Nuclear Physics

Question paper 4

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Particle & Nuclear Physics
Sub Topic	Nuclear Physics
Paper Type	Theory
Booklet	Question paper 4

Time Allowed:	**71 minutes**
Score:	**/59**
Percentage:	**/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** The variation with nucleon number ***A*** of the binding energy per nucleon $\boldsymbol{B}_{\mathrm{E}}$ of nuclei is shown in Fig. 8.1.

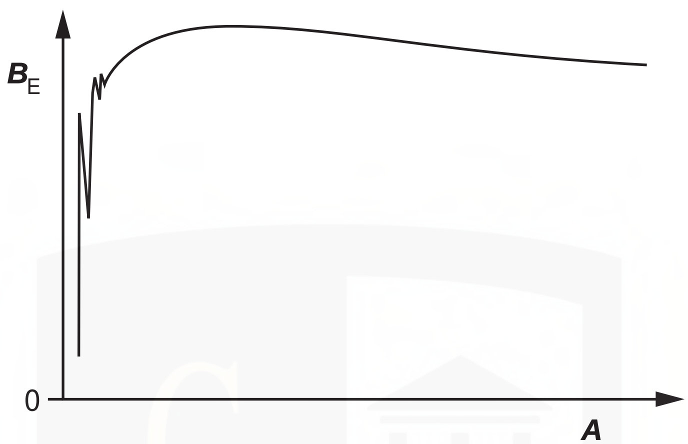

Fig. 8.1

On Fig. 8.1, mark the approximate positions of

(i) iron-56 (label this point Fe), [1]

(ii) zirconium-97 (label this point Zr), [1]

(iii) hydrogen-2 (label this point H). [1]

(b) **(i)** State what is meant by ***nuclear fission***.

....

....

....[2]

(ii) By reference to Fig. 8.1, explain how fission is energetically possible.

....

....

....

....[2]

2 **(a)** State what is meant by the ***binding energy*** of a nucleus.

....

....

.... [2]

(b) Show that the energy equivalence of 1.0 u is 930 MeV.

[3]

(c) Data for the masses of some particles and nuclei are given in Fig. 8.1.

	mass / u
proton	1.0073
neutron	1.0087
deuterium ($^{2}_{1}H$)	2.0141
zirconium ($^{97}_{40}Zr$)	97.0980

Fig. 8.1

Use data from Fig. 8.1 and information from **(b)** to determine, in MeV,

(i) the binding energy of deuterium,

binding energy = ... MeV [2]

(ii) the binding energy **per nucleon** of zirconium.

binding energy per nucleon = ... MeV [3]

3 In some power stations, nuclear fission is used as a source of energy.

(a) State what is meant by ***nuclear fission***.

....

....

....[2]

(b) The nuclear fission reaction produces neutrons. In the power station, the neutrons may be absorbed by rods made of boron-10.
Complete the nuclear equation for the absorption of a single neutron by a boron-10 nucleus with the emission of an α-particle.

$${}^{10}_{5}B + \text{......................} \rightarrow {}^{\cdots\cdots}_{3}Li + \text{......................}$$ [3]

(c) Suggest why, when neutrons are absorbed in the boron rods, the rods become hot as a result of this nuclear reaction.

....

....

....

....[3]

4 **(a)** Explain what is meant by the ***potential energy*** of a body.

....

....

....[2]

(b) Two deuterium ($^2_1$H) nuclei each have initial kinetic energy $\boldsymbol{E}_K$ and are initially separated by a large distance.
The nuclei may be considered to be spheres of diameter 3.8×10^{-15} m with their masses and charges concentrated at their centres.
The nuclei move from their initial positions to their final position of just touching, as illustrated in Fig. 4.1.

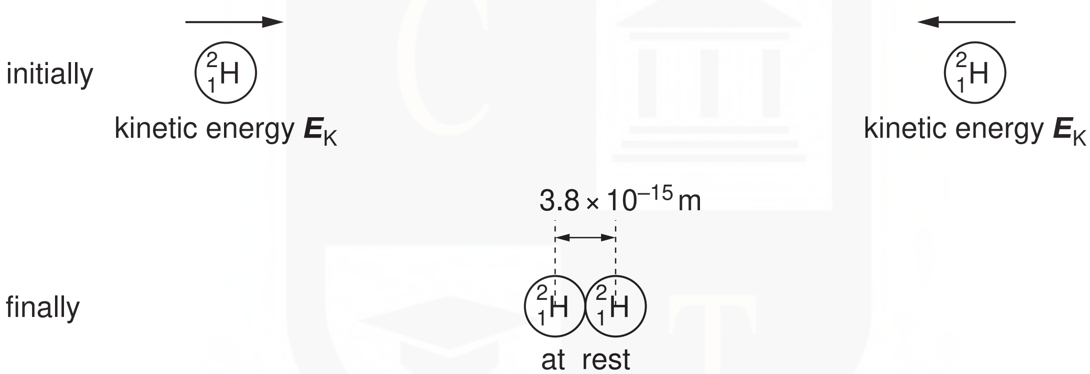

Fig. 4.1

(i) For the two nuclei approaching each other, calculate the total change in

1. gravitational potential energy,

energy = ... J [3]

2. electric potential energy.

energy = ... J [3]

(ii) Use your answers in **(i)** to show that the initial kinetic energy $\boldsymbol{E}_K$ of each nucleus is 0.19 MeV.

[2]

(iii) The two nuclei may rebound from each other. Suggest one other effect that could happen to the two nuclei if the initial kinetic energy of each nucleus is greater than that calculated in **(ii)**.

....

....[1]

5 A π^0 meson is a sub-atomic particle.
A stationary π^0 meson, which has mass 2.4×10^{-28} kg, decays to form two γ-ray photons.
The nuclear equation for this decay is

$$\pi^0 \longrightarrow \gamma + \gamma.$$

(a) Explain why the two γ-ray photons have the same energy.

....

....

....[2]

(b) Determine, for each γ-ray photon,

(i) the energy, in joule,

energy = ... J [2]

(ii) the wavelength,

wavelength = ... m [2]

(iii) the momentum.

momentum = ... N s [2]

6 Americium-241 is an artificially produced radioactive element that emits α-particles.

A sample of americium-241 of mass 5.1 μg is found to have an activity of 5.9×10^5 Bq.

(a) Determine, for this sample of americium-241,

(i) the number of nuclei,

number = ... [2]

(ii) the decay constant,

decay constant = ... s^{-1} [2]

(iii) the half-life, in years.

half-life = ... years [2]

(b) Another radioactive element has a half-life of approximately 4 hours.
Suggest why measurement of the mass and activity of a sample of this element is not appropriate for the determination of its half-life.

....

.... [1]

7 The controlled reaction between deuterium ($^{2}_{1}H$) and tritium ($^{3}_{1}H$) has involved ongoing research for many years. The reaction may be summarised as

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n + \boldsymbol{Q}$$

where $\boldsymbol{Q}$ = 17.7 MeV.

Binding energies per nucleon are shown in Fig. 8.1.

	binding energy per nucleon / MeV
$^{2}_{1}H$	1.12
$^{1}_{0}n$	–
$^{4}_{2}He$	7.07

Fig. 8.1

(a) Suggest why binding energy per nucleon for the neutron is not quoted.

....

.... [1]

(b) Calculate the mass defect, in kg, of a helium $^{4}_{2}He$ nucleus.

mass defect = ... kg [3]

(c) **(i)** State the name of the type of reaction illustrated by this nuclear equation.

.... [1]

(ii) Determine the binding energy per nucleon, in MeV, of tritium ($^{3}_{1}H$).

binding energy per nucleon = ... MeV [3]