8 **(a)** A fusion reaction between a deuterium ($^{2}_{1}H$) nucleus and tritium ($^{3}_{1}H$) nucleus is shown below.

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$$

For the fusion reaction to occur the separation between the deuterium and tritium nuclei must be less than 10^{-14} m. This means that the average kinetic energy of these hydrogen nuclei needs to be about 70 keV. The energy released by the fusion reaction is 18 MeV.

(i) Calculate the repulsive electrical force between the deuterium and tritium nuclei at a separation of 10^{-14} m.

force = ... N [2]

(ii) Assume that a mixture of these hydrogen nuclei behaves as an ideal gas. Estimate the temperature of the mixture of nuclei required for this fusion reaction.

temperature = ... K [2]

(iii) In practice, fusion occurs at a much lower temperature. Suggest a reason why.

....

....

.... [1]

(iv) Calculate the change in mass in a single fusion reaction.

change in mass = ... kg [2]

(b) A radioisotope that decays forming another isotope is known as a parent isotope and the newly formed isotope is known as the daughter product. For a sample initially made up of pure parent isotope, Fig. 8.2 shows the variation with time t of the activity A of the parent isotope. The daughter product in this case does not decay and is described as 'stable'.

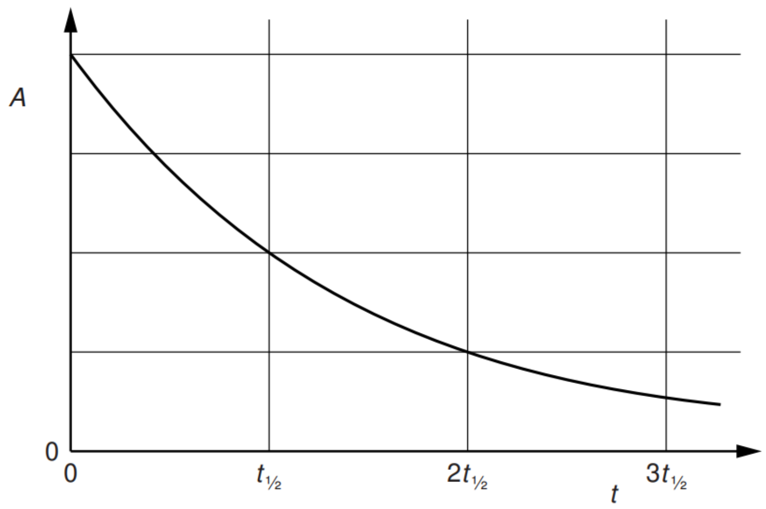

Fig. 8.2

(i) On the axes of Fig. 8.3, sketch a graph to show the variation with time t of the number D of daughter nuclei in the sample.

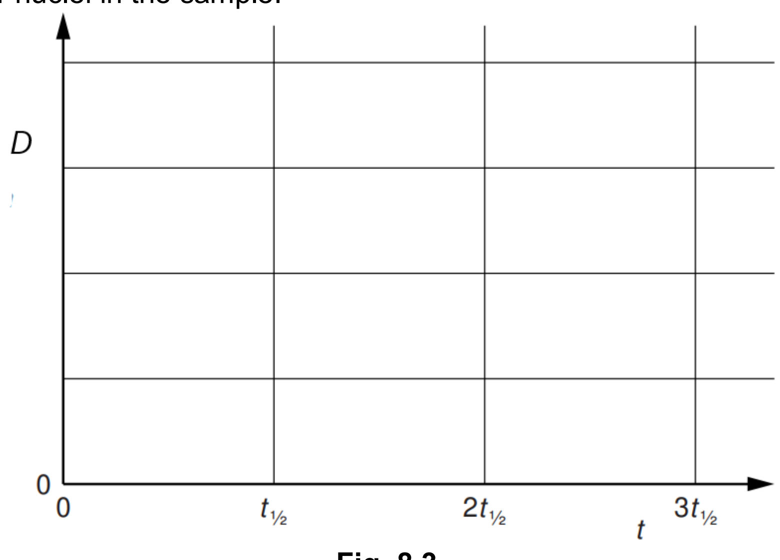

Fig. 8.3

[2]

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(ii) Show that the number of daughter nuclei *D* after time *t* is given by

$$D = N_0(1 - e^{-\lambda t})$$

where N_0 is the original number of parent nuclei and λ is the decay constant of the parent nuclei.

[1]

(iii) The ratio of the number of parent nuclei to number of daughter nuclei can be used to calculate the age of rocks. The uranium isotope $^{238}_{92}U$ is the beginning of a 'radioactive series' that ends with the stable isotope of lead, $^{206}_{82}Pb$.

The half-life of the $^{238}_{92}U$ series is 4.47×10^9 years.

1. Show that a total of eight alpha decays and six beta decays will produce $^{206}_{82}Pb$ from $^{238}_{92}U$.

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[2]

2. A rock is assumed to have contained no lead-206 when it was formed. In a sample of the rock, the ratio

$$\frac{\text{number of lead-206 atoms present in rock sample}}{\text{original number of uranium-238 atoms present in rock sample}}$$

is measured to be 0.39.

Calculate the time since formation of rock, assuming that all the lead-206 formed has remained in the rock.

time since formation of rock = ... years [2]

(iv) The same rock sample also contains uranium-235, which undergoes a series of decays to form the stable isotope lead-207.

The half-life of this $^{235}_{92}U$ series is 7.0×10^{8} years. The ratio

$$\frac{\text{number of lead-207 atoms present in rock sample}}{\text{number of remaining uranium-235 atoms present in rock sample}}$$

is measured to be 22.8.

1. Show that the number of daughter nuclei after time t is given by $D = N\left(\frac{1}{e^{-\lambda t}} - 1\right)$ where N is the number of parent nuclei remaining at time t.

[2]

2. Use the equation for D given in **(iv)1** and the data given to calculate the value for the age of the rock based on the uranium-235 decay series.

age of rock = ... years [2]

3. Rocks are often dated using three separate decay series. Suggest and explain two advantages of using three decay series to date rocks rather than just one.

....

....

....

....

.... [2]

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