Centre Number						Candidate Number				
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Other Names										
Candidate Signature										

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

AQA

General Certificate of Education
Advanced Level Examination
June 2015

Physics A PHYA5/1

Unit 5 Nuclear and Thermal Physics
Section A

Thursday 18 June 2015 9.00 am to 10.45 am

For this paper you must have:
- a calculator
- a pencil and 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.
- 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.

Section A

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

1 (a) Which ionizing radiation produces the greatest number of ion pairs per mm in air?
Tick (✓) the correct answer.

[1 mark]

α particles	
β particles	
γ rays	
X-rays	

1 (b) (i) Complete **Table 1** below showing the typical maximum range in air for α and β particles.

[2 marks]

Table 1

Type of radiation	Typical range in air / m
α	
β	

1 (b) (ii) γ rays have a range of at least 1 km in air.
However, a γ ray detector placed 0.5 m from a γ ray source detects a noticeably smaller count-rate as it is moved a few centimetres further away from the source.

Explain this observation.

[1 mark]

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1 (c) Following an accident, a room is contaminated with dust containing americium which is an α-emitter.

Explain the most hazardous aspect of the presence of this dust to an unprotected human entering the room.

[2 marks]

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6

Turn over for the next question

2 (a) Scattering experiments are used to investigate the nuclei of gold atoms.
In one experiment, alpha particles, all of the same energy (monoenergetic), are incident on a foil made from a single isotope of gold.

2 (a) (i) State the main interaction when an alpha particle is scattered by a gold nucleus.

[1 mark]

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2 (a) (ii) The gold foil is replaced with another foil of the same size made from a mixture of isotopes of gold. Nothing else in the experiment is changed.

Explain whether or not the scattering distribution of the monoenergetic alpha particles remains the same.

[1 mark]

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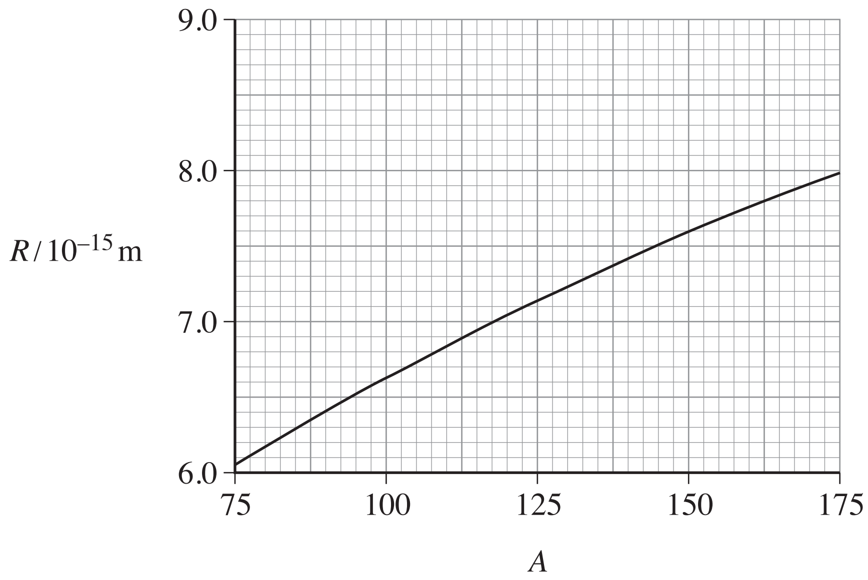
2 (b) Data from alpha-particle scattering experiments using elements other than gold allow scientists to relate the radius R, of a nucleus, to its nucleon number, A.
Figure 1 shows the relationship obtained from the data in a graphical form, which obeys the relationship $R = r_0 A^{\frac{1}{3}}$.

Figure 1



2 (b) (i) Use information from **Figure 1** to show that r_0 is about 1.4×10^{-15} m.

[1 mark]

2 (b) (ii) Show that the radius of a $^{27}_{13}\text{Al}$ nucleus is about 4×10^{-15} m.

[2 marks]

2 (c) Calculate the density of a $^{27}_{13}\text{Al}$ nucleus.

State an appropriate unit for your answer.

[3 marks]

density .... unit ....

8

Turn over ▶

3 A rod made from uranium-238 ($^{238}_{92}U$) is placed in the core of a nuclear reactor where it absorbs free neutrons.

When a nucleus of uranium-238 absorbs a neutron it becomes unstable and decays to neptunium-239 ($^{239}_{93}Np$), which in turn decays to plutonium-239 ($^{239}_{94}Pu$).

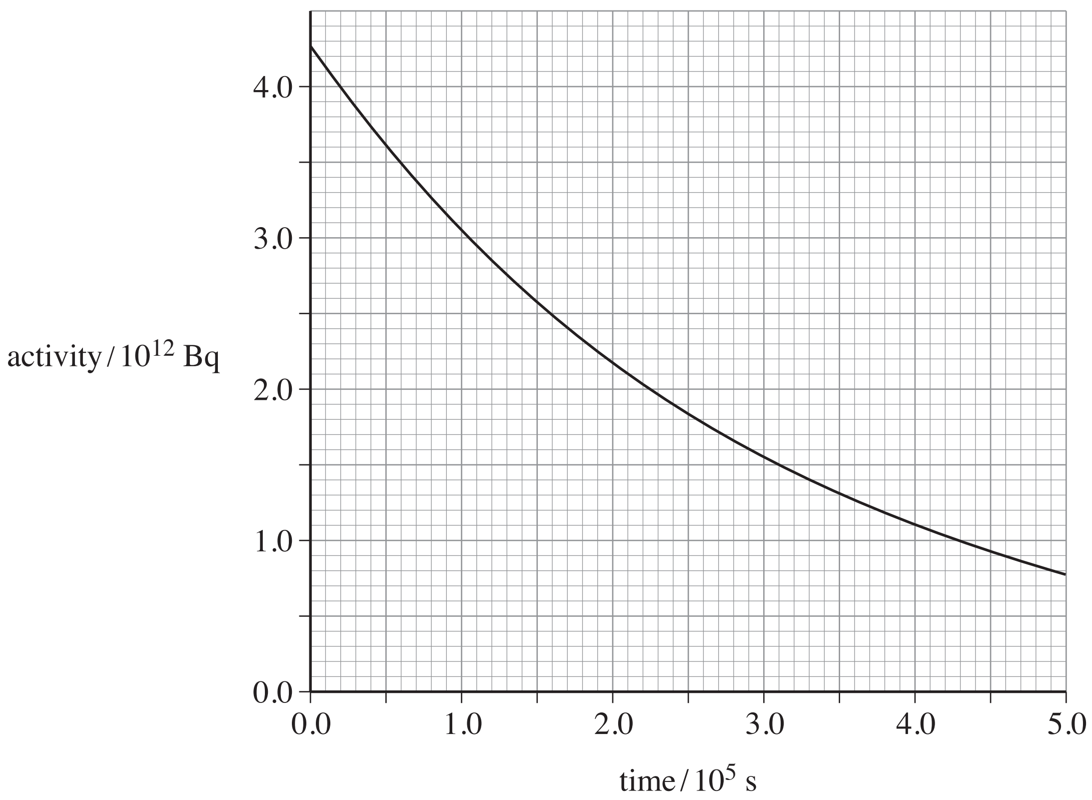
3 (a) Write down the nuclear equation that represents the decay of neptunium-239 into plutonium-239.

[2 marks]

3 (b) A sample of the rod is removed from the core and its radiation is monitored from time $t = 0$ s.

The variation of the activity with time is shown in **Figure 2**.

Figure 2



3 (b) (i) Show that the decay constant of the sample is about $3.4 \times 10^{-6}\ \mathrm{s}^{-1}$.

[2 marks]

3 (b) (ii) Assume that the activity shown in **Figure 2** comes only from the decay of neptunium.

Estimate the number of neptunium nuclei present in the sample at the time when monitoring began at time $t = 0\ \mathrm{s}$.

[1 mark]

number of nuclei ....

Question 3 continues on the next page

Turn over ▶

Do not write outside the box

3 (c) (i) A chain reaction is maintained in the core of a thermal nuclear reactor that is operating normally.

Explain what is meant by a chain reaction, naming the materials and particles involved.

[2 marks]

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3 (c) (ii) Explain the significance of critical mass in the operation of a thermal nuclear reactor.

[2 marks]

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3 (c) (iii) Substantial shielding around the core protects nearby workers from the most hazardous radiations. Radiation from the core includes α and β particles, γ rays, X–rays, neutrons and neutrinos.

Explain why the shielding becomes radioactive.

[2 marks]

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11

Do not write outside the box

4 (a) Lead has a specific heat capacity of $130\ \mathrm{J\ kg^{-1}\ K^{-1}}$.

Explain what is meant by this statement.

[1 mark]

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4 (b) Lead of mass $0.75\ \mathrm{kg}$ is heated from $21\ ^\circ\mathrm{C}$ to its melting point and continues to be heated until it has all melted.

Calculate how much energy is supplied to the lead.
Give your answer to an appropriate number of significant figures.

melting point of lead = $327.5\ ^\circ\mathrm{C}$
specific latent heat of fusion of lead = $23\ 000\ \mathrm{J\ kg^{-1}}$

[3 marks]

energy supplied .... J

4

Turn over ▶

5 (a) The concept of an absolute zero of temperature may be explained by reference to the behaviour of a gas.
Discuss **one** experiment that can be performed using a gas which would enable you to explain absolute zero and determine its value.
It is not necessary to give full details of the apparatus. Your answer should:

- include the quantities that are kept constant
- identify the measurements to be taken
- explain how the results may be used to find absolute zero
- justify why the value obtained is absolute zero.

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

[6 marks]

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Question 5 continues on the next page

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5 (b) (i) State **two** assumptions about the **movement** of molecules that are used when deriving the equation of state, $pV = \frac{1}{3} N m (c_{rms})^2$ for an ideal gas.

[2 marks]

1 ....

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2 ....

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5 (b) (ii) Three molecules move at the speeds shown in **Table 2**.

Table 2

molecule	**speed / $m\ s^{-1}$**
1	4000
2	5000
3	6000

Calculate their mean square speed.

[1 mark]

mean square speed .... $m^2\ s^{-2}$

Do not write outside the box

5 (c) At a particular temperature the mean square speed of a sample of nitrogen molecules is $2.54 \times 10^5\ \mathrm{m^2\ s^{-2}}$. The pressure of the gas is $7.9 \times 10^4\ \mathrm{Pa}$. Assume that the nitrogen behaves as an ideal gas.
Calculate the volume occupied by one mole of the nitrogen molecules.

mass of a nitrogen molecule = $4.65 \times 10^{-26}\ \mathrm{kg}$

[2 marks]

volume .... $\mathrm{m^3}$

11

END OF SECTION A

Turn over ▶

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