7.2 Nuclear Reactions

Question Paper

Course	DP IB Physics
Section	7. Atomic, Nuclear & Particle Physics
Topic	7.2 Nuclear Reactions
Difficulty	Medium

Time allowed: 70

Score: /57

Percentage: /100

Question 1a

A nuclear fission reaction occurs that has the following equation:

$$ {}_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{38}^{90}Sr + {}_{54}^{143}Xe + 3{}_{0}^{1}n $$

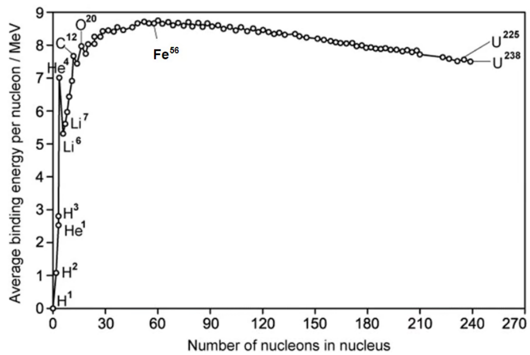
(a)
Given the following information, estimate the amount of energy released during the fission reaction:

- Binding energy per nucleon of Uranium 235: 7.59 MeV/nucleon
- Binding energy per nucleon of Strontium 90: 8.70 MeV/nucleon
- Binding energy per nucleon of Xenon-143: 8.20 MeV/nucleon

[2 marks]

Question 1b

The binding energy per nucleon curve is shown:



(b)
With reference to the binding energy per nucleon curve:

(i)
Explain why fission is possible

[2]

(ii)
Identify the source of energy released during this process

[2]

[4 marks]

Question 1c

(c)
A Uranium-235 nucleus undergoes fission into two approximately equally sized products.

Use the data from the figure in part (b) to show that the energy released as a result of the fission is approximately 4×10^{-11} J.

Show on the graph how you have used the data.

[5 marks]

Question 1d

(d)
Under the right conditions, two hydrogen-2, ^{2}H, nuclei can fuse to make a helium-4, ^{4}He, nucleus.

Nuclei	Mass / u
^{2}H	2.0135
^{4}He	4.0026

Using the data in the above table, calculate the energy available as a result of the fusion of two hydrogen-2 nuclei.

[4 marks]

Question 2a

(a)
This question is about nuclear physics.

(i)
Define mass defect

(ii)
Define binding energy

[2 marks]

Question 2b

(b) If deuterium is combined using fusion, then the following reaction will occur:

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{1}H + ^{1}_{1}H$$

The following data is given for this interaction:

- Binding energy per nucleon of deuterium $^{2}_{1}H$: 1.12 MeV/nucleon
- Binding energy per nucleon of tritium $^{3}_{1}H$: 2.82 MeV/nucleon

Estimate the energy released from this fusion reaction.

[2 marks]

Question 2c

(c)
In order for the fusion reaction in part (b) to actually take place, very high temperatures are needed such as those found within the core of a star. Suggest why this the case.

[2 marks]

Question 2d

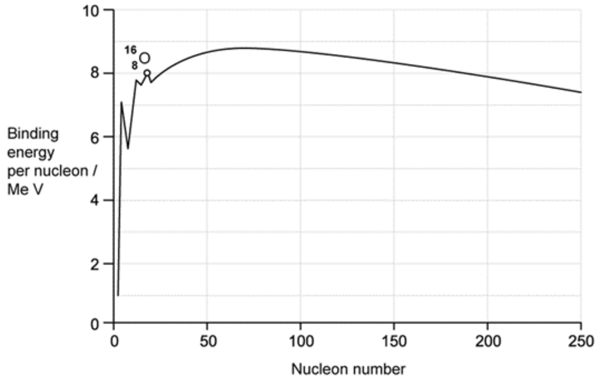
Fission and fusion reactions release different amounts of energy.

(d)
Discuss **other** reasons why it would be preferable to use fusion rather than fission for the production of electricity, assuming that the technical problems associated with fusion can be overcome.

[3 marks]

Question 3a

The image below shows how the binding energy per nucleon varies with nucleon number.



Fission and fusion are two nuclear processes in which energy can be released.

a)

(i)
On the image, mark the element with the highest binding energy per nucleon.

[1]

(ii)
Explain why nuclei that undergo fission are restricted to a different part of the graph than those that undergo fusion.

[2]

[3 marks]

Question 3b

(b)
Explain with reference to the figure in part (a), why the energy released per nucleon from fusion is greater than that from fission.

[3 marks]

Question 3c

(c)
Explain how the binding energy of an oxygen $^{16}_{8}O$ nucleus can be calculated with information obtained in the figure from part (a).

[2 marks]

Question 3d

The mass of an $^{16}_{8}O$ nucleus is 15.991 u.

(d)
Calculate:

(i)
The mass difference, in kg, of the $^{16}_{8}O$ nucleus.

[2]

(ii)
The binding energy, in MeV, of an oxygen $^{16}_{8}O$nucleus.

[1]

[3 marks]

Question 4a

(a)

Bismuth-214 ($^{214}_{83}Bi$) decays into Polonium-214 ($^{214}_{84}Po$) by beta minus decay.

The binding energy per nucleon of Bismuth-214 is 7.774 MeV and the binding energy per nucleon of Polonium-214 is 7.785 MeV.

Beta-minus decay is described by the following equation:

$$^{214}_{83}Bi \rightarrow ^{214}_{84}Po + \beta^- + \overline{v_e}$$

Show that the energy released in the β^- decay of bismuth is about 2.35 MeV and state where the energy comes from.

[3 marks]

Question 4b

(b)

If an additional neutron is accelerated into the Polonium-214 ($^{214}_{84}Po$) to produce the isotope Polonium-215 ($^{215}_{84}Po$), use the following information to deduce the binding energy per nucleon of this new isotope.

Mass of $^{215}_{84}Po$ nucleus = 3.571140×10^{-25} kg

[5 marks]

Question 4c

Polonium-215 ($^{215}_{84}Po$) is radioactive and decays by the producing alpha radiation, which is known to be a particularly stable.

(c)
Determine the binding energy of alpha radiation.

The following information is available:

- Mass of a Helium-4 nucleus: 4.001265 u

[3 marks]

Question 4d

(d)
A student claims that the amount of matter within a marble directly converted into energy would be enough to provide 1 year of current human energy consumption globally which is estimated to be 5.80×10^{18} J.

If the matter within marble is approximately 6.02×10^{23} u, determine if this statement is true, using the mass-energy equivalence.

[2 marks]

Question 5a

(a)
Explain why the mass of an alpha-particle (α) is less than the total mass of two individual protons and two individual neutrons.

[2 marks]

Question 5b

(b)
Show that the energy equivalence of 1.0 u is 931.5 MeV.

[2 marks]

Question 5c

(c)
Data for the masses of some nuclei are given below

Nuclei	**Mass / u**
Deuterium ($^{2}_{1}H$)	2.0141
Zirconium ($^{97}_{40}Zr$)	97.0980

Use the data to determine the binding energy of deuterium in MeV.

[2 marks]

Question 5d

(d)
Using the data given in part (c), determine the binding energy per nucleon of zirconium in MeV.

[3 marks]