8 **(a)** Define the term radioactive *decay constant*.

.....

.....

.....[2]

(b) State the relation between the activity A of a sample of a radioactive isotope containing N atoms and the decay constant λ of the isotope.

.....[1]

(c) Radon is a radioactive gas with half-life 56 s. For health reasons, the maximum permissible level of radon in air in a building is set at 1 radon atom for every 1.5×10^{21} molecules of air. 1 mol of air in the building is contained in $0.024\,m^3$.

Calculate, for this building,

(i) the number of molecules of air in $1.0\,m^3$,

number = ...

(ii) the maximum permissible number of radon atoms in $1.0\,m^3$ of air,

number = ...

(iii) the maximum permissible activity of radon per cubic metre of air.

activity = ... Bq

[5]

6 Strontium-90 decays with the emission of a β-particle to form Yttrium-90. The reaction is represented by the equation

$$^{90}_{38}\text{Sr} \rightarrow {}^{90}_{39}\text{Y} + {}^{0}_{-1}\text{e} + 0.55 \text{ MeV}.$$

The decay constant is 0.025 year^{-1}.

(a) Suggest, with a reason, which nucleus, $^{90}_{38}$Sr or $^{90}_{39}$Y, has the greater binding energy.

.....

.....

..... [2]

(b) Explain what is meant by the decay constant.

.....

.....

..... [2]

(c) At the time of purchase of a Strontium-90 source, the activity is 3.7×10^6 Bq.

(i) Calculate, for this sample of strontium,

1. the initial number of atoms,

number = ... [3]

2. the initial mass.

mass = ... kg [2]

(ii) Determine the activity A of the sample 5.0 years after purchase, expressing the answer as a fraction of the initial activity A_0. That is, calculate the ratio $\frac{A}{A_0}$.

ratio = ... [2]

May 04

8 Fig. 8.1 shows the variation with nucleon number of the binding energy per nucleon of a nucleus.

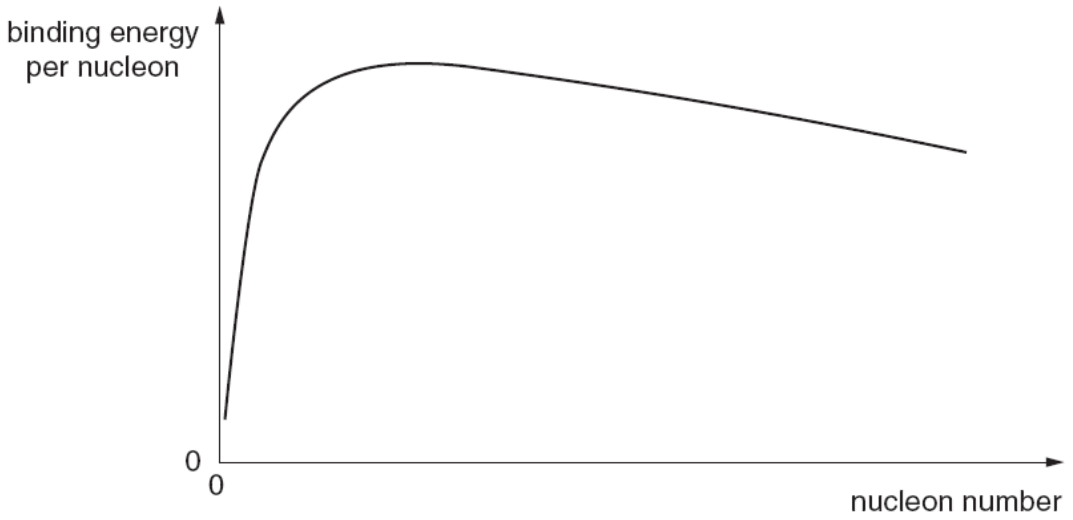


Fig. 8.1

(a) On Fig. 8.1, mark with the letter S the position of the nucleus with the greatest stability. [1]

(b) One possible fission reaction is

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{144}_{56}\text{Ba} + {}^{90}_{36}\text{Kr} + 2{}^{1}_{0}\text{n}.$$

(i) On Fig. 8.1, mark possible positions for

1. the Uranium-235 ($^{235}_{92}$U) nucleus (label this position U),

2. the Krypton-90 ($^{90}_{36}$Kr) nucleus (label this position Kr). [1]

(ii) The binding energy per nucleon of each nucleus is as follows.

$^{235}_{92}$U: 1.2191×10^{-12} J

$^{144}_{56}$Ba: 1.3341×10^{-12} J

$^{90}_{36}$Kr: 1.3864×10^{-12} J

Use these data to calculate

1. the energy release in this fission reaction (give your answer to three significant figures),

energy = ... J [3]

2. the mass equivalent of this energy.

mass = ... kg [2]

(iii) Suggest why the neutrons were not included in your calculation in **(ii)**.

.....

..... [1]

6 The isotopes Radium-224 ($^{224}_{88}$Ra) and Radium-226 ($^{226}_{88}$Ra) both undergo spontaneous α-particle decay. The energy of the α-particles emitted from Radium-224 is 5.68 MeV and from Radium-226, 4.78 MeV.

(a) (i) State what is meant by the *decay constant* of a radioactive nucleus.

.....

.....

.....[2]

(ii) Suggest, with a reason, which of the two isotopes has the larger decay constant.

.....

.....

.....

.....[3]

(b) Radium-224 has a half-life of 3.6 days.

(i) Calculate the decay constant of Radium-224, stating the unit in which it is measured.

decay constant = ...[2]

(ii) Determine the activity of a sample of Radium-224 of mass 2.24 mg .

activity = ... Bq [4]

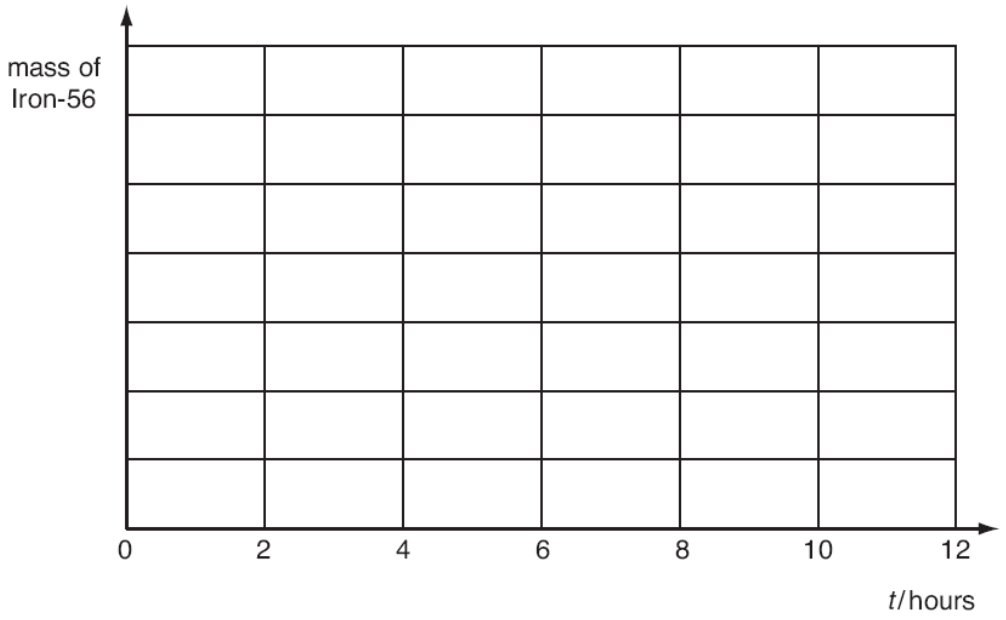
(c) Calculate the number of half-lives that must elapse before the activity of a sample of a radioactive isotope is reduced to one tenth of its initial value.

number of half-lives = ...[2]

May 05

7 The isotope Manganese-56 decays and undergoes β-particle emission to form the stable isotope Iron-56. The half-life for this decay is 2.6 hours.
Initially, at time $t = 0$, a sample of Manganese-56 has a mass of 1.4 μg and there is no Iron-56.

(a) Complete Fig. 7.1 to show the variation with time t of the mass of Iron-56 in the sample for time $t = 0$ to time $t = 11$ hours.



[2]

Fig. 7.1

(b) For the sample of Manganese-56, determine

(i) the initial number of Manganese-56 atoms in the sample,

number = ...[2]

(ii) the initial activity.

activity = ... Bq [3]

(c) Determine the time at which the ratio

$$\frac{\text{mass of Iron-56}}{\text{mass of Manganese-56}}$$

is equal to 9.0.

time = ... hours [2]

7 Fig. 7.1 illustrates the variation with nucleon number A of the binding energy per nucleon E of nuclei.

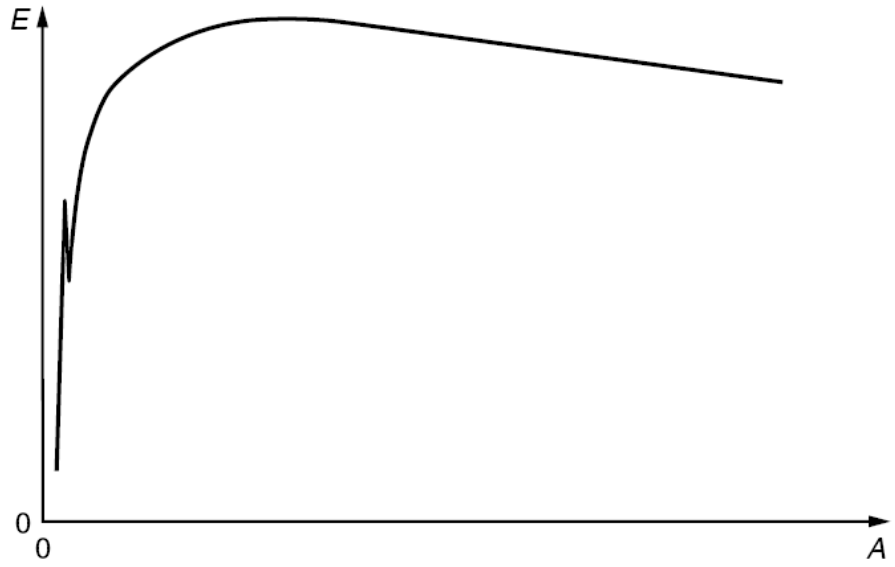


Fig. 7.1

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

.....

.....

..... [2]

(ii) On Fig. 7.1, mark with the letter S the region of the graph representing nuclei having the greatest stability. [1]

(b) Uranium-235 may undergo fission when bombarded by a neutron to produce Xenon-142 and Strontium-90 as shown below.

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{142}_{54}\text{Xe} + {}^{90}_{38}\text{Sr} + \text{neutrons}$$

(i) Determine the number of neutrons produced in this fission reaction.

number = ... [1]

(ii) Data for binding energies per nucleon are given in Fig. 7.2.

isotope	binding energy per nucleon / MeV
Uranium-235	7.59
Xenon-142	8.37
Strontium-90	8.72

Fig. 7.2

Calculate

1. the energy, in MeV, released in this fission reaction,

energy = ... MeV [3]

2. the mass equivalent of this energy.

mass = ... kg [3]

8 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,

number = ... [2]

(ii) the decay constant,

decay constant = ... s^{-1} [2]

(iii) the half-life in years.

half-life = ... years [2]

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

.....

..... [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.

.....

..... [1]

6 **(a)** Define the *decay constant* of a radioactive isotope.

.....

.....

..... [2]

(b) Strontium-90 is a radioactive isotope having a half-life of 28.0 years. Strontium-90 has a density of $2.54\,g\,cm^{-3}$.

A sample of Strontium-90 has an activity of 6.4×10^9 Bq. Calculate

(i) the decay constant λ, in s^{-1}, of Strontium-90,

λ = ... s^{-1} [2]

(ii) the mass of Strontium-90 in the sample,

mass = ... g [4]

(iii) the volume of the sample.

volume = ... cm^3 [1]

(c) By reference to your answer in **(b)(iii)**, suggest why dust that has been contaminated with Strontium-90 presents a serious health hazard.

.....

.....

..... [2]

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

.....

.....[1]

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

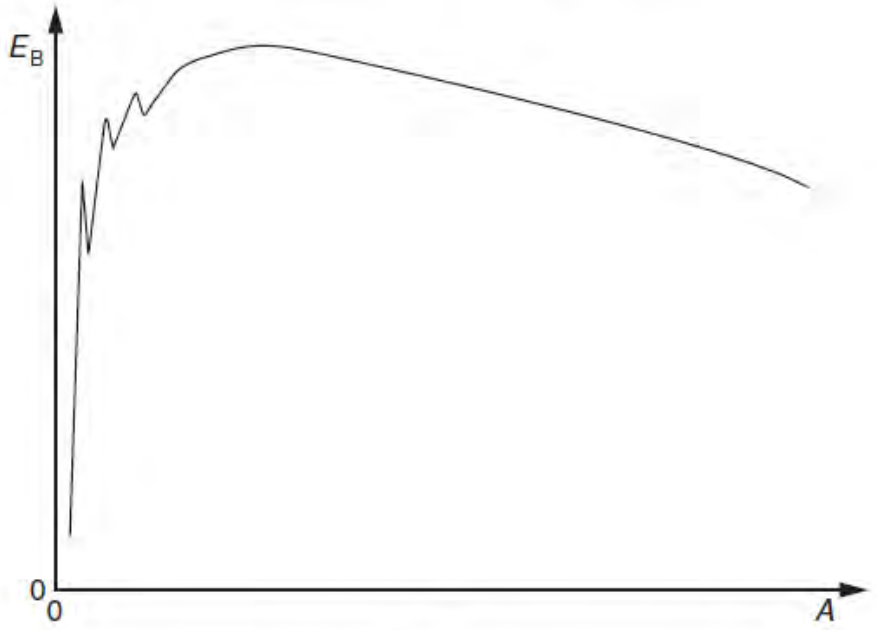


Fig. 7.1

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.

.....

.....

.....[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.

time = ... s [3]

May 08

8 A positron ($^{0}_{+1}e$) is a particle that has the same mass as an electron and has a charge of $+1.6 \times 10^{-19}$ C.
A positron will interact with an electron to form two γ-ray photons.

$$^{0}_{+1}e + ^{0}_{-1}e \rightarrow 2\gamma$$

Assuming that the kinetic energy of the positron and the electron is negligible when they interact,

(a) suggest why the two photons will move off in opposite directions with equal energies,

.....

.....

.....

.....

.....

.....[3]

(b) calculate the energy, in MeV, of one of the γ-ray photons.

energy = ... MeV [3]

9 **(a)** A sample of a radioactive isotope contains N nuclei at time t. At time $(t + \Delta t)$, it contains $(N - \Delta N)$ nuclei of the isotope.

For the period Δt, state, in terms of N, ΔN and Δt,

(i) the mean activity of the sample,

activity = ... [1]

(ii) the probability of decay of a nucleus.

probability = ... [1]

(b) A cobalt-60 source having a half-life of 5.27 years is calibrated and found to have an activity of 3.50×10^5 Bq. The uncertainty in the calibration is ±2%.

Calculate the length of time, in days, after the calibration has been made, for the stated activity of 3.50×10^5 Bq to have a maximum possible error of 10%.

time = ... days [4]