8 **(a)** State what is meant by the *binding energy* of a nucleus and how it is related to the mass defect.

....

....

....

....[2]

(b) The binding energy graph on Fig. 8.1 shows the variation with nucleon number A of the binding energy per nucleon. Some common nuclides are plotted on the graph, with a few of them labelled as shown.

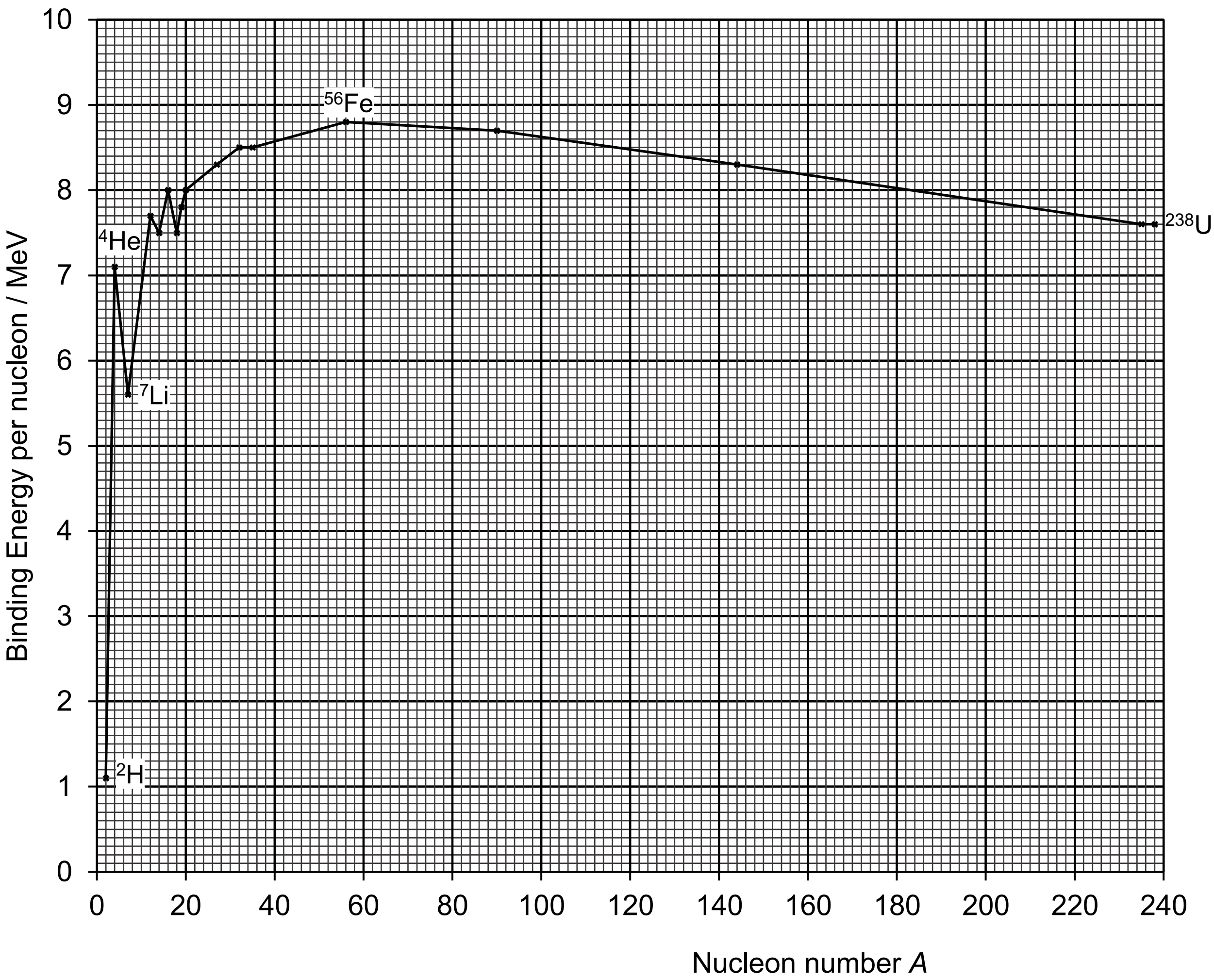

Fig. 8.1

(i) Explain why hydrogen-1 is not typically included in a binding energy graph.

....

....[1]

(ii) A nuclear power station uses uranium-235 as fuel in fission reactions. One possible fission reaction is

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{144}_{54}\text{Xe} + {}^{90}_{38}\text{Sr} + 2\,{}^{1}_{0}\text{n}\,.$$

1. Use data from Fig. 8.1 to show that energy released in the reaction is about 190 MeV.

[2]

2. Hence, calculate the energy released in the fission of 1.0 kg of uranium-235.

energy released = ... MeV [2]

(c) A small sample of waste produced by the reactor in **(b)(ii)** contains strontium-90 ($^{90}_{38}\text{Sr}$). Strontium-90 is radioactive and undergoes beta decay into a daughter nuclide Yttrium- 90 (Y).

(i) In beta decay, it was discovered that an antineutrino ($\bar{\nu}$) must be emitted given that two conservation laws are not violated. State the two conservation laws.

....

....[1]

(ii) Complete the beta decay equation, including all the decay products.

$^{90}_{38}\text{Sr} \rightarrow$ [1]

(iii) A radiation detector is placed close to the sample to measure the count rate for strontium-90 found in the sample. Fig. 8.2 below shows the variation with time *t* of the count rate.

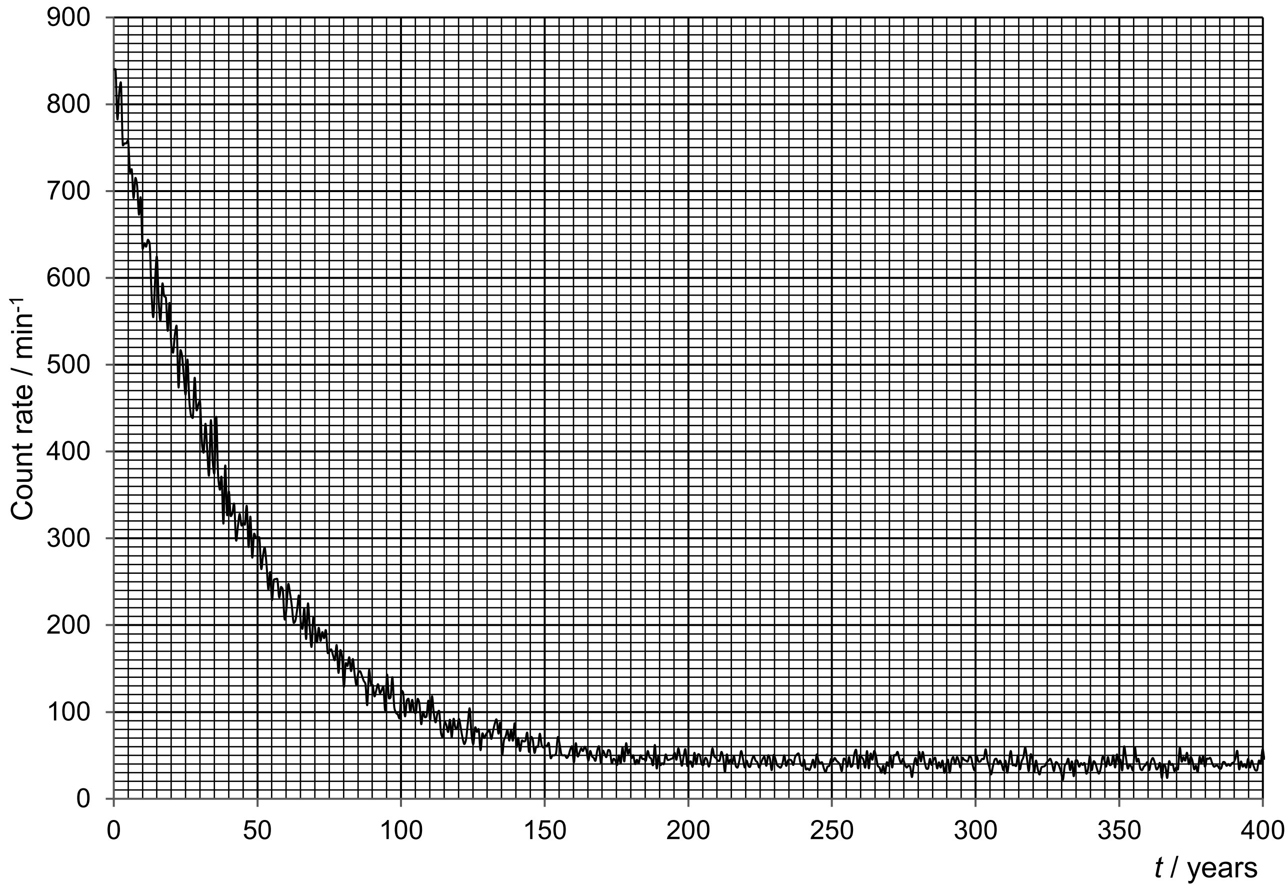

Fig. 8.2

1. State the feature of Fig. 8.2 that indicates the random nature of radioactive decay.

....[1]

2. Use Fig. 8.2 to determine the half-life of strontium-90.

half-life = ... years [4]

3. Hence, determine the probability that a nuclide of strontium-90 will undergo decay in 1 year.

probability = ...[1]

(d) Nuclear fusion occurs in the core of stars composed of ionised gas. A possible fusion reaction is

$$ {}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{2}_{1}\text{H} + {}^{0}_{1}\text{e} \, . $$

Each ${}^{1}_{1}\text{H}$ nuclide can be considered to be a sphere of radius 0.0010 pm. Fusion occurs when the two nuclides are able to overcome the force of repulsion between them and collide.

(i) Show that the minimum total kinetic energy required of the two ${}^{1}_{1}\text{H}$ nuclides for fusion to occur is 1.2×10^{-13} J.

[2]

(ii) If the ionised gas is assumed to be ideal, determine the temperature of the gas required for fusion to occur.

temperature = ... K [2]

(iii) The temperature of the core of the Sun is known to be about 1.5×10^{7} K. With reference to **(d)(i)** and **(d)(ii)**, comment on the actual kinetic energy of the nuclei in the Sun's core.

....

....[1]

[Total: 20]