OCR
Oxford Cambridge and RSA

A level Physics B

H557/02 Scientific literacy in physics

Question Set 17

1 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, with a daughter product which does not decay, **Fig. 1.1** shows how the number of parent and daughter nuclei change with time. The daughter product in this case is described as 'stable'.

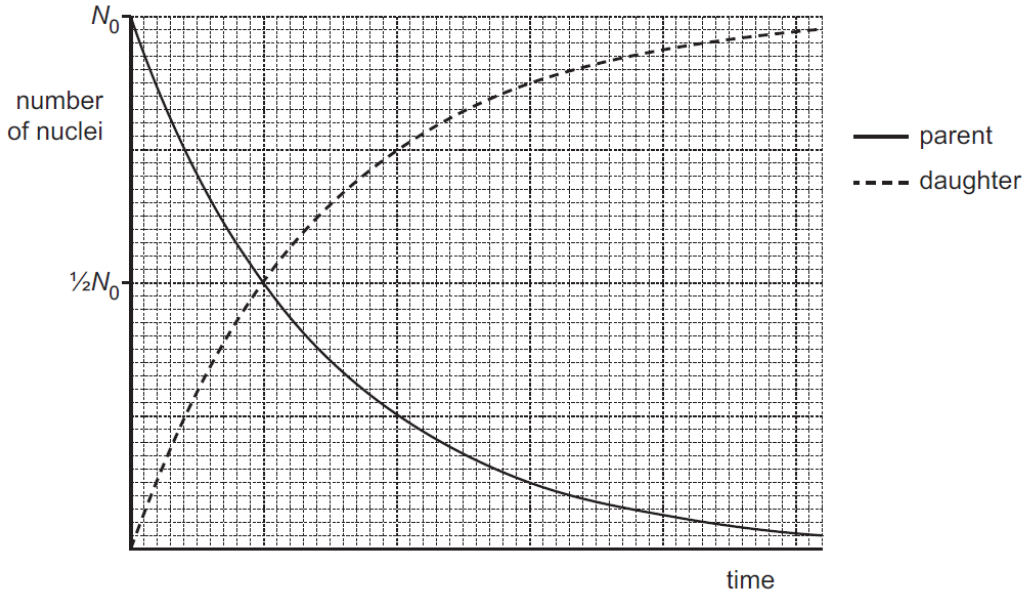

Fig. 1.1

(a) For a stable product, the number of daughter nuclei D at time t is given by the equation

$$D = N_0 - N$$

where N_0 is the original number of parent nuclei and N is the number of parent nuclei at time t.

Show that the number of daughter nuclei after time t is given by

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

[1]

(b) 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, $^{206}_{82}Pb$.

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

[2]

(ii) The half-life of the series is 4.47×10^{9} years. This means that it will take about 4.5 billion years before half the uranium-238 (^{238}U) has decayed into lead-206 (^{206}Pb).

Show that the decay constant for this process is about 1.6×10^{-10} year^{-1}. **[1]**

(iii) A rock is assumed to have contained no lead-206 when it was formed.

In a sample of the rock, the ratio

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

is measured to be 0.39.

Calculate how long ago the rock formed, assuming that all the lead-206 formed has remained in the rock.

time since formation of rock =……..……...years

[3]

(c)

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 series is 7.0×10^8 years. The ratio

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

is measured to be 22.8.

(i) Use the relationship $N = N_0 e^{-\lambda t}$ to 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.

[1]

(ii) Use the equation for D given in **(c)(i)** 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

[3]

(iii) Rocks are often dated using three separate decay series. Suggest and explain an advantage of three decay series to date rocks rather than just one.

[2]

Total Marks for Question Set 17: 13