Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

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

General Certificate of Education
Advanced Level Examination
June 2011

Physics A PHYA5/1

Unit 5 Nuclear and Thermal Physics
Section A

Monday 27 June 2011 9.00 am to 10.45 am

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

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.

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.

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.

Section A

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

1 The fissile isotope of uranium, $^{233}_{92}U$, has been used in some nuclear reactors.
It is normally produced by neutron irradiation of thorium-232.
An irradiated thorium nucleus emits a β^- particle to become an isotope of protactinium.

This isotope of protactinium may undergo β^- decay to become $^{233}_{92}U$.

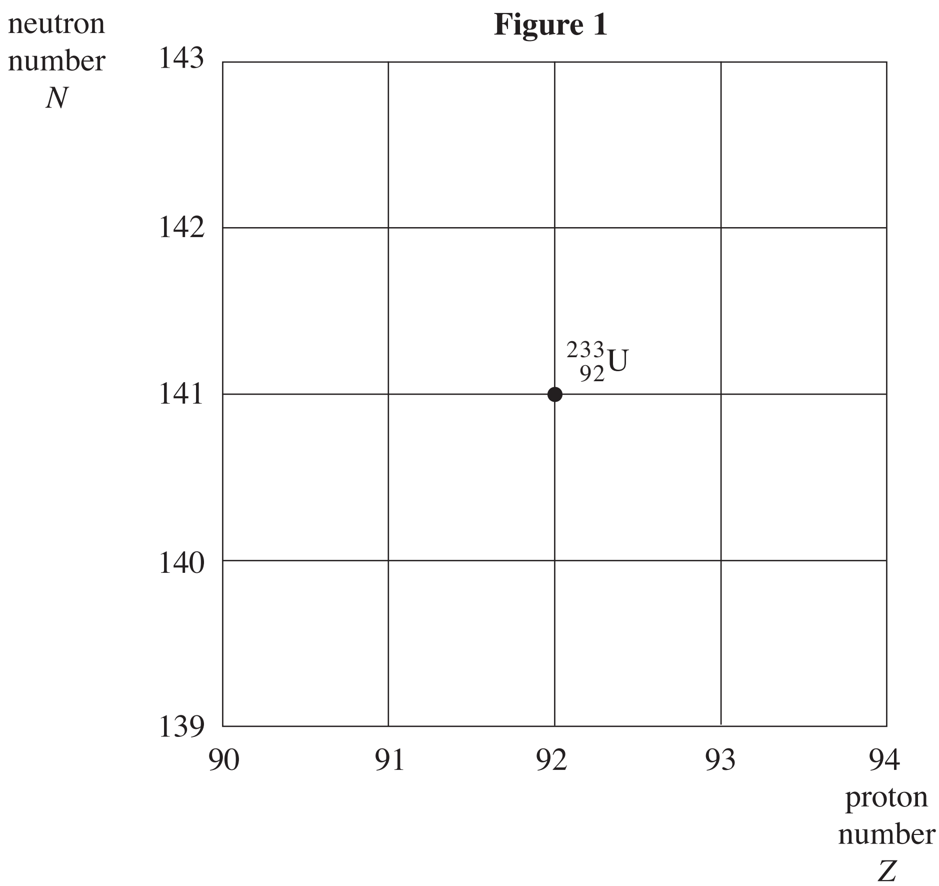
1 (a) Complete the following equation to show the β^- decay of protactinium.

$$^{\cdots\cdots}_{\cdots\cdots}Pa \rightarrow ^{233}_{92}U + \beta^- + \ldots\ldots\ldots$$

(2 marks)

1 (b) Two other nuclei, **P** and **Q**, can also decay into $^{233}_{92}U$.
P decays by β^+ decay to produce $^{233}_{92}U$.
Q decays by α emission to produce $^{233}_{92}U$.
Figure 1 shows a grid of neutron number against proton number with the position of the $^{233}_{92}U$ isotope shown.
On the grid label the positions of the nuclei **P** and **Q**.

Figure 1



(2 marks)

Do not write outside the box

1 (c) A typical fission reaction in the reactor is represented by

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

1 (c) (i) Calculate the number of neutrons, x.

answer = ...neutrons
(1 mark)

1 (c) (ii) Calculate the energy released, in MeV, in the fission reaction above.

mass of neutron = 1.00867 u

mass of $^{233}_{92}U$ nucleus = 232.98915 u

mass of $^{91}_{36}Kr$ nucleus = 90.90368 u

mass of $^{139}_{56}Ba$ nucleus = 138.87810 u

answer = ...MeV
(3 marks)

8

Turn over ▶

2 The first artificially produced isotope, phosphorus $^{30}_{15}P$, was formed by bombarding an aluminium isotope, $^{27}_{13}Al$, with an α particle.

2 (a) Complete the following nuclear equation by identifying the missing particle.

$$^{27}_{13}\text{Al} + \alpha \rightarrow {}^{30}_{15}\text{P} + \;\ldots\ldots\ldots$$

(1 mark)

2 (b) For the reaction to take place the α particle must come within a distance, *d*, from the centre of the aluminium nucleus.
Calculate *d* if the nuclear reaction occurs when the α particle is given an initial kinetic energy of at least 2.18×10^{-12} J.

The electrostatic potential energy between two point charges Q_1 and Q_2 is equal to $\dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r}$ where *r* is the separation of the charges and ε_0 is the permittivity of free space.

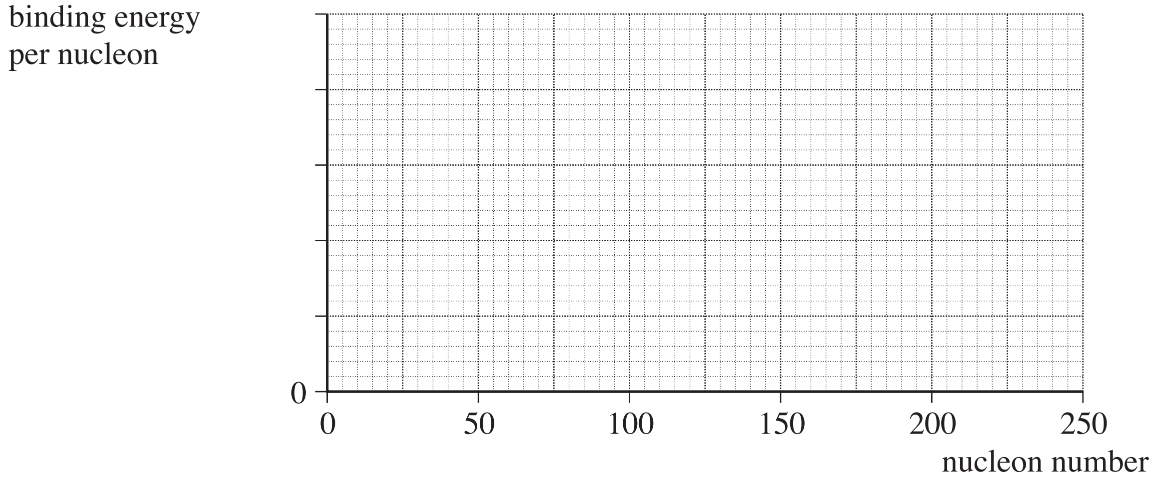
answer = ...m

(3 marks)

4

3 (a) Sketch a graph of binding energy per nucleon against nucleon number for the naturally occurring nuclides on the axes given in **Figure 2**.
Add values and a unit to the binding energy per nucleon axis.

Figure 2



(4 marks)

3 (b) Use the graph to explain how energy is released when some nuclides undergo fission and when other nuclides undergo fusion.

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(3 marks)

7

4 An electrical heater is placed in an insulated container holding 100 g of ice at a temperature of –14 °C. The heater supplies energy at a rate of 98 joules per second.

4 (a) After an interval of 30 s, all the ice has reached a temperature of 0 °C.
Calculate the specific heat capacity of ice.

answer = ...$J\,kg^{-1}\,K^{-1}$

(2 marks)

4 (b) Show that the final temperature of the water formed when the heater is left on for a further 500 s is about 40 °C.

specific heat capacity of water = 4200 $J\,kg^{-1}\,K^{-1}$

specific latent heat of fusion of water = $3.3 \times 10^5\ J\,kg^{-1}$

(3 marks)

4 (c) The whole procedure is repeated in an uninsulated container in a room at a temperature of 25 °C.
State and explain whether the final temperature of the water formed would be higher or lower than that calculated in part (b).

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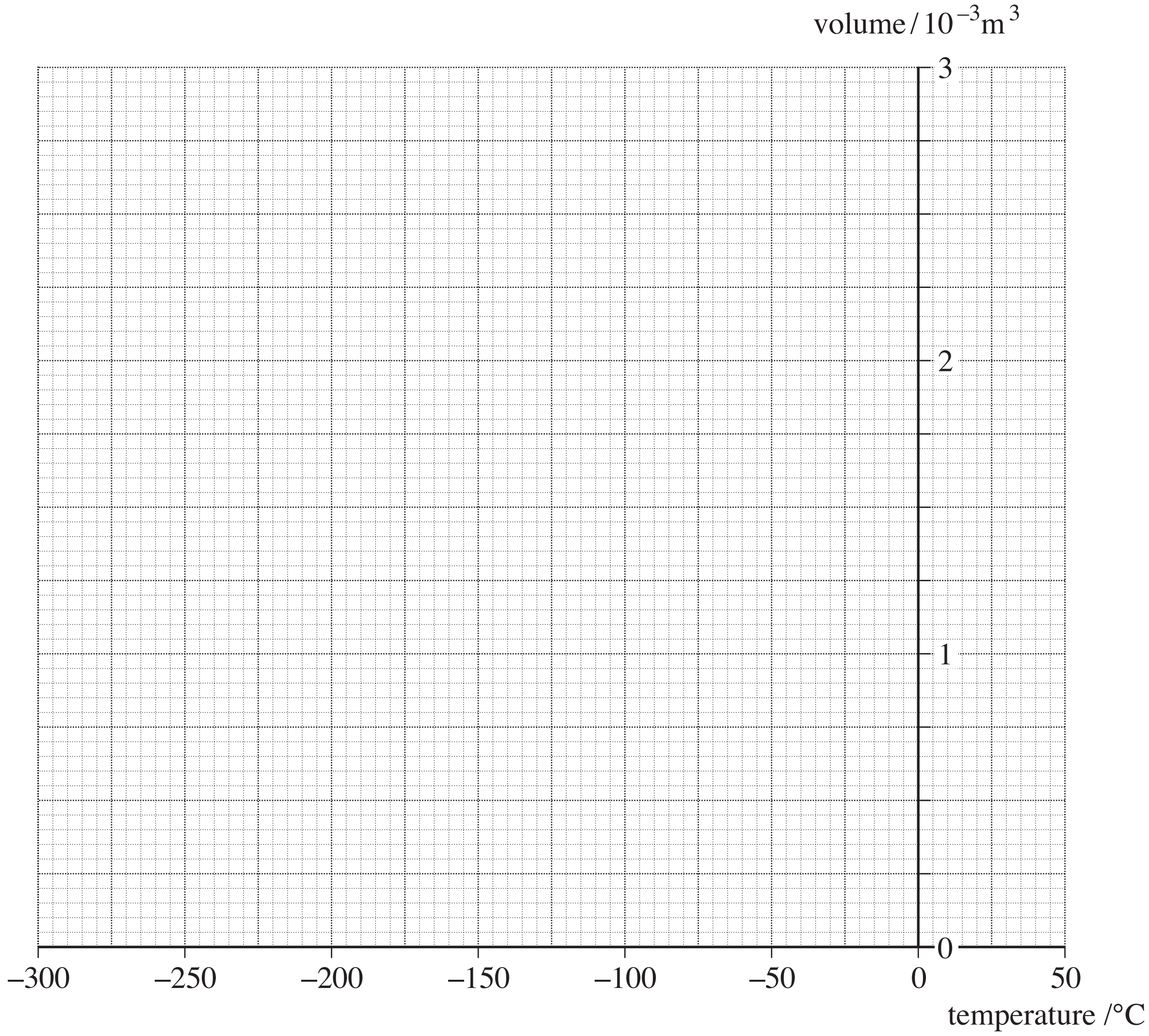
(2 marks)

7

5 A fixed mass of ideal gas at a low temperature is trapped in a container at constant pressure. The gas is then heated and the volume of the container changes so that the pressure stays at 1.00×10^5 Pa.
When the gas reaches a temperature of 0 °C the volume is 2.20×10^{-3} m^3.

5 (a) Draw a graph on the axes below to show how the volume of the gas varies with temperature in °C.



(2 marks)

5 (b) Calculate the number of moles of gas present in the container.

answer = ...moles
(2 marks)

Turn over ▶

5 (c) Calculate the average kinetic energy of a molecule when this gas is at a temperature of 50.0 °C. Give your answer to an appropriate number of significant figures.

answer = ...J

(3 marks)

5 (d) Calculate the total internal energy of the gas at a temperature of 50.0 °C.

answer = ...J

(1 mark)

5 (e) By considering the motion of the molecules explain how a gas exerts a pressure and why the volume of the container must change if the pressure is to remain constant as the temperature increases.

The quality of your written communication will be assessed in this question.

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(6 marks)

14