10 (a) The radioactive decay process is described as both spontaneous and random. Explain what is meant by

(i) *spontaneous* decay, and

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………………… [1]

(ii) *random* decay.

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…………………………………………………………………………………………………

………………………………………………………………………………………………… [1]

(b) A sample contains X nuclei of thallium-208 at time t. At time Δt later, the sample contains $(X - \Delta X)$ nuclei of thallium-208.

Write down the expressions, in terms of X, ΔX, t and Δt, for

(i) the average activity of the sample in time Δt

[1]

(ii) the probability of decay of a thallium nucleus in time Δt

[1]

(iii) the decay constant λ for thallium-208

[1]

(c) A source of β-emission, which may be considered to be a point source radiating uniformly in all directions is situated 0.400 m away from a Geiger-Muller tube which has an effective area of 5.0 cm^2. The recorded count rate at a given time is 250 s^{-1}.

(i) Estimate a value for the activity of the source at this time.

activity of source = ……………….. s^{-1} [2]

(ii) Given that the half-life is 45 seconds, calculate a value for the number of radioactive atoms present in the sample 135 seconds before the measurement was made.

initial number of atoms = ……………….. [2]

(iii) Suggest and explain whether the answer in **(ii)** is an over-estimation or an under-estimation of the actual results obtained.

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…………………………………………………………………………………………… [3]

(iv) Suggest why a magnetic material can be used to shield a person from the harmful effects of the β emissions.

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…………………………………………………………………………………………

………………………………………………………………………………………… [1]

(d) **(i)** Describe the physical process of nuclear fission.

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… [2]

(ii) Explain why this process may release energy.

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… [1]

(iii) Fig. 10.1 shows a portion of a graph indicating how the binding energy per nucleon of various nuclides varies with their nucleon numbers.

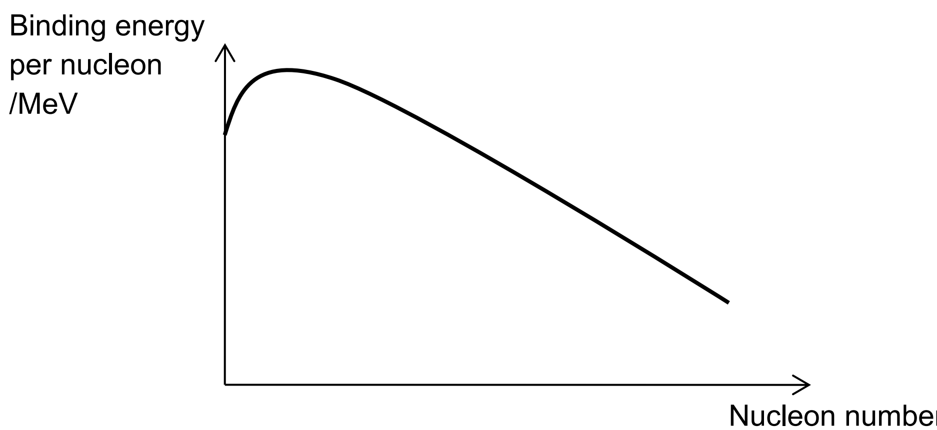

Fig. 10.1

1. Indicate on the graph with an "**X**", the position of the nucleon number and its associated binding energy per nucleon for a nucleus that is least stable. [1]

2. Give reasoning for your answer in **1**.

…………………………………………………………………………………………

………………………………………………………………………………………… [1]

(iv) When a nucleus of uranium-235 disintegrates into barium-141 and krypton-92, the loss in mass is 3.1×10^{-28} kg.

Calculate the number of uranium-235 nuclei that disintegrates in order to release 100 GeV of energy.

number of nuclei = ……………….. [2]

[Total: 20]

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