THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS B (ADVANCED PHYSICS) 2864/01

Field and Particle Pictures

Candidates answer on the question paper

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator

Wednesday 10 June 2009
Afternoon

Duration: 1 hour 15 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **70**.
- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- Four marks are available for the quality of written communication in Section B.
- The values of standard physical constant are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.
- This document consists of **16** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Section	**Max.**	**Mark**
A	**20**	
B	**50**	
TOTAL	**70**	

Answer **all** the questions.

Section A

1 Here is a list of units.

J C^{-1} **J kg^{-1}** **N C^{-1}** **T** **Wb**

(a) Which is the correct unit for electric field strength?

.... **[1]**

(b) Which is the correct unit for absorbed dose?

.... **[1]**

2 The graph of Fig. 2.1 shows how the flux in a coil of wire changes with time.

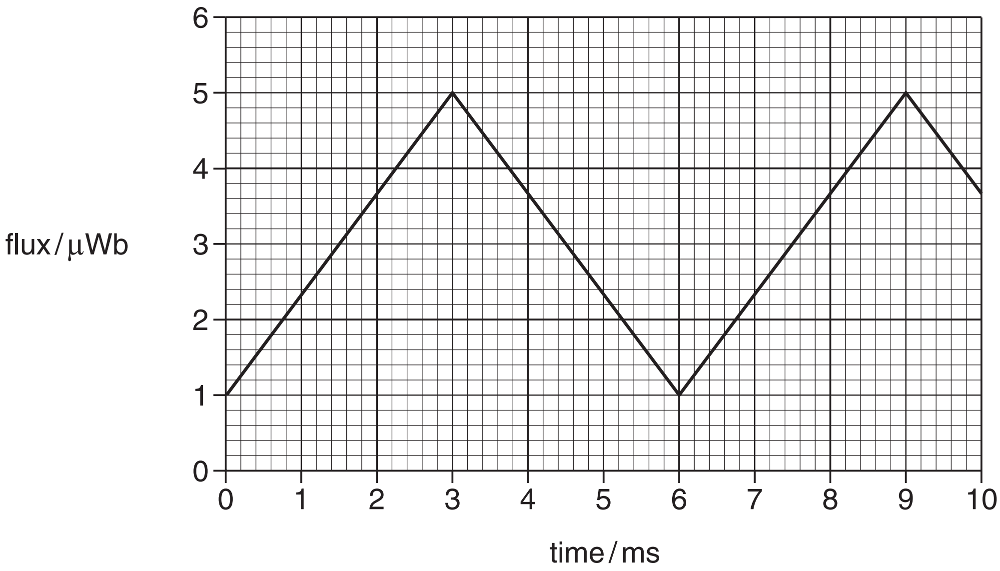


Fig. 2.1

The coil has 420 turns.

Calculate the maximum emf generated in the coil of wire.

emf = ... V **[2]**

3 What is the meaning of the quantity E in this relationship, and for what condition is it true?

$$E = k\frac{Q}{r^2}$$

[2]

4 Uranium-234 decays to thorium-230, emitting an alpha particle in the process.

Here are the masses of the particles involved.

particle	**nuclear mass / u**
alpha	4.00151
thorium-230	229.98373
uranium- 234	233.99045

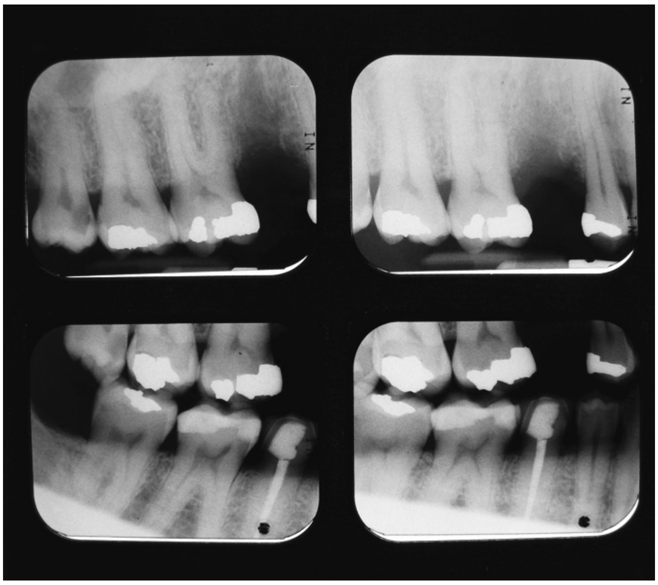
By comparing the rest energy of the particles, calculate the kinetic energy of the emitted alpha particle.

$u = 1.7 \times 10^{-27}\,\text{kg}$

$c = 3.0 \times 10^{8}\,\text{m s}^{-1}$

kinetic energy = ... J **[3]**

5 Dental X-ray images are useful for diagnosing problems with teeth.



X-ray radiation is ionising, so people who work with it are at risk of developing cancer. The maximum allowed dose equivalent for people who work with X-rays is 2.0×10^{-2} Sv per year. The risk of developing cancer is 3% Sv^{-1}.

(a) Calculate the risk to a worker in a dental surgery developing cancer over a 25 year period who is exposed to the maximum allowed dose equivalent.

risk = ... % **[1]**

(b) People who work in dental surgeries can reduce their dose equivalent by wearing lead-lined aprons. Suggest **two** other ways of reducing their dose equivalent.

[2]

6 A 6.0 MeV alpha particle enters a region of magnetic field.

(a) Show that the velocity of the alpha particle is about 2×10^7 m s^{-1}.

$e = 1.6 \times 10^{-19}$ C

$m_{alpha} = 6.6 \times 10^{-27}$ kg

[2]

(b) Calculate the force on the alpha particle as it passes at right angles to the magnetic field of strength 0.4 Wb m^{-2}.

$Q_{alpha} = 3.2 \times 10^{-19}$ C

force = ... N **[1]**

7 Fig. 7.1 represents the electric field around an electron.

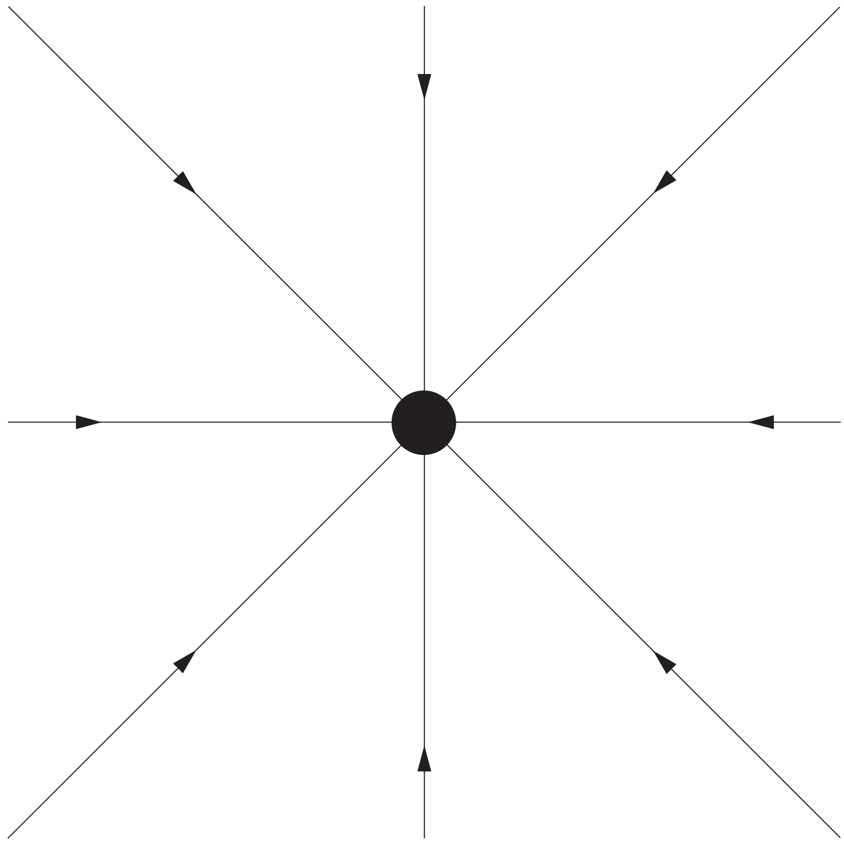


Fig. 7.1

(a) What feature of the diagram allows you to compare the strength of the electric field at two points in the field?

[1]

(b) On Fig. 7.1, sketch three equipotential loops at equal intervals of potential. **[2]**

8 The nuclear symbol for the isotope thorium-230 is $^{230}_{90}Th$.

Complete the table for a single atom of thorium-230 to show the number of each type of particle in one atom of $^{230}_{90}Th$.

type of particle	number
electron	
proton	
neutron	

[1]

9 Ionising radiation from radioactive substances damages living cells, increasing their risk of growing into cancer tumours. Specks of radioactive material which become lodged in the lungs are especially dangerous.

Why is the risk of developing cancer reduced if the speck in the lungs emits gamma photons instead of alpha or beta particles?

[1]

[Section A Total: 20]

Section B

In this section, four marks are available for the quality of written communication.

10 This question is about the permanent magnet motor shown in Fig. 10.1.

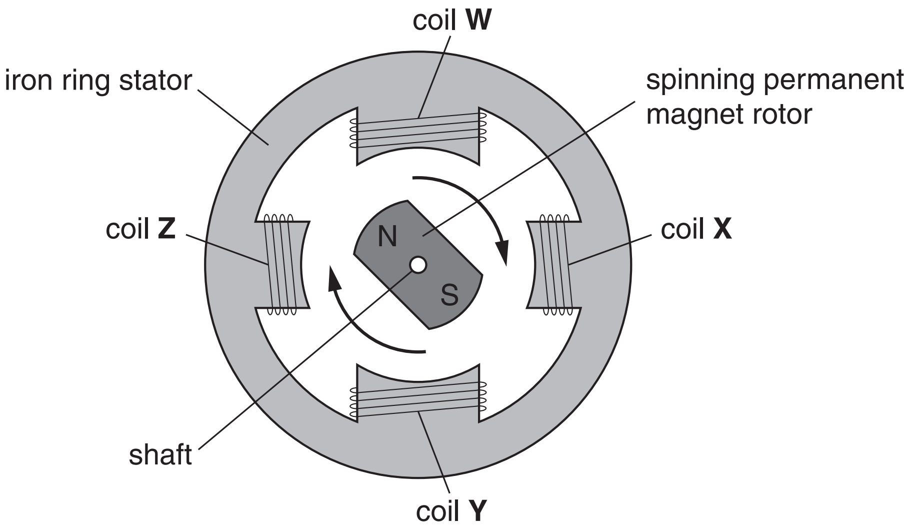


Fig. 10.1

Pulses of current in the four coils force the magnet to spin clockwise as shown in Fig. 10. 1. Only one pair of coils, at opposite sides of the iron ring, carry a current at any one time.

(a) (i) At the instant shown in Fig. 10.1, only coils **W** and **Y** carry a current.

On Fig. 10.1, sketch **two** loops of flux which pass through the magnet and the coils **W** and **Y**. **[2]**

(ii) Suggest why the flux loop patterns that you have drawn show that the magnet is being forced to turn clockwise.

[1]

(iii) The force on the rotor can be increased by increasing the current in the coils.

Suggest **three** other modifications to the motor of Fig. 10.1 which would increase the force turning the rotor.

[3]

(b) The graph of Fig. 10.2 shows the pulses of current in coils **W** and **Y**.

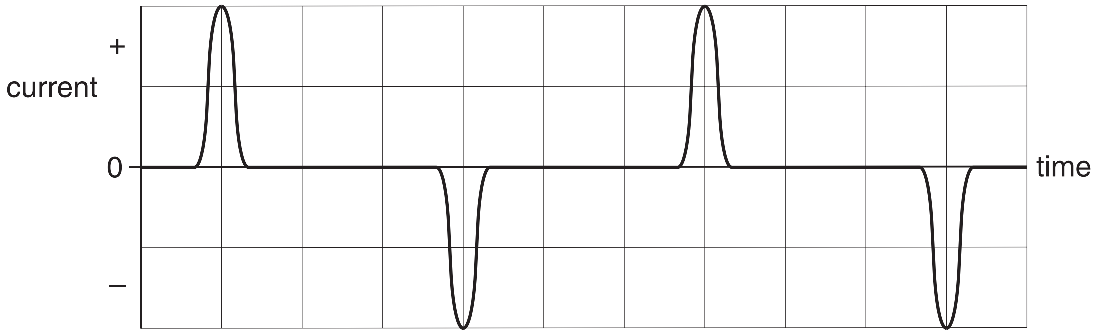


Fig. 10.2

(i) On Fig. 10.2, sketch the required pulses of current in coils **X** and **Z** to maintain the spinning motion of the magnet. **[1]**

(ii) The motor still works when the permanent magnet rotor is replaced by a rotor made from a non-magnetic metal, such as copper. Explain why the rotating magnetic field created by the pulses of current in the coils causes the copper rotor to spin.

[3]

[Total: 10]

11 This question is about the scattering of protons from atomic nuclei.

(a) A beam of high energy protons are fired at a very thin sheet of iron.

It is observed that

- most of the protons pass straight through the sheet
- a few protons are reflected back from the sheet.

In both cases, the protons lose very little energy.

State and explain what these observations suggest about the structure of an iron atom.

[4]

(b) Fig. 11.1 shows the path of a single proton which is deflected through an angle of 45° by the nucleus of an iron atom.

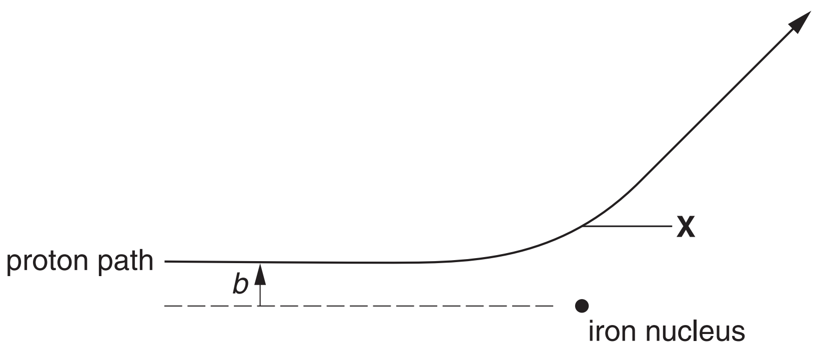


Fig. 11.1

(i) Draw an arrow on Fig. 11.1 to show the direction of the force on the proton when it is at the point marked **X**. **[1]**

(ii) The point **X** is 3.2×10^{-14} m from the centre of the nucleus.

Calculate the force on the proton when it is at **X**.

$k = 9.0 \times 10^{9}\,N\,m^{2}\,C^{-2}$
proton charge = 1.6×10^{-19} C
nucleus charge = 4.2×10^{-18} C

force = ... N **[3]**

(iii) The deflection of the proton is due to the component of the force at right angles to the direction of motion. On Fig. 11.2, sketch a graph to show how this component of the force changes as the proton moves along its path. **Z** indicates the point of closest approach to the nucleus. **[2]**

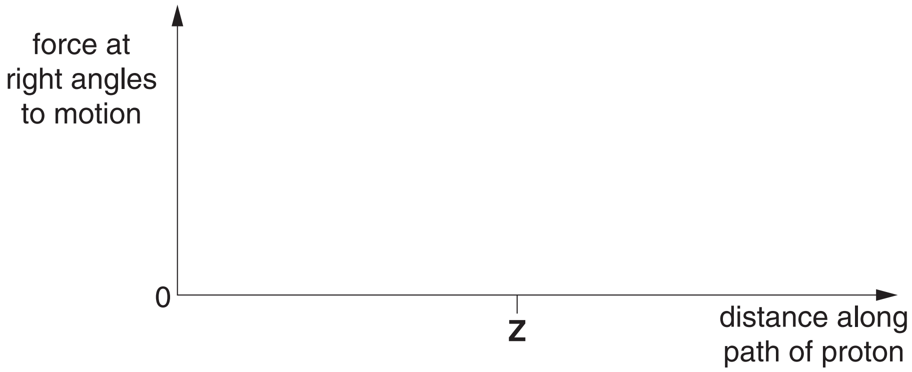


Fig. 11.2

(c) The proton is one of a large number in a beam, each of which approaches the nucleus with a different value of *b*, shown in Fig. 11.1.

On Fig. 11.3, sketch a graph to show how the angle of deflection depends on the value of *b*. **[2]**

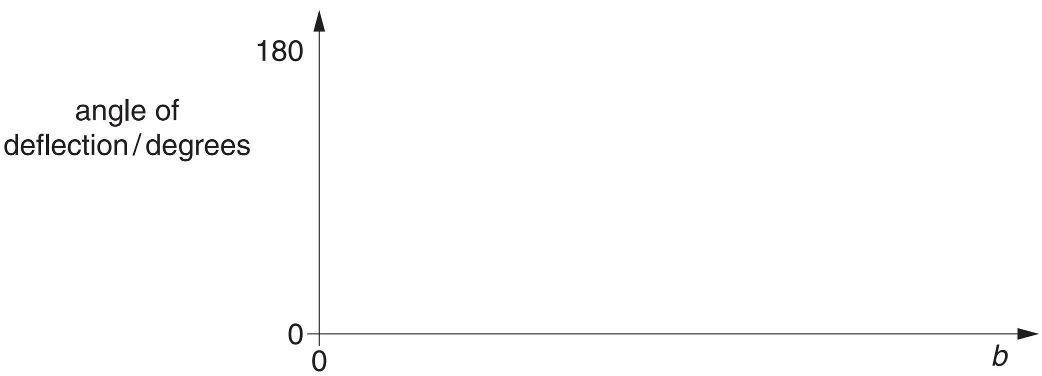


Fig. 11.3

[Total: 12]

12 Fig. 12.1 shows a pair of metal electrodes at either end of a glass tube filled with helium and neon gases to form a laser which emits a beam of photons.

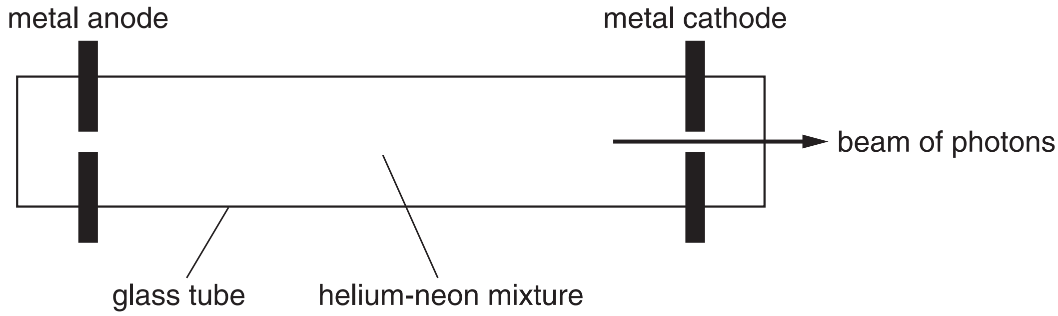


Fig. 12.1

(a) When an external power supply is connected, electrons are accelerated from the cathode to the anode by a uniform electric field. On Fig. 12.1, draw a pair of arrowed lines to represent that field. **[2]**

Fig. 12.2 shows some of the energy levels of electrons in helium and neon atoms.

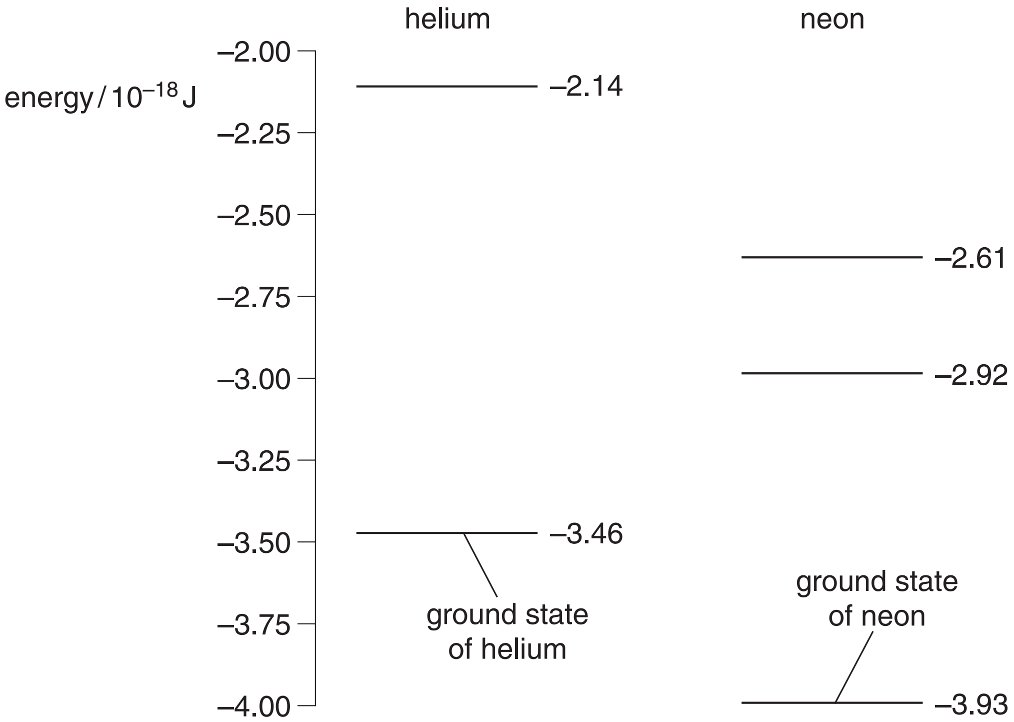


Fig. 12.2

(b) **(i)** Helium atoms can be raised from their ground state to the excited state at -2.14×10^{-18} J when they collide with the accelerated electrons.

Calculate the minimum kinetic energy of the electrons for this to happen.

kinetic energy = ... J **[1]**

(ii) Helium atoms usually stay in their excited state long enough for them to collide with a neon atom in its ground state. Show that this can raise the neon atoms to their excited state at -2.61×10^{-18} J.

[1]

(c) The helium-neon laser of Fig. 12.1 normally emits large numbers of identical photons in the red region of the spectrum, with a wavelength of 633 nm.

(i) Calculate the energy of these photons.

$h = 6.6 \times 10^{-34}$ J s

$c = 3.0 \times 10^{8}$ m s^{-1}

energy = ... J **[3]**

(ii) Draw an arrowed line on Fig. 12.2 to show the transition between the two energy levels which gives rise to these photons. **[1]**

(d) All of the energy levels shown in Fig. 12.2 are negative. This means that the electrons are bound and cannot escape from the attraction of the nucleus. Use the wave properties of electrons to explain why they can only have a few discrete values of energy rather than any value.

[3]

[Total: 11]

13 Isaac Newton spent many years trying, in vain, to turn mercury into gold.

The invention of the nuclear reactor has now made this possible. When one of the stable isotopes of mercury absorbs neutrons, the resulting nucleus quickly decays to a stable isotope of gold.

(a) A sample of mercury is placed in the core of a nuclear reactor.

It absorbs neutrons, subsequently emitting positrons to become gold.

(i) Complete these nuclear equations for the conversion of mercury-196 into gold-197.

$$^{196}_{\cdots\cdots}\text{Hg} \quad + \quad ^{\cdots\cdots}_{\cdots\cdots}\text{n} \quad \rightarrow \quad ^{197}_{80}\text{Hg}$$

$$^{197}_{80}\text{Hg} \quad \rightarrow \quad ^{197}_{\cdots\cdots}\text{Au} \quad + \quad ^{\cdots\cdots}_{1}\text{e} \quad + \quad ^{\cdots\cdots}_{\cdots\cdots}\nu$$

[3]

(ii) The second reaction produces a positron and a neutrino.

State why the reaction has to produce both particles.

[1]

(iii) Describe the processes in the core of a nuclear reactor which make it a good source of neutrons.

[3]

(b) This method of obtaining gold is not very practical. The production rate can be calculated from the measured activity of a sample of mercury placed in the core of a nuclear reactor for a known time.

Suppose that 2.4×10^{-3} kg of mercury is placed in the core of a nuclear reactor for eight minutes (480 s). Its measured activity is 17 kBq immediately after it has been withdrawn from the reactor core.

(i) Show that the activity requires about 6×10^{9} nuclei of mercury-197 in the final sample.

half-life of mercury-197 = 2.3×10^{5} s

[3]

(ii) Calculate the percentage of mercury atoms in the sample which eventually became gold atoms after spending eight minutes in the nuclear reactor.

1 $u = 1.7 \times 10^{-27}$ kg

percentage of atoms changed = ... % **[3]**

[Total: 13]

Quality of Written Communication **[4]**

[Section B Total: 50]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE