IB$_2$

Physics SL

Friday 20.9.2022

Tot : / 32 marks

Name: _____

Problem 1 [/10 marks]

(a) Describe the phenomenon of natural radioactive decay. *[3]*

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(b) A nucleus of americium-241 (Am-241) decays into a nucleus of neptunium-237 (Np-237) in the following reaction.

$$^{241}_{95}\text{Am} \rightarrow {}^{237}_{X}\text{Np} + {}^{4}_{2}\alpha$$

(i) State the value of X. *[1]*

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(ii) Explain in terms of mass why energy is released in the reaction in (b). *[2]*

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(iii) Define *binding energy* of a nucleus. *[1]*

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(iv) The following data are available.

Nuclide	Binding energy per nucleon / MeV
americium-241	7.54
neptunium-237	7.58
helium-4	7.07

Determine the energy released in the reaction in (b). *[3]*

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Problem 2 [/ 10 marks]

(ii) The mass of a nucleus of plutonium $\left({}^{239}_{94}\mathrm{Pu}\right)$ is 238.990396 u. Deduce that the binding energy per nucleon for plutonium is 7.6 MeV. *[3]*

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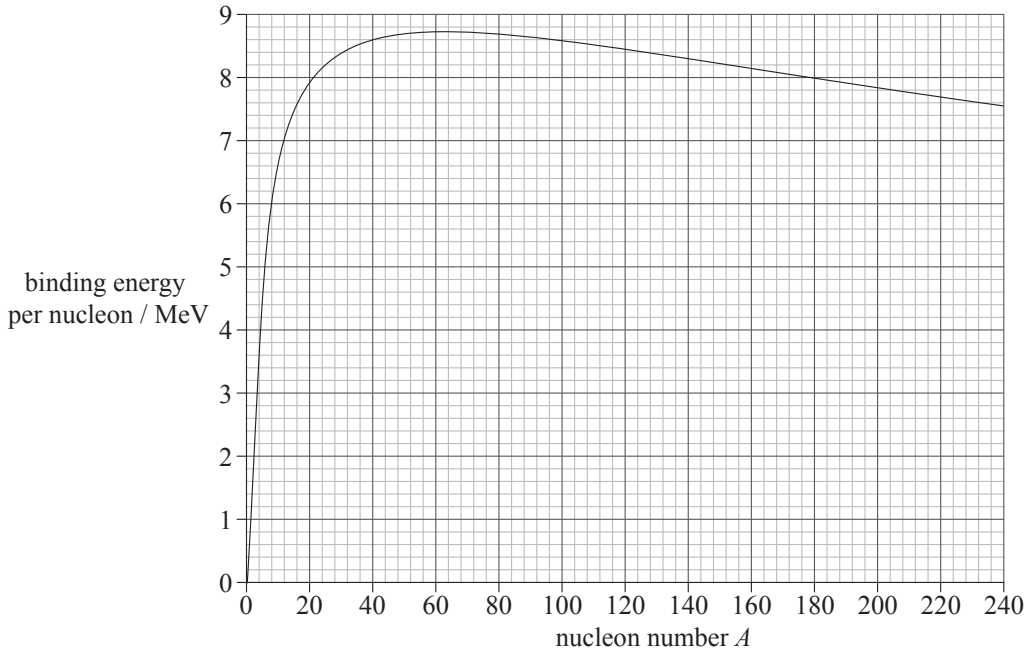
(b) The graph shows the variation with nucleon number A of the binding energy per nucleon.



Plutonium $\left({}^{239}_{94}\mathrm{Pu}\right)$ undergoes nuclear fission according to the reaction given below.

$$ {}^{239}_{94}\mathrm{Pu} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{91}_{38}\mathrm{Sr} + {}^{146}_{56}\mathrm{Ba} + x\,{}^{1}_{0}\mathrm{n} $$

(i) Calculate the number x of neutrons produced. *[1]*

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(ii) Use the graph to estimate the energy released in this reaction. *[2]*

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(c) Stable nuclei with a mass number greater than about 20, contain more neutrons than protons. By reference to the properties of the nuclear force and of the electrostatic force, suggest an explanation for this observation. *[4]*

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Problem 3 [/ 8 marks]

Let us consider a sample 1.0 kg of strontium-94 (Sr-94).

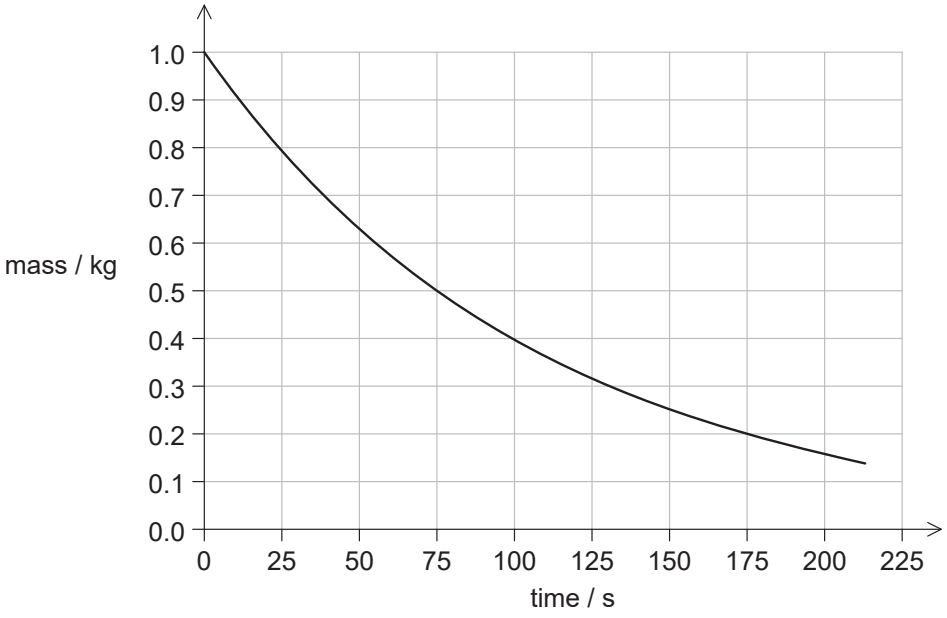
Sr-94 is radioactive and undergoes beta-minus decay into a daughter nuclide X.

The reaction for this decay is

$$^{94}_{38}\text{Sr} \rightarrow \begin{matrix}\square \\ \square\end{matrix} \text{X} + \square + \square$$

1) complete the reaction (providing the missing information) [4]

The graph shows the variation with time of the mass of Sr-94 remaining in the samp



2)

(ii) State the half-life of Sr-94.

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(iii) Calculate the mass of Sr-94 remaining in the sample after 10 minutes.

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Four paper1 questions [/ 4 marks]

Q1

A detector, placed close to a radioactive source, detects an activity of 260 Bq. The average background activity at this location is 20 Bq. The radioactive nuclide has a half-life of 9 hours.

What activity is detected after 36 hours?

A. 15 Bq

B. 16 Bq

C. 20 Bq

D. 35 Bq

Q2

Which of the following statements best describes the **random** nature of radioactive decay?

A. The decaying nucleus emits either an α-particle, or a β-particle or a γ-ray photon.

B. The type of radiation emitted by the decaying nucleus cannot be predicted.

C. The time at which a particular nucleus will decay cannot be predicted.

D. The decay of a nucleus is unaffected by environmental conditions.

Q3

A freshly prepared sample contains $4.0\,\mu g$ of iodine-131. After 24 days, $0.5\,\mu g$ of iodine-131 remain. The best estimate of the half-life of iodine-131 is

A. 8 days.

B. 12 days.

C. 24 days.

D. 72 days.

Q4

The average binding energy per nucleon of the ${}^{15}_{8}O$ nucleus is 7.5 MeV. What is the total energy required to separate the nucleons of one nucleus of ${}^{15}_{8}O$?

A. 53 MeV

B. 60 MeV

C. 113 MeV

D. 173 MeV