Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________

A-level
PHYSICS A

Unit 5 Nuclear and Thermal Physics
Section A

Wednesday 21 June 2017 Morning

Time allowed: The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 55 minutes on this section.

Materials

For this paper you must have:
- a calculator
- a pencil and a ruler
- a question paper/answer book for Section B (enclosed).

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this section is 40.
- You are expected to use a calculator, where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert in Section B.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

Section A

The maximum mark for this section is 40.
You are advised to spend approximately 55 minutes on this section.

1 The artificial radioisotope phosphorus $^{32}_{15}\mathrm{P}$ is formed when naturally occurring phosphorus $^{31}_{15}\mathrm{P}$ is bombarded with hydrogen $^{2}_{1}\mathrm{H}$ nuclei.

1 (a) Which of the following equations correctly represent interactions that form $^{32}_{15}\mathrm{P}$?
Place a tick (✓) in the right-hand column for **each** correct equation.

[1 mark]

Equation	**Tick (✓) all correct equations**
$^{31}_{15}\mathrm{P} + ^{2}_{1}\mathrm{H} \rightarrow ^{32}_{15}\mathrm{P} + ^{1}_{0}\mathrm{n}$	
$^{31}_{15}\mathrm{P} + ^{2}_{1}\mathrm{H} \rightarrow ^{32}_{15}\mathrm{P} + ^{1}_{1}\mathrm{H}$	
$^{31}_{15}\mathrm{P} + ^{2}_{1}\mathrm{H} \rightarrow ^{32}_{15}\mathrm{P} + ^{4}_{2}\alpha$	
$^{31}_{15}\mathrm{P} + ^{2}_{1}\mathrm{H} \rightarrow ^{32}_{15}\mathrm{P} + ^{1}_{1}\mathrm{p}$	

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1 (b) For the reaction to take place the centre of the hydrogen $^{2}_{1}\mathrm{H}$ nucleus must come within a distance d from the centre of the phosphorus $^{31}_{15}\mathrm{P}$ nucleus.

The nuclear reaction occurs when the hydrogen nucleus is given a minimum initial kinetic energy of 6.5×10^{-13} J.

Calculate d.

[3 marks]

d = ____________________________ m

Turn over for the next question

4

2 The age of an ancient axe handle can be determined by comparing the radioactive decay of $^{14}_{6}\mathrm{C}$ from living wood with that of wood taken from the ancient axe handle. A sample of 3.5×10^{23} atoms of carbon is removed for investigation from a block of living wood. In living wood 1 in 10^{12} of the carbon atoms is of the radioactive isotope $^{14}_{6}\mathrm{C}$.

The decay constant of $^{14}_{6}\mathrm{C}$ is $3.84 \times 10^{-12}\,\mathrm{s}^{-1}$

2 (a) State what is meant by decay constant.

[1 mark]

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2 (b) Calculate, in years, the half-life of $^{14}_{6}\mathrm{C}$.
Give your answer to an appropriate number of significant figures.

1 year = $3.15 \times 10^{7}\,\mathrm{s}$

[3 marks]

half-life = ______________________ years

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2 (c) Show that the rate of decay of the $^{14}_{6}C$ atoms in the living wood sample is about $1.3\ Bq$.

[2 marks]

2 (d) A sample of 3.5×10^{23} atoms of carbon is removed from a piece of wood taken from the ancient axe handle. The rate of decay due to the $^{14}_{6}C$ atoms in this sample is $0.85\ Bq$.

Calculate, in years, the age of the ancient axe handle.

[3 marks]

age = ______________________ years

Question 2 continues on the next page

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2 (e) State **two** reasons why it is difficult to obtain an accurate age of the ancient axe handle using this carbon dating method.

[2 marks]

1 ____

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2 ____

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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

[2 marks]

3 (b) (i) When a $^{233}_{92}\mathrm{U}$ nucleus absorbs a slow-moving neutron and undergoes fission one possible pair of fission fragments is krypton $^{91}_{36}\mathrm{Kr}$ and barium $^{139}_{56}\mathrm{Ba}$.

Complete the following equation to represent this fission process.

[1 mark]

$$^{1}_{0}\mathrm{n} + {}^{233}_{92}\mathrm{U} \rightarrow {}^{91}_{36}\mathrm{Kr} + {}^{139}_{56}\mathrm{Ba} + \_\_\_\_\_\_\_\_$$

3 (b) (ii) Calculate the energy released, in J, when a single $^{233}_{92}\mathrm{U}$ nucleus undergoes fission in this way.

binding energy per nucleon of $^{233}_{92}\mathrm{U}$ = 7.60 MeV

binding energy per nucleon of $^{91}_{36}\mathrm{Kr}$ = 8.55 MeV

binding energy per nucleon of $^{139}_{56}\mathrm{Ba}$ = 8.37 MeV

[3 marks]

energy released = ______________________ J

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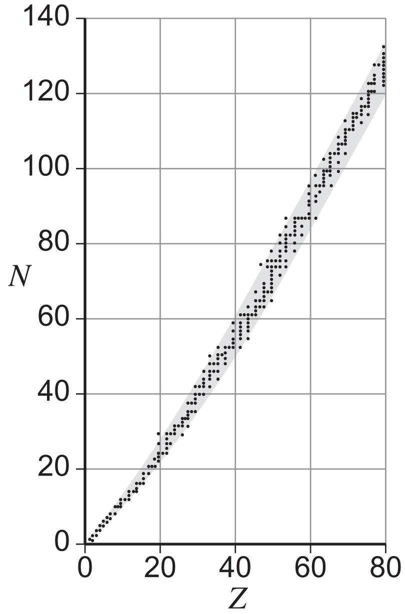
3 (b) (iii) Calculate the loss of mass when a $^{233}_{92}\mathrm{U}$ nucleus undergoes fission in this way.

[2 marks]

loss of mass = ______________________ kg

3 (c) **Figure 1** shows how neutron number N varies with proton number Z for stable nuclei.

Figure 1



Explain with reference to **Figure 1**, why fission fragments are unstable and deduce which type of radiation they are likely to emit initially.

[3 marks]

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11

Turn over ▶

4 $1.50\ \mathrm{mol}$ of an ideal gas is trapped in a container of constant volume. The gas is then heated so that the pressure of the gas changes.

4 (a) (i) Calculate the average kinetic energy of a molecule when this gas is at a temperature of $25.0\ °\mathrm{C}$.

[2 marks]

average kinetic energy = ____________________________ J

4 (a) (ii) Calculate the total internal energy of the gas at a temperature of $25.0\ °\mathrm{C}$.

[1 mark]

total internal energy = ____________________________ J

4 (b) Explain how the gas exerts a pressure and why the pressure changes as the temperature increases.

Your answer should include:

- how the pressure is related to molecular motion
- the laws of physics that are used when relating pressure to molecular motion
- an explanation of what happens to the pressure as the temperature increases.

The quality of your written communication will be assessed in your answer.

[6 marks]

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Turn over for the next question

9

Turn over ▶

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5 Water of mass 0.250 kg at a temperature of 2.0 ºC is poured into a glass beaker. The beaker has a mass of 0.200 kg and is initially at a temperature of 28.0 ºC.

specific heat capacity of water = $4190 \text{ J kg}^{-1} \text{ K}^{-1}$
specific heat capacity of glass = $840 \text{ J kg}^{-1} \text{ K}^{-1}$

5 (a) Show that the final temperature T_f of the water is about 6 ºC when it reaches thermal equilibrium with the beaker.
Assume no heat is gained from or lost to the surroundings.

[2 marks]

5 (b) The water and beaker are cooled from T_f to a temperature of 2.0 ºC by adding ice at a temperature of 0 ºC.

Calculate the mass of ice added.
Assume no heat is gained from or lost to the surroundings.

specific latent heat of fusion of ice = $3.34 \times 10^5 \text{ J kg}^{-1}$

[3 marks]

mass = ____________________________ kg

5

END OF QUESTIONS