9 The radioactive isotope americium-241 ($^{241}_{95}$Am) emits an α-particle as it decays to neptunium-237 ($^{237}_{93}$Np).

(a) Data for the decay are given in Table 9.1.

Table 9.1

nucleus	mass of nucleus / 10^{-27} kg
americium-241	400.19774
neptunium-237	393.54304
helium-4	6.64466

(i) Show that the energy released in the decay of an americium-241 nucleus is 9.0×10^{-13} J.

[2]

(ii) State the principle of conservation of linear momentum.

.....

.....

..... [2]

(iii) The kinetic energy of an α-particle emitted by the decay of a stationary americium-241 nucleus is 8.784×10^{-13} J.

Show that the kinetic energy of the neptunium-237 nucleus after the decay is 1.483×10^{-14} J.

[4]

(iv) Suggest why the sum of the kinetic energies of the α-particle and the neptunium-237 nucleus after the decay is not equal to the energy released in the decay given in **(a)(i)**.

.....

.....

..... [1]

(b) Americium-241 has a decay constant of $5.08 \times 10^{-11}\,s^{-1}$.

A sample of pure americium-241 has an activity of 8.13 kBq at time $t = 0$.

(i) Calculate the number of nuclei in the sample at $t = 0$.

number of nuclei = ... [2]

(ii) Calculate the half-life of americium-241.

half-life = ... s [1]

(iii) On Fig. 9.1, draw a graph to show the variation of the number of americium-241 nuclei with t from $t = 0$ to $t = 6.0 \times 10^{10}$ s. Label this line **A**.

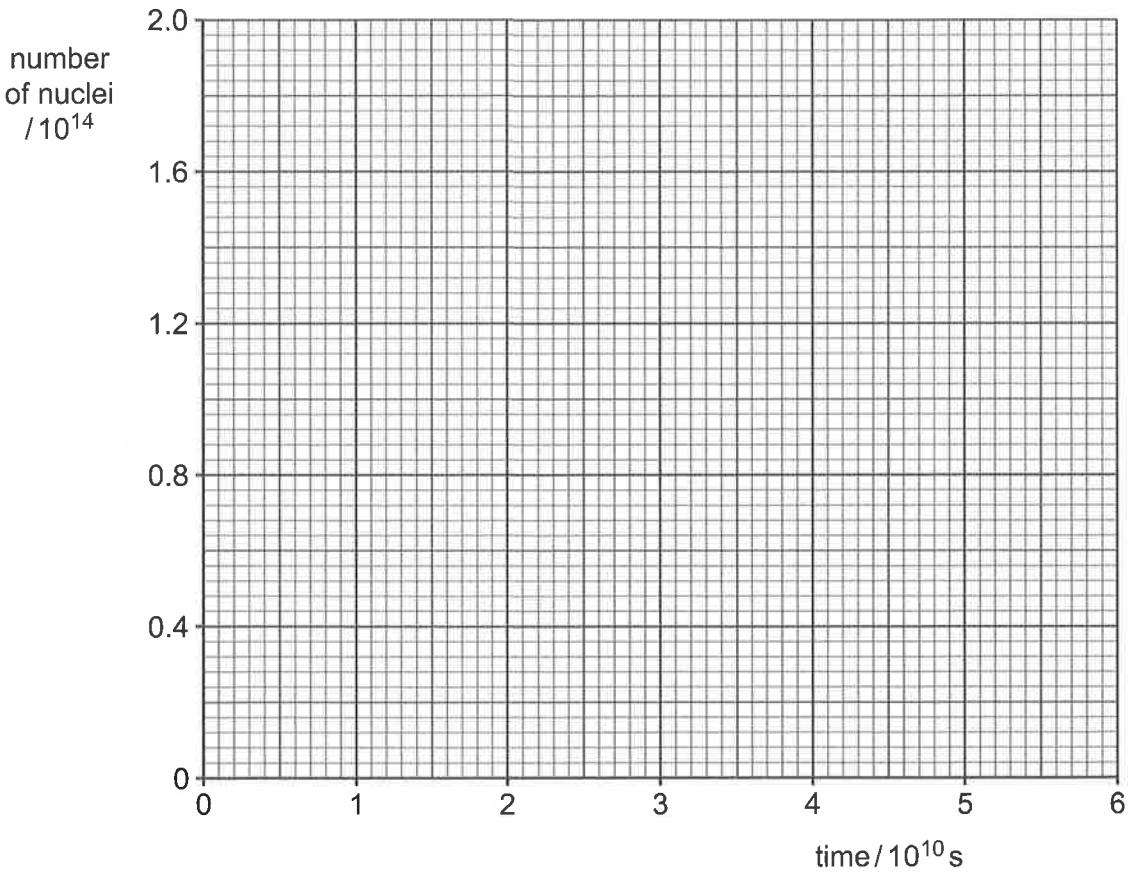

Fig. 9.1

[2]

(iv) Draw a second line on Fig. 9.1 to show how the number of neptunium-237 nuclei present in the sample varies from $t = 0$ to $t = 6.0 \times 10^{10}$ s. Neptunium-237 does not decay significantly over this time. Label this line **N**. [2]

(c) A sample of a pure beta emitter has the same initial number of nuclei as the sample of americium-241 in **(b)**. The pure beta emitter decays to a stable isotope. The probability of decay per unit time of a nucleus of the beta emitter is much greater than that of a nucleus of americium-241.

Describe and explain, without calculation, any difference in:

(i) the initial activity of the sample of the beta emitter compared with the initial activity of the sample of americium-241

.....

.....

..... [2]

(ii) the time taken for the activity of the sample of the beta emitter to fall to 1 Bq compared with the time taken for the activity of the sample of americium-241 to fall to 1 Bq.

.....

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..... [2]

[Total: 20]

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