Centre Number						Candidate Number				
Surname										
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 2014

Physics A

PHYA5/1

Unit 5 Nuclear and Thermal Physics
Section A

Thursday 19 June 2014 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.
- 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.

J U N 1 4 P H Y A 5 1 0 1

Section A

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

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

[2 marks]

....

....

....

1 (b) (i) When a $^{235}_{92}\mathrm{U}$ nucleus absorbs a slow-moving neutron and undergoes fission one possible pair of fission fragments is technetium $^{112}_{43}\mathrm{Tc}$ and indium $^{122}_{49}\mathrm{In}$.
Complete the following equation to represent this fission process.

[1 mark]

$$^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{112}_{43}\mathrm{Tc} + {}^{122}_{49}\mathrm{In} + \ldots\ldots\ldots\ldots$$

1 (b) (ii) Calculate the energy released, in MeV, when a single $^{235}_{92}\mathrm{U}$ nucleus undergoes fission in this way.

binding energy per nucleon of $^{235}_{92}\mathrm{U} = 7.59\,\mathrm{MeV}$

binding energy per nucleon of $^{112}_{43}\mathrm{Tc} = 8.36\,\mathrm{MeV}$

binding energy per nucleon of $^{122}_{49}\mathrm{In} = 8.51\,\mathrm{MeV}$

[3 marks]

energy released .... MeV

1 (b) (iii) Calculate the loss of mass when a $^{235}_{92}\mathrm{U}$ nucleus undergoes fission in this way.

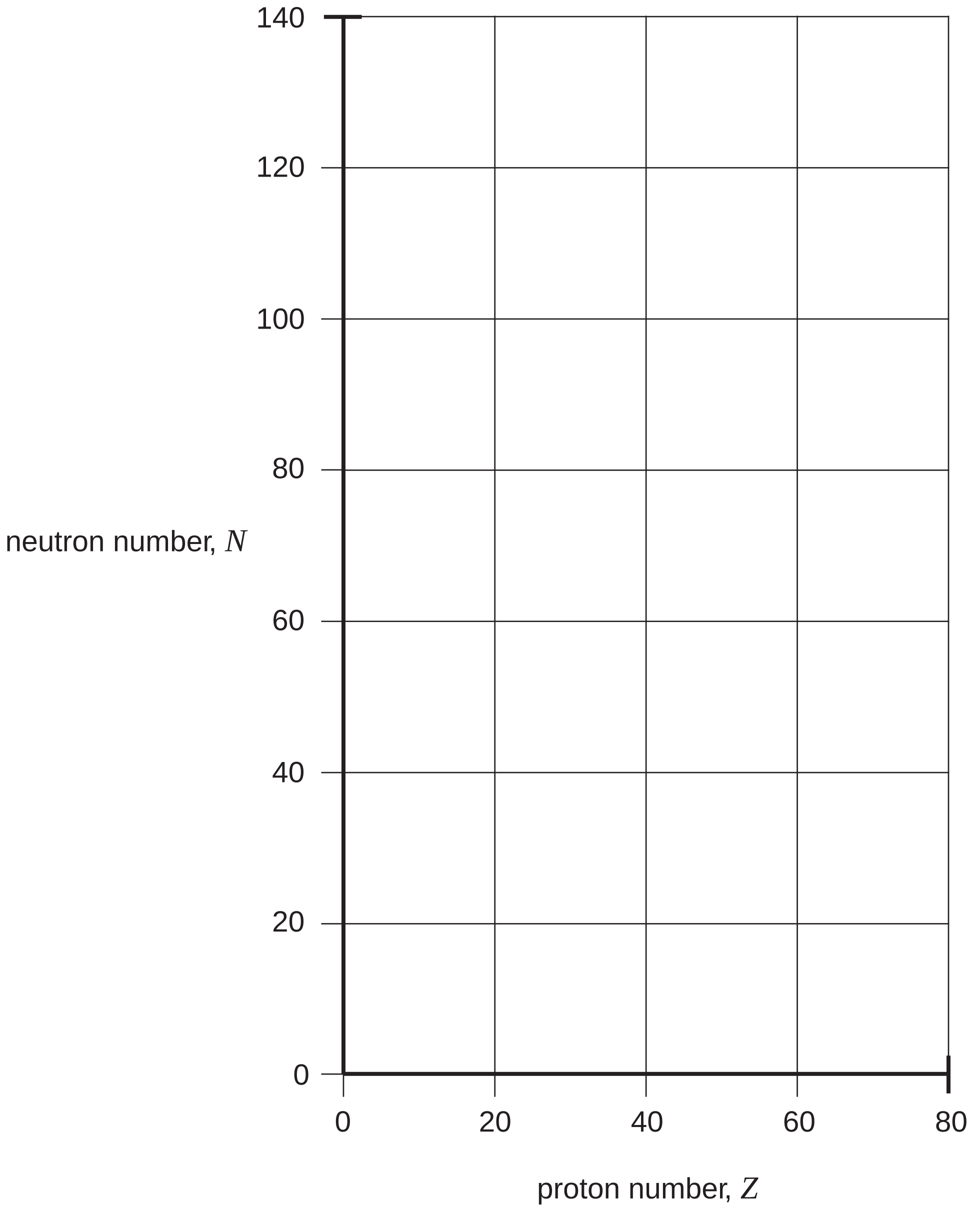
[2 marks]

loss of mass .... kg

1 (c) (i) On **Figure 1** sketch a graph of neutron number, N, against proton number, Z, for stable nuclei.

[1 mark]

Figure 1



Turn over ▶

1 (c) (ii) With reference to **Figure 1**, explain why fission fragments are unstable and explain what type of radiation they are likely to emit initially.

[3 marks]

....

....

....

....

....

....

12

Do not write outside the box

2 The carbon content of living trees includes a small proportion of carbon-14, which is a radioactive isotope. After a tree dies, the proportion of carbon-14 in it decreases due to radioactive decay.

2 (a) (i) The half-life of carbon-14 is 5740 years.
Calculate the radioactive decay constant in yr^{-1} of carbon-14.

[1 mark]

decay constant .... yr^{-1}

2 (a) (ii) A piece of wood taken from an axe handle found on an archaeological site has 0.375 times as many carbon-14 atoms as an equal mass of living wood.
Calculate the age of the axe handle in years.

[3 marks]

age .... yr

2 (b) Suggest why the method of carbon dating is likely to be unreliable if a sample is:

[2 marks]

2 (b) (i) less than 200 years old,

....

....

....

2 (b) (ii) more than 60 000 years old.

....

....

....

6

3 (a) Define the Avogadro constant.

[1 mark]

....

....

....

3 (b) (i) Calculate the mean kinetic energy of krypton atoms in a sample of gas at a temperature of 22 ºC.

[1 mark]

mean kinetic energy .... J

3 (b) (ii) Calculate the mean-square speed, $(c_{rms})^2$, of krypton atoms in a sample of gas at a temperature of 22 ºC.
State an appropriate unit for your answer.

mass of 1 mole of krypton = 0.084 kg

[3 marks]

mean-square speed.................................... unit ....

3 (c) A sample of gas consists of a mixture of krypton and argon atoms.
The mass of a krypton atom is greater than that of an argon atom.
State and explain how the mean-square speed of krypton atoms in the gas compares with that of the argon atoms at the same temperature.

[2 marks]

....

....

....

....

....

7

Turn over for the next question

4 (a) Define the specific latent heat of vaporisation of water.

[2 marks]

....

....

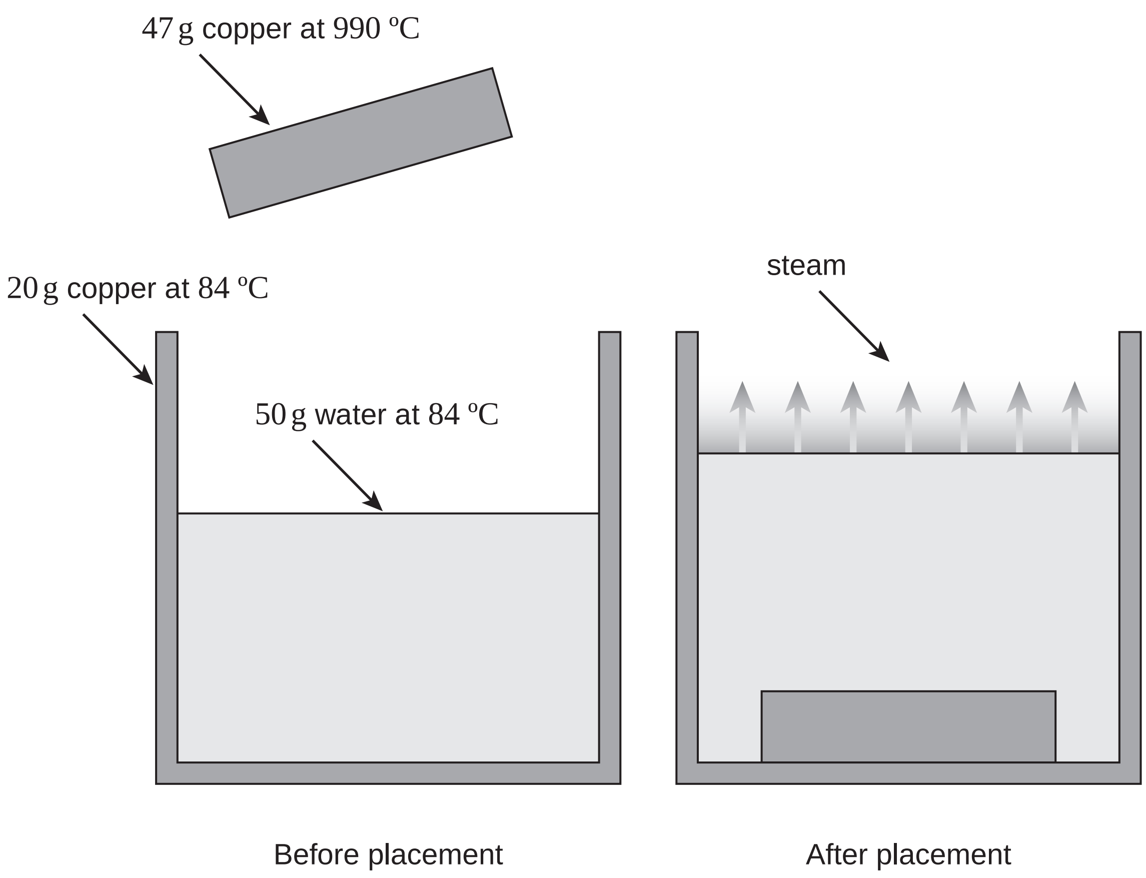
....

....

4 (b) An insulated copper can of mass 20 g contains 50 g of water both at a temperature of 84 ºC. A block of copper of mass 47 g at a temperature of 990 ºC is lowered into the water as shown in **Figure 2**. As a result, the temperature of the can and its contents reaches 100 ºC and some of the water turns to steam.

specific heat capacity of copper = $390\ \mathrm{J\,kg^{-1}\,K^{-1}}$
specific heat capacity of water = $4200\ \mathrm{J\,kg^{-1}\,K^{-1}}$
specific latent heat of vaporisation of water = $2.3 \times 10^{6}\ \mathrm{J\,kg^{-1}}$

Figure 2



4 (b) (i) Calculate how much thermal energy is transferred from the copper block as it cools to 100 ºC.
Give your answer to an appropriate number of significant figures.

[2 marks]

thermal energy transferred .... J

4 (b) (ii) Calculate how much of this thermal energy is available to make steam.
Assume no heat is lost to the surroundings.

[2 marks]

available thermal energy .... J

4 (b) (iii) Calculate the maximum mass of steam that may be produced.

[1 mark]

mass .... kg

7

5 (a) A nuclear reactor core is contained in a steel vessel surrounded by concrete. State and explain the purpose of the concrete other than its structural function.

[2 marks]

....

....

....

....

5 (b) A quantity of highly active waste removed from a nuclear reactor consists of similar amounts of two radioisotopes, X and Y.
X has a half-life of about 20 days and emits γ rays and β^- particles. Y has a half-life of about 20 years and emits α particles. Assume that both X and Y become relatively stable after their initial decays.
Discuss the problems of storing the waste until it is safe and describe and explain the way in which the waste would normally be treated.

Your account should include details of:

- a comparison of the storage problems associated with X and Y in both the short term and the long term
- how the waste is treated initially at the reactor site and how it could be stored safely for a long time.

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

[6 marks]

....

....

....

....

....

....

....

....

....

....

8

END OF SECTION A

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED