7.2 Nuclear Reactions

Question Paper

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

Time allowed: 70

Score: /57

Percentage: /100

Question 1a

(a)
Define unified atomic mass unit.

[2]

[2 marks]

Question 1b

The unified atomic mass unit (a.m.u) is roughly equal to the mass of one nucleon.

(b)
Calculate the mass of a nucleus of uranium–238. Give your answer to 3 significant figures.
You may take 1 a.m.u to be 1.66×10^{-27} kg.

[3]

[3 marks]

Question 1c

Einstein's Theory of Relativity showed that mass could be converted into energy, and energy into mass. This is summarised in the equation:

$$\Delta E = \Delta mc^2$$

(c)
Define the terms in the equation and give the units:

(i)
E

[1]

(ii)
m

[1]

(iii)
c

[1]

[3 marks]

Question 1d

(d)
Calculate the energy (in J) released if all of the mass in the nucleus of uranium–238 were converted into energy.

[2]

[2 marks]

Question 2a

(a)
Define:

(i)
Binding energy.

[1]

(ii)
Mass defect.

[1]

[2 marks]

Question 2b

The nuclear rest mass of oxygen-16 $\left({}^{16}_{8}\mathrm{O}\right)$ is 15.994 914 u.

The mass defect, Δm, equation describes the relationship between the proton number, Z, the number of neutrons, N, the proton rest mass, m_p, the neutron rest mass, m_n, and the nuclear rest mass, m_{total}.

$$\Delta m = Zm_p + Nm_n - m_{total}$$

(b)
Calculate the mass defect of oxygen-16. Give your answer to 6 d.p.

[4]

[4 marks]

Question 2c

The mass defect (from part (b)) can be used to calculate the binding energy.

(c)
Calculate the total binding energy for a nucleus of oxygen–16 in J

[3]

[3 marks]

Question 2d

(d)
Determine the binding energy per nucleon of oxygen–16 in J.

[2]

[2 marks]

Question 3a

The binding energy per nucleon of Helium–4 $\left({}_{2}^{4}\mathrm{He}\right)$ is 7.1 MeV.

(a)
Determine the energy required to completely separate the nucleons of the atom of helium. Give your answer in MeV.

[2]

[2 marks]

Question 3b

(b)

Match the processes with the correct definition by drawing a line:

Nuclear fusion	The splitting of a large atomic nucleus into smaller nuclei
Nuclear fission	The joining of two small nuclei to produce a larger nucleus

[2]

[2 marks]

Question 3c

(c)

Complete the following sentences using appropriate words:

Helium is formed inside main sequence stars due to the process of nuclear _____. For this process to occur, both nuclei must have high _____ energy. This high energy is because the protons inside the nuclei are _____ charged and a great deal of energy is needed to overcome the _____ force of repulsion.

[3]

[3 marks]

Question 3d

(d)
Complete the following sentences using appropriate words:

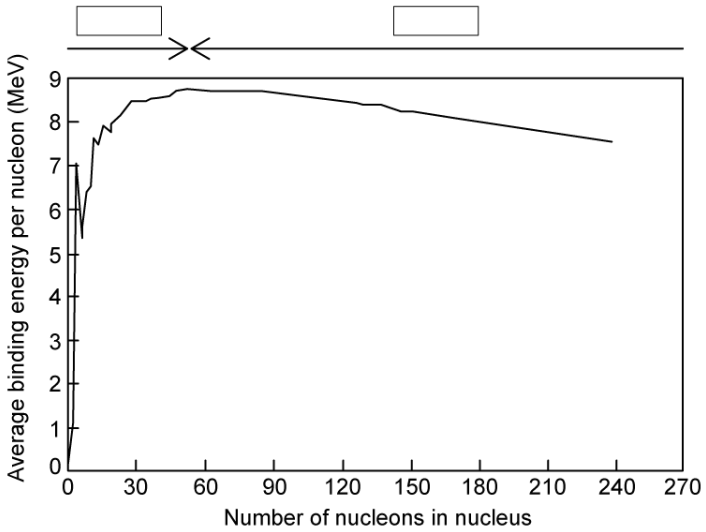
Nuclear _____ can be induced by firing _____ at a nucleus. When the nucleus is struck it splits into two or more _____ nuclei and more _____. This leads to a chain reaction.

[2]

[2 marks]

Question 4a

The chart shows the binding energy per nucleon for a number of nuclei.



(a)
Label the chart to show:

(i)
Where fusion of these elements occurs to release energy

[1]

(ii)
Where fission of these elements occurs to release energy

[1]

(ii)
The location of Iron $\left({}^{56}_{26}\mathrm{Fe}\right)$ by drawing an X

[1]

[3 marks]

Question 4b

(b)
In terms of the forces acting within the nucleus, explain why:

(i)
Fusion occurs for nuclides with low nucleon numbers.

[2]

(i)
Fission occurs for nuclides with high nucleon numbers.

[2]

[4 marks]

Question 4c

In both fission and fusion, there is a mass defect between the original nuclei and the daughter nuclei.

(c)
Complete the sentences by circling the correct word.

In fusion, the mass of the nucleus that is created is slightly **more / less** than the total mass of the original nuclei and the daughter nucleus is **more / less** stable.

In fission, an unstable nucleus is converted into more stable nuclei with a **larger / smaller** total mass. In both cases, this difference in mass, the mass defect, is equal to the binding energy that is released.

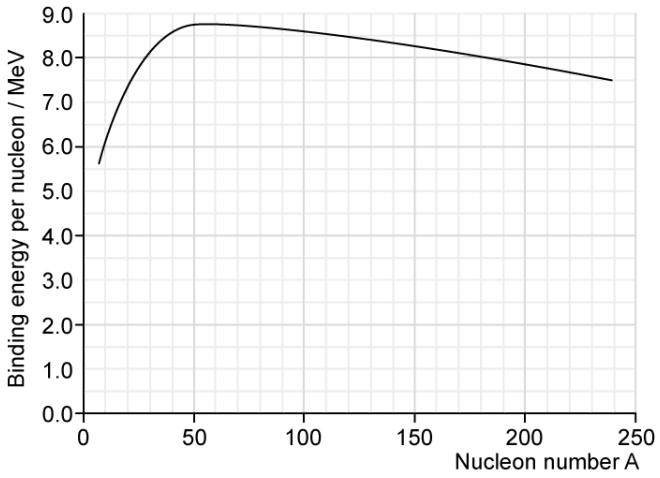
Fission / Fusion releases much more energy per kg than **fission / fusion**. The greater the increase in binding energy, the **more / less** energy is released.

[4]

[4 marks]

Question 4d

The graph shows the binding energy per nucleon in MeV plotted against nucleon number, A.



(d)
Use the graph to find the binding energy of the following nuclei.

(i)
Platinum–190.

[1]

(ii)
Silicon–28.

[1]

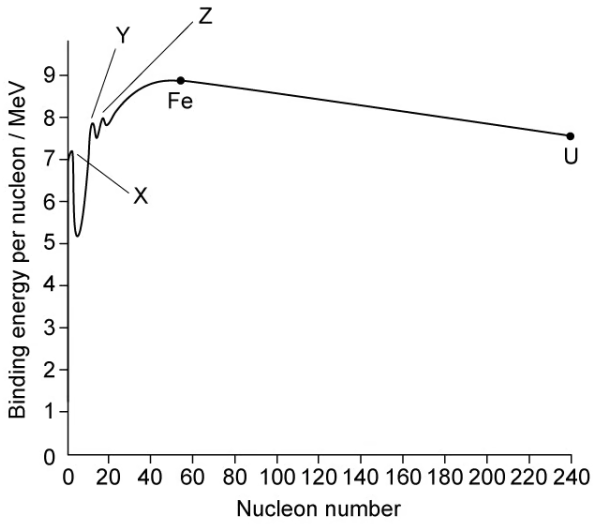
(iii)
Tellurium–120.

[1]

[3 marks]

Question 5a

The graph below shows the binding energy per nucleon against the number of nucleons in the nucleus.



There are three nuclei, labelled X, Y and Z, which do not sit on the line of the graph.

(a)
Match up the labels to the correct element by drawing a line between the boxes

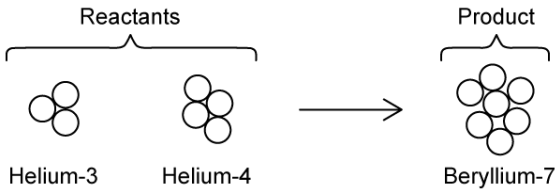
[3]

X	Oxygen
Y	Helium
Z	Carbon

[3 marks]

Question 5b

Helium can fuse together to form beryllium as shown in the reaction below:



(b)
State and explain which is larger, the mass of the reactants or the mass of the products.

[3]

[3 marks]

Question 5c

The table shows the mass of each reactant and daughter nucleus:

Nucleus	Mass / u
Helium - 3	3.01493
Helium - 4	4.00151
Beryllium - 7	7.01473

(c)
Using the information in the table:

(i)
Calculate the mass of the reactants, m_R in atomic mass units.

[2]

(ii)
Calculate the mass defect, Δm, between the reactants and the daughter nuclei in atomic mass units.

[3]

[5 marks]

Question 5d

Helium–3 and helium–4 fuse together to form beryllium–7.

The mass defect, Δm for this fusion reaction is equal to 2.8×10^{-30} kg.

(d)
Calculate the energy released, ΔE, in the fusion of beryllium–7.

[2]

[2 marks]