Uranium-234 is radioactive and emits α-particles at what appears to be a constant rate.

A sample of Uranium-234 of mass 2.65 µg is found to have an activity of 604 Bq.

(a) Calculate, for this sample of Uranium-234,

(i) the number of nuclei,

$$n = \frac{2.65 \times 10^{-6}}{234}$$

$$= 1.13247... \times 10^{-8}$$

$$N = n N_A = 6.8175 \times 10^{15}$$

number = 6.82×10^{15} [2]

(ii) the decay constant,

$$A = \lambda N$$

$$\lambda = \frac{A}{N} = \frac{604}{6.82 \times 10^{15}} = 8.859 \times 10^{-14}$$

decay constant = 8.86×10^{-14} s^{-1} [2]

(iii) the half-life in years.

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{8.86 \times 10^{-14}}$$

$$= 7.82 \times 10^{12} = 2.17.. \times 10^{9} \text{ hour}$$

half-life = 2.48×10^{5} years [2]

Use

(b) Suggest why the activity of the Uranium-234 appears to be constant.

Half-life is very long.

[1]

(c) Suggest why a measurement of the mass and the activity of a radioactive isotope is not an accurate means of determining its half-life if the half-life is approximately one hour.

There will be appreciable decay of source while taking the measurements.

[1]

(Question 8 of Paper 4, Winter, 2006)

(a) Explain what is meant by the *binding energy* of a nucleus.

Energy required to seperate the nucleons to infinity

....[1]

(b) Fig. 7.1 shows the variation with nucleon number (mass number) A of the binding energy per nucleon E_B of nuclei.

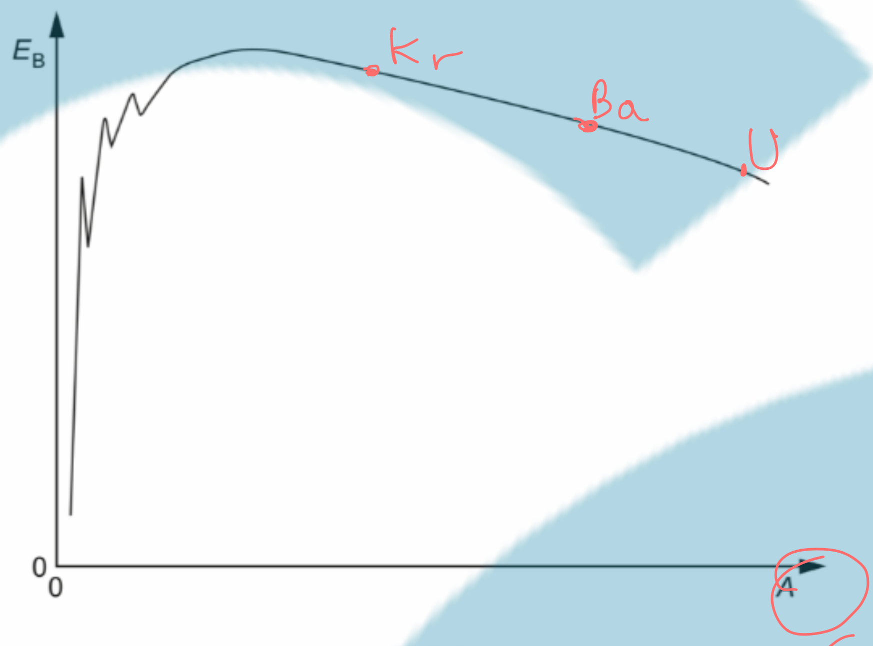

Fig. 7.1

One particular fission reaction may be represented by the nuclear equation

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n.$$

(i) On Fig. 7.1, label the approximate positions of

1. the uranium ($^{235}_{92}U$) nucleus with the symbol U,

2. the barium ($^{141}_{56}Ba$) nucleus with the symbol Ba,

3. the krypton ($^{92}_{36}Kr$) nucleus with the symbol Kr. [2]

(ii) The neutron that is absorbed by the uranium nucleus has very little kinetic energy. Explain why this fission reaction is energetically possible.

Binding energy is given by A×Eb and the binding energy of Ba + Kr is greater than the binding energy of U

....[2]

(c) Barium-141 has a half-life of 18 minutes. The half-life of Krypton-92 is 3.0 s.
In the fission reaction of a mass of Uranium-235, equal numbers of barium and krypton nuclei are produced.
Estimate the time taken after the fission of the sample of uranium for the ratio

$$\frac{\text{number of Barium-141 nuclei}}{\text{number of Krypton-92 nuclei}}$$

to be approximately equal to 8.

$$\lambda_{Br} = \frac{\ln 2}{1080} = 6.418 \times 10^{-4}\ s^{-1}$$

$$\lambda_K = \frac{\ln 2}{3} = 2.31 \times 10^{-1}\ s^{-1}$$

$$\frac{N_{Br}}{N_{Kr}} = \frac{\cancel{N_0} e^{-\lambda t}}{\cancel{N_0} e^{-\lambda t}}$$

$$8 = \frac{e^{-t(6.418 \times 10^{-4})}}{e^{-t(2.31 \times 10^{-1})}}$$

$$8 = e^{-6.418 \times 10^{-4} t + 2.31 \times 10^{-1} t}$$

$$\ln 8 = 0.23036\, t$$

$$t = 9.02699\ s$$

time = ...9...... s [3]

(Question 6 of Paper 4, Winter, 2007)

(a) State what is meant by the *binding energy* of a nucleus.

....

....

.... [2]

(b) Show that the energy equivalence of 1.0 u is 930 MeV.

$1.66 \times 10^{-27} \times c^2 = \dfrac{1.49193 \times 10^{-10}\,J}{1.6 \times 10^{-19}}$

$= 932.458 \times 10^{6}\,eV$

$= 930\,MeV$

[3]

(c) Data for the masses of some particles and nuclei are given in Fig. 8.1.

	mass / u
proton	1.0073
neutron	1.0087
deuterium ($^{2}_{1}H$)	2.0141
zirconium ($^{97}_{40}Zr$)	97.0980

Fig. 8.1

Use data from Fig. 8.1 and information from **(b)** to determine, in MeV,

(i) the binding energy of deuterium,

$E = \Delta m c^2$

$\Delta m = (2.0141 - (1.0073 + 1.0087))\,u$

$\therefore\ 1.9 \times 10^{-3}\,u = ?$

$\therefore\ 1u = 930\,MeV$

$? = 1.767$

binding energy = ...1.8.......... MeV [2]

(ii) the binding energy **per nucleon** of zirconium.

$\Delta m = [(97.0980 - [(40 \times 1.0073) + (57 \times 1.0087)]] \times 930]$

$= \dfrac{6.416 \times 10^{2}}{97} = 6.61$

binding energy per nucleon = ...6.61.......... MeV [3]

(Question 8 of Paper 4, Variant 2, Summer, 2011)