separation increases. The potential energy is given by $E_P = \frac{kZe^2}{r}$ and so will be a maximum at the point of closet separation and will tend to zero as the separation increases. These observations give the graphs in the answers in the textbook.

26 **a** As the energy increases the alpha particle can approach closer and closer to the nucleus. Eventually it will be within the range of the strong nuclear force and some alphas will be absorbed by the nucleus and will not scatter.

b Since the nuclear charge of aluminum is smaller than that of gold the alphas will get closer to aluminum and so will experience the nuclear force first. Hence deviations will first be seen for aluminum.

27 The radius of a nucleus of mass number A is $R = 1.2\times A^{1/3}\times 10^{-15}$ m and its mass is $M = Am_n$ (here m_n is the mass of a nucleon). The density is therefore $\rho = \frac{M}{\frac{4}{3}\pi R^3} = \frac{A\times m_n}{\frac{4}{3}\pi(1.2\times A^{1/3}\times 10^{-15})^3} = \frac{m_n}{\frac{4}{3}\pi(1.2\times 10^{-15})^3}$ and so is independent of A. An estimate of this density is $\rho = \frac{1.67\times 10^{-27}}{\frac{4}{3}\pi(1.2\times 10^{-15})^3} \approx 10^{17}\ \text{kg m}^{-3}$.

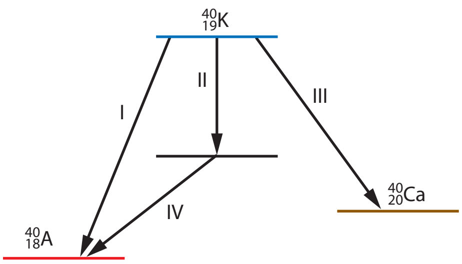
28 **a** The main evidence is the discrete energies of alpha particles and gamma partivcles in alpha and gamma decay.

b ${}^{226}_{88}\text{Ra} \rightarrow {}^{226}_{88}\text{Ra} + {}^{0}_{0}\gamma$

c $hf = \frac{hc}{\lambda} = \Delta E \Rightarrow \lambda = \frac{hc}{\Delta E}$. Hence $\lambda = \frac{6.63\times 10^{-34}\times 3.0\times 10^{8}}{0.0678\times 10^{6}\times 1.6\times 10^{-19}} = 1.83\times 10^{-11}$ m.

29 Plutonium $\left({}^{242}_{94}\text{Pu}\right)$ decays into uranium $\left({}^{238}_{92}\text{U}\right)$ by alpha decay. The energy of the alpha particles takes four distinct values, 4.90 MeV, 4.86 MeV, 4.76 MeV and 4.60 MeV. In all cases a gamma ray photon is also emitted except when the alpha energy is 4.90 MeV. Use this information to suggest a possible nuclear energy level diagram for uranium.

30



The four indicated transitions are:

I: ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{18}\text{Ar} + e^{+} + \nu$ (beta plus decay)

II: ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{19}\text{K} + \gamma$ (gamma decay)

III: ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{18}\text{Ar} + e^{+} + \nu$ (beta plus decay)

IV: ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{20}\text{Ca} + e^{-} + \nu$ (beta minus decay)

31 **a** We know that $\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{3.00} = 0.231\ \text{s}^{-1}$.

b We start with $\frac{1}{100}\quad 6.02\quad 10^{23} = 6.02\quad 10^{21}$ nuclei and so:

i $N = 6.02 \times 10^{21} \times e^{-0.231\times 1} = 4.78 \times 10^{21}$;
ii $N = 6.02 \times 10^{21} \times e^{-0.231\times 2} = 3.79 \times 10^{21}$;
iii $N = 6.02 \times 10^{21} \times e^{-0.231\times 3} = 3.01 \times 10^{21}$.

32 **a** The probability of decay within a half-life is always $\frac{1}{2}$.

b The probability that the nucleus will not decay after the passage of three half – lives is $\underbrace{\frac{1}{2}}_{\text{no decay}} \quad \underbrace{\frac{1}{2}}_{\text{no decay}} \quad \underbrace{\frac{1}{2}}_{\text{no decay}} = \frac{1}{8}$.

Hence the probability that the nucleus will decay some time within three half – lives is $1 - \frac{1}{8} = \frac{7}{8} = 0.875$.

c The probability of decay in any one half – life interval is 0.5.
More mathematically, we want to find $P(D|N)$ where we use the notation of conditional probability and the events D and N stand for D = decay in the next half-life and N = no decay in the first 4 half lives. Then $P(D|N) = \frac{P(D \cap N)}{P(N)}$. Now, $P(N) = \frac{1}{2^4} = \frac{1}{16}$ and $P(D \cap N) = \frac{1}{32}$. Hence $P(D|N) = \frac{1}{2}$.

33 The half-life is so long so that what we are really asked to find is the initial activity of 1.0 g of pure radium. We have that $A = \lambda N_0 e^{-\lambda t}$ so that the initial activity is λN_0. A mass of 1.0 g of radium corresponds to $\frac{1.0}{226.025} = 0.0044243$ moles and hence $N_0 = 0.0044243 \quad 6.02 \quad 10^{23} = 2.6634 \quad 10^{21}$ nuclei. Since $\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{1600 \times 365 \times 24 \times 60 \times 60} = 1.3737 \times 10^{-11}\ \text{s}^{-1}$ we find an activity of $1.3737 \times 10^{-11} \times 2.6634 \times 10^{21} = 3.66 \times 10^{10}$ Bq.

34 The decay constant is $\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{12} = 0.0578\ \text{d}^{-1}$ and so $A = \lambda N_0 e^{-\lambda t} = 3.5 \times e^{-0.0578\times 20} = 1.1$ MBq.

35 The decay constant is $\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{6 \times 24 \times 60 \times 60} = 1.34 \times 10^{-6}\ \text{s}^{-1}$. From $A = \lambda N_0 e^{-\lambda t}$ we find

$0.50 \times 10^6 = 1.34 \times 10^{-6} \times N_0 e^{-1.34\times 10^{-6}\times 24\times 60\times 60} \Rightarrow N_0 = 4.2 \times 10^{11}$.

36 After time t the number of uranium atoms remaining in the rocks is $N = N_0 e^{-\lambda t}$ and so the number that decayed (and hence eventually became lead) is $N - N_0 = N_0(1 - e^{-\lambda t})$. Hence we have that $\frac{N_0(1-e^{-\lambda t})}{N_0 e^{-\lambda t}} = 0.80$.
This means that $1 - e^{-\lambda t} = 0.80 e^{-\lambda t} \Rightarrow 1 = 1.80 e^{-\lambda t} \Rightarrow e^{\lambda t} = 1.80$. Hence $\lambda t = \ln(1.80) = 0.5878$. Since $\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{4.5 \times 10^9} = 1.54 \times 10^{-10}\ \text{yr}^{-1}$ we find $t = \frac{0.5878}{1.54 \times 10^{-10}} = 3.8 \times 10^9$ yr.

37 The method of question **36** may be used but here, clearly, a ratio of 1:7 corresponds to three half – lives and so the age is about $t = 3 \quad 1.37 \quad 10^9 = 4.1 \quad 10^9$ yr.

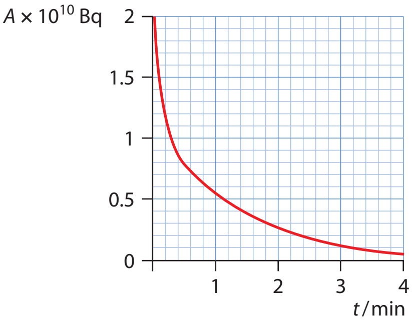
38 The activity is given by $A = \lambda N = \lambda N_0 e^{-\lambda t}$ where $\lambda = \frac{\ln 2}{T_{1/2}}$ is the decay constant.

a $\frac{A_A}{A_B} = \frac{\lambda_A N_{0A}}{\lambda_B N_{0B}} = \frac{3}{4} \times 1 = \frac{3}{4} = 0.75$

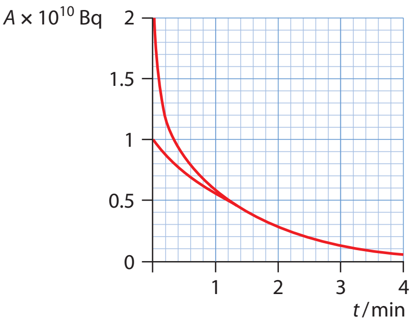
b $\frac{A_A}{A_B} = \frac{\lambda_A N_{0A} e^{-\lambda_A \times 4}}{\lambda_B N_{0B} e^{-\lambda_B \times 4}} = \frac{3}{4} \times \frac{e^{-\frac{\ln 2}{4}\times 4}}{e^{-\frac{\ln 2}{3}\times 4}} = 0.95$

c $\frac{A_A}{A_B} = \frac{\lambda_A N_{0A} e^{-\lambda_A \times 12}}{\lambda_B N_{0B} e^{-\lambda_B \times 12}} = \frac{3}{4} \times \frac{e^{-\frac{\ln 2}{4}\times 12}}{e^{-\frac{\ln 2}{3}\times 12}} = 1.5$

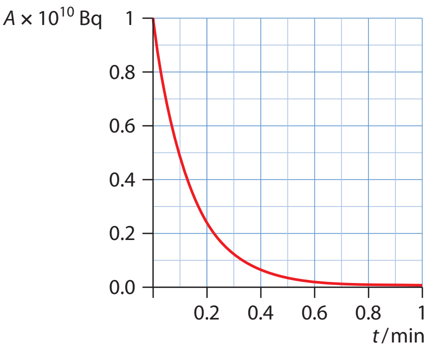
39 This is a very difficult question and many different possibilities must be considered. Essentially we must be able to determine form a graph of activity versus time the initial activities of the two isotopes and their respective half – lives. One possibility is represented by the following graph in which a short (S) and a long (L) half – life isotopes are present. The shape of the curve is not a pure exponential.



We see that after about 1 minute we have a smooth exponential curve which implies that one of the isotopes has essentially decayed away, leaving behind just one isotope. This is justified by estimating a half-life for times greater than 1 minute. We get consistently a half-life of 1 minute for the long half – life isotope. Extending smoothly the exponential curve backwards, we intercept the vertical axis at about 1 10^{10} Bq.



Thus the activity of isotope L is given by $A_L = 10^{10} \quad 0.5^{t/1}$. This means that the initial activity of the other isotope is also 1 10^{10} Bq. Subtracting from the data points of the given graph the activity of this isotope we get the following graph.



This represents the decay of just isotope S. From this graph we find a half-life of about 0.1 minute. Obviously, this analysis gets more complicated when the half- lives are not so different or when the initial activities are very different.

40 **a** If the mass (in grams) is m and the molar mass is , the number of moles of the radioactive isotope is $\frac{m}{}$. The initial number of nuclei is then $N_0 = \frac{m}{} \quad N_A$ since one mole contains Avogadro's number of molecules.

b The activity is $A = \lambda N = \lambda N_0 e^{-\lambda t} = \lambda \frac{m}{\mu} N_A e^{-\lambda t}$ and the initial activity is thus $A_0 = \lambda \frac{m}{\mu} N_A x$. Measuring the initial activity then allows determination of the decay constant and hence the half-life from $\lambda = \frac{\ln 2}{T_{1/2}}$.