9 **(a)** Radioactive decay is a random and spontaneous process.

Explain what is meant by

(i) a *random* process,

.....

.....[1]

(ii) a *spontaneous* process.

.....

.....[1]

(b) An unstable nucleus of mass number A undergoes α-decay, as illustrated in Fig. 9.1.

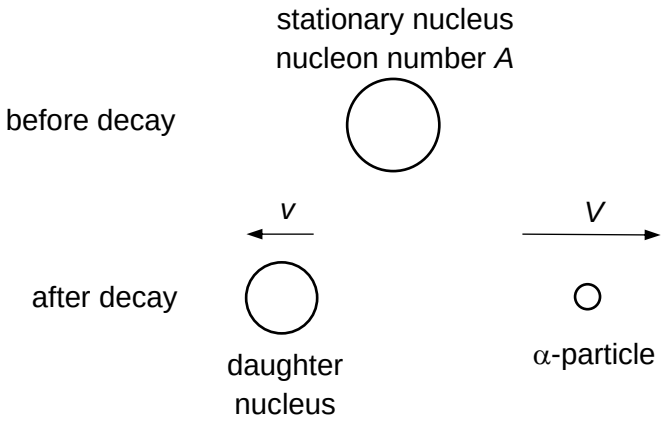

Fig. 9.1

The nucleus is stationary before the decay.

After the decay, the initial speed of the α-particle is V and that of the daughter nucleus is v.

(i) Derive an equation, in terms of A, v and V, to represent conservation of linear momentum for this decay.

.....

.....[1]

(ii) Show that the ratio

$$\frac{\text{initial kinetic energy of } \alpha - \text{particle}}{\text{initial kinetic energy of daughter nucleus}}$$

is equal to (¼ A – 1).

[2]

(c) Data for the α-decay of bismuth-212 ($^{212}_{83}Bi$) to form thallium-208 ($^{208}_{81}Tl$) are given in Fig. 9.2.

nucleus	mass of nucleus / u
bismuth-212	211.9459
thallium-208	207.9374
helium-4	4.0015

Fig. 9.2

(i) Use the data of Fig. 9.2 to calculate, to two places of decimals, the energy released during the decay.

energy = ... MeV [4]

(ii) Use your answer in **(c)(i)** to show that, based on the expression in **(b)(ii)**, the energy of the α-particle is 6.42 MeV.

[2]

(d) In practice, the α-particle is found to have an energy of 6.10 MeV, rather than 6.42 MeV, as calculated in **(c)(ii)**.

Suggest

(i) an explanation for the difference in energy,

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.....[1]

(ii) why it is likely that the thallium nucleus and the α-particle do not move off in opposite directions.

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.....

.....

.....[2]

(e) Some data for the half-lives and decay constants of bismuth-212 and thallium-208 are given in Fig. 9.3.

nucleus	half-life / s	decay constant / s^{-1}
bismuth-212	.....	1.9×10^{-4}
thallium-208	190	3.7×10^{-3}

Fig. 9.3

(i) Define *half-life*.

.....

.....[1]

(ii) Complete Fig. 9.3 by calculating the half-life of bismuth-212.

[1]

(iii) Initially, a radioactive source contains N nuclei of bismuth-212.

After two hours, it is found that the number of bismuth-212 nuclei has reduced to approximately ¼ N. However, although bismuth-212 decays to form thallium-208, the number of thallium nuclei is much less than ¾ N.

Suggest an explanation for these observations.

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.....[4]

[Total: 20]

End of Paper