(Question B1 continued)

Part 2 Radioactive decay

(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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(This question continues on the following page)

(Question B1, part 2 continued)

(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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Part 2 Radioactive decay

(a) emission of (alpha/beta/gamma) particles/photons/electromagnetic radiation;
nucleus becomes more (energetically) stable;
constant probability of decay (per unit time);
is random process;
activity/number of unstable nuclei in sample reduces by half over constant time intervals/exponentially;
not affected by temperature/environment / is spontaneous process; ***[3 max]***

(b) (i) 93; ***[1]***

(ii) mass of products is less than mass of reactants / there is a mass defect;
mass is converted into energy (according to equation $E = mc^2$); ***[2]***

(iii) the (minimum) energy required to (completely) separate the nucleons in a nucleus / the energy released when a nucleus is assembled from its constituent nucleons; ***[1]***

(iv) calculation of binding energies as shown below;
americium-241 = 241 × 7.54 = 1817.14 MeV
neptunium-237 = 237 × 7.58 = 1796.46 MeV
helium-4 = 4 × 7.07 = 28.28 MeV
energy released is the difference of binding energies;
and so equals 7.60 MeV; ***[3]***
*Award **[2 max]** for an answer that multiplies by the number of neutrons or number of protons.*
Ignore any negative sign in answer.