Physics
Intermediate 2

Radioactivity
Problem Practice
Sections A & B

Section A—Record Sheet

Section	Question	Answer 1	Answer 2	
Ionising Radiations	1			
	2			
	3			
	4			
	5			
	6			
	7			Score :
Dosimetry	8			
	9			
	10			
	11			
	12			
	13			Score :
Half Life & Safety	14			
	15			
	16			
	17			Score :
Nuclear Reactions	18			
	19			Score :

Section B—Record Sheet

Section	Question	Attempted	RED	AMBER	GREEN
Ionising Radiations	1				
	2				
Dosimetry	3				
Half Life & Safety	4				
	5				
	6				
	7				
Nuclear Reactions	8				
	9				
	10				
	11				
	12				
	13				

RED - I don't understand the question
I NEED HELP!

AMBER - I understand most of the question
I NEED TO REVISE A LITTLE MORE!

GREEN - I got the correct answer first time!!
I UNDERSTAND THIS TOPIC

Section A

Answer questions in your Homework Jotter.
Show working for each question.

1. An atom of helium consists of electrons, neutrons and protons.

The nucleus contains

A electrons only

B neutrons and electrons

C protons and electrons

D protons and neutrons

E protons, neutrons and electrons.

2. A student makes the following three statements.

I Alpha particles produce much greater ionisation density than beta particles or gamma rays.

II Alpha particles are fast moving electrons.

III Alpha particles can be stopped by a piece of paper.

Which of these statements is/are correct?

A I only

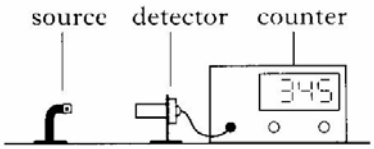
B II only

C III only

D I and III only

E I, II and III

3. Measurements of the count rate from a radioactive source were taken using the apparatus shown below.



A sheet of paper, 2 mm of aluminium and 15 mm of lead were placed in turn between the radioactive source and the detector.

Information about the count rate obtained with and without the absorbers is given in the following table.

Absorber	*Corrected count-rate* (counts per second)
none	80
1 sheet of paper	65
2 mm of aluminium	35
15 mm of lead	5

The radiation emitted by the source is

A α only

B β only

C α and β only

D β and γ only

E α, β and γ.

Section A

Answer questions in your Homework Jotter.
Show working for each question.

4. A student writes the following statements.

I Alpha radiation is part of the electromagnetic spectrum.

II Alpha radiation is more ionising than beta or gamma radiation.

III Alpha radiation is more penetrating than beta or gamma radiation.

Which of the statements is/are true?

A I only
B II only
C III only
D I and II only
E I and III only

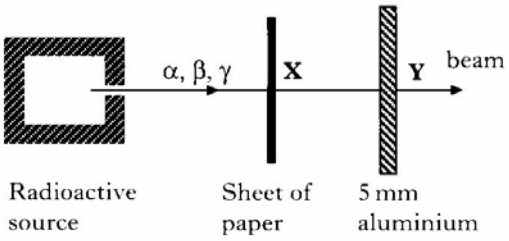
5. An alpha particle has

A the same mass as a helium nucleus, positive charge and is strongly ionising
B the same mass as an electron, negative charge and is weakly ionising
C the same mass as a helium nucleus, negative charge and is weakly ionising
D the same mass as an electron, negative charge and is strongly ionising
E the same mass as a helium nucleus, positive charge and is weakly ionising.

6. Which row correctly describes alpha, beta and gamma radiations?

	α	β	γ
A	electrons from the nucleus	helium nucleus	electro-magnetic radiation
B	electro-magnetic radiation	helium nucleus	electrons from the nucleus
C	helium nucleus	electro-magnetic radiation	electrons from the nucleus
D	helium nucleus	electrons from the nucleus	electro-magnetic radiation
E	electro-magnetic radiation	electrons from the nucleus	helium nucleus

7. A radioactive source emits α, β and γ radiations in a beam as shown.



The main radiation(s) in the beam at **X** and **Y** are

	Position **X**	*Position* **Y**
A	α and β	β
B	β and γ	β
C	α and γ	γ
D	α and β	α
E	β and γ	γ

Section A

Answer questions in your Homework Jotter.
Show working for each question.

8. The activity of a radioactive source is measured in

A joules

B becquerels

C sieverts

D grays

E watts.

9. Which row in the table below shows the correct units for activity and dose equivalent?

	Activity	*Dose equivalent*
A	becquerel	gray
B	becquerel	sievert
C	gray	sievert
D	gray	becquerel
E	sievert	gray

10. Measurements are made of the absorbed dose and dose equivalent received by workers in the nuclear industry. The relationship between absorbed dose and dose equivalent is

A $Q = DH$

B $D = HQ$

C $H = DQ$

D $H = \frac{Q}{D}$

E $H = \frac{D}{Q}$.

11. A patient's thyroid gland is exposed to radiation. Information about the radiation and the dose received by the gland is shown.

Absorbed dose = 500 μGy

Energy absorbed = 15 μJ

Quality factor = 20

The mass of the thyroid gland is

A 0·01 kg

B 0·03 kg

C 0·04 kg

D 0·33 kg

E 0·75 kg.

12. Which of the following increases the dose equivalent from a radioactive source?

A Increasing distance

B Handling with tongs

C Standing beside it for a long time

D Storing in a lead container

E Storing under water

13. A worker in a nuclear power station is accidentally exposed to 3·0 mGy of gamma radiation and 0·50 mGy of fast neutrons.

The radiation weighting factor for gamma radiation is 1 and for fast neutrons is 10.

The total equivalent dose received by the worker, in mSv, is

A 3·50

B 8·00

C 11·0

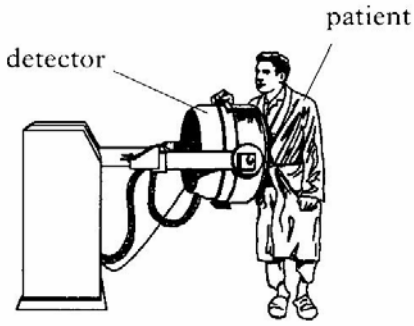
D 35·0

E 38·5.

Section A

Answer questions in your Homework Jotter.
Show working for each question.

14. A radioactive substance is to be injected into a patient so that blood flow can be monitored.



A number of different substances which emit either β or γ radiation are available.

The substances have different half-lives.

Which substance, A, B, C, D or E is the most suitable?

Substance	*Radiation emitted*	*Half-life*
A	β	2 days
B	β	2 years
C	γ	2 seconds
D	γ	2 days
E	γ	2 years

15. The activity of a sample of a radioactive substance is 80 Bq. The half-life of the substance is 4 hours.

The time for the activity to fall to 10 Bq is

A 4 hours

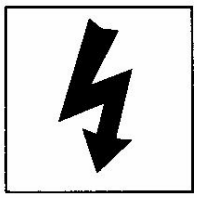
B 6 hours

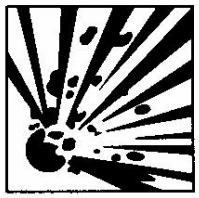
C 8 hours

D 12 hours

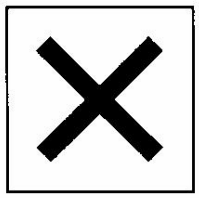
E 20 hours.

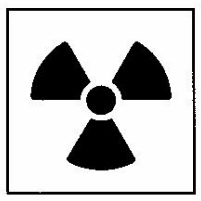
16. Which sign is used to indicate the presence of radioactive material?

A 

B 

C 

D 

E 

Section A

Answer questions in your Homework Jotter.
Show working for each question.

17. An alpha particle has

A the same mass as a helium nucleus, positive charge and is strongly ionising

B the same mass as an electron, negative charge and is weakly ionising

C the same mass as a helium nucleus, negative charge and is weakly ionising

D the same mass as an electron, negative charge and is strongly ionising

E the same mass as a helium nucleus, positive charge and is weakly ionising.

18. Which of the following increases the dose equivalent from a radioactive source?

A Increasing distance

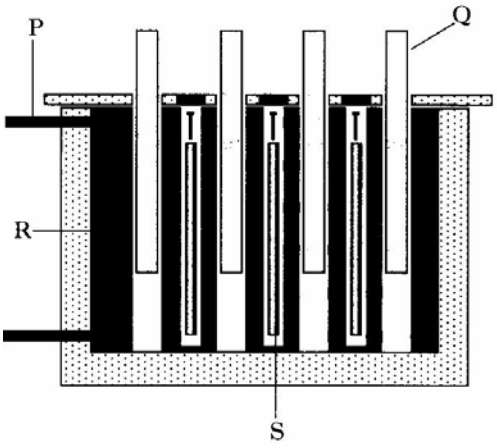
B Handling with tongs

C Standing beside it for a long time

D Storing in a lead container

E Storing under water

19. The diagram shows a nuclear reactor in a power station.



Which row shows the parts of the reactor?

	P	Q	R	S
A	moderator	fuel rod	coolant	control rod
B	control rod	moderator	coolant	fuel rod
C	moderator	control rod	coolant	fuel rod
D	coolant	control rod	moderator	fuel rod
E	coolant	fuel rod	moderator	control rod

Section B

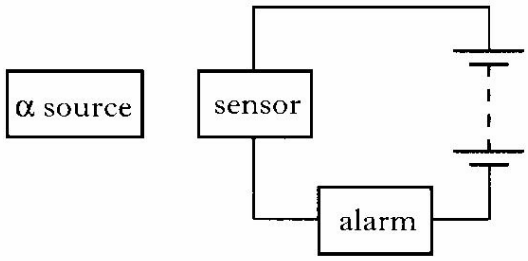
Answer questions in your Homework Jotter.
Show working for each question.

1. *Marks*

Some smoke alarms use a radioactive source which emits α-particles.

The detector operates because of ionisation caused by the α-particles in the space between the α source and the sensor.

If smoke or dust enters the space, the alarm operates.



(*a*) (i) What is an α-particle?

(ii) What is meant by "ionisation"?

(iii) Why is an α source used instead of a source which emits β-particles or γ-rays?

(iv) The smoke alarm manufacturer has to choose from three α emitting sources. The half-life of each source is shown in the table.

Source	*Half-life*
A	4 hours
B	4 weeks
C	400 years

Which source should the manufacturer choose?

Explain your answer. **5**

Section B

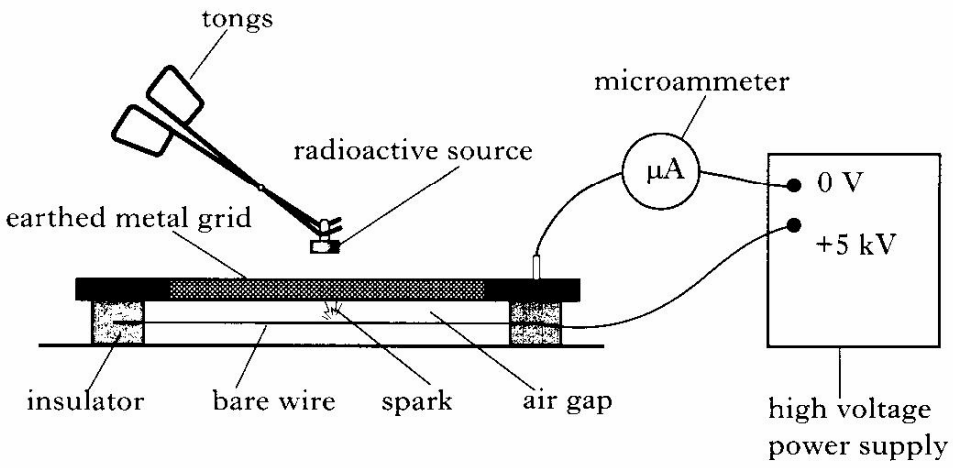
Answer questions in your Homework Jotter.

Show working for each question.

2. *Marks*

A spark counter consists of a thin bare wire at a high voltage, mounted on insulators beneath an earthed metal grid. There is an insulating air gap between the wire and the grid. The apparatus is connected to a sensitive microammeter and a high voltage supply as shown. The voltage of the supply is 5 kV.

When a student brings a radioactive source close to the spark counter, the air between the wire and grid is ionised and sparks jump between the wire and the grid.



(*a*) The radioactive source emits alpha particles and beta particles.

State what is meant by:

(i) an alpha particle; **1**

(ii) a beta particle. **1**

(*b*) The student finds that if the source is 3 cm from the grid, there is almost continuous sparking. When the distance is increased to 6 cm, there are very few sparks.

(i) Explain what is meant by *ionisation*. **1**

(ii) Which of the two types of radiation in (*a*) above is more effective at producing sparks? Explain your answer using the student's results. **2**

(*c*) The student now fixes the source 5 cm above the grid. Over a period of 1 minute, the student counts 87 sparks. During this period the average reading on the microammeter is 0·29 μA.

Calculate the average quantity of charge which is transferred from the wire to the grid by each spark. **3**

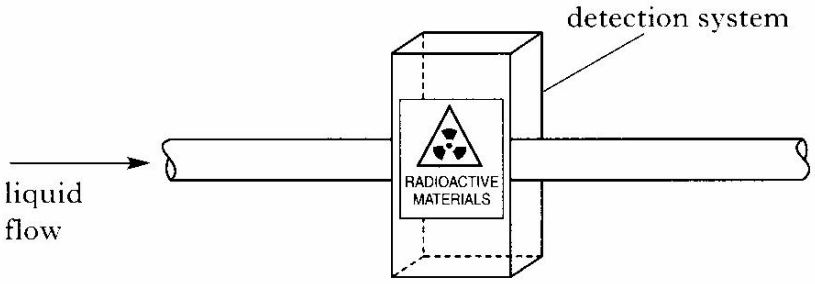
(8)

Section B

Answer questions in your Homework Jotter.
Show working for each question.

3. *Marks*

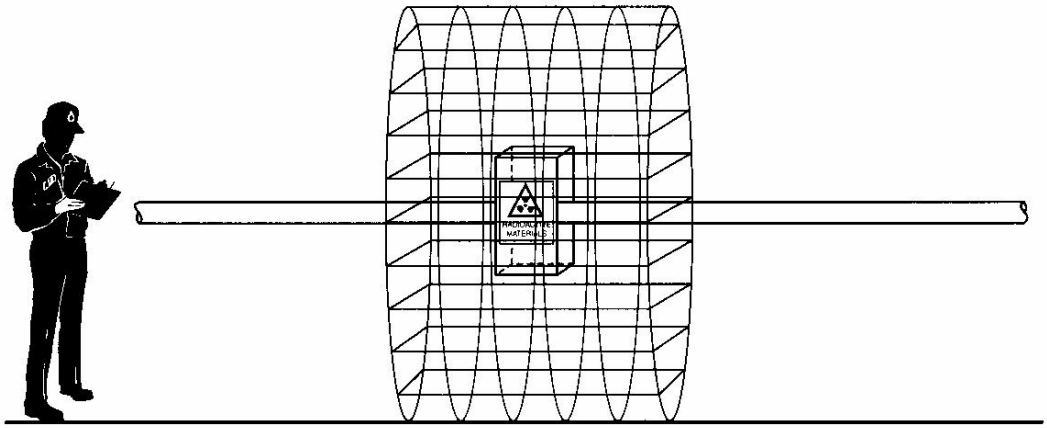
The oil industry uses radioactive sources to monitor the flow of liquids in pipes. The complete detection system is attached to the outside of the pipe as shown.



(*a*) The source used has an activity of 1·11 GBq.
Explain what is meant by this statement. **2**

(*b*) A sample of tissue exposed to this radiation receives an absorbed dose of 0·13 mGy.
The quality factor of the radiation is 9. Calculate the dose equivalent for this sample. **2**

(*c*) The system is surrounded by a large cage as shown in the diagram.



What is the purpose of this cage? **2**

(6)

Section B

Answer questions in your Homework Jotter.
Show working for each question.

4. The following table contains information about two radioactive sources used in medicine.

Radioactive source	*Activity* (MBq)	*Half-life* (days)
R	1600	8
S	80	74

(*a*) Calculate the number of decays of source R in 30 s. **2**

(*b*) These radioactive sources can be disposed of after their activity has fallen below 40 MBq.

Show, by calculation, which source, R or S, will be the first to reach an activity of 40 MBq. **3**

(*c*) State **two** safety precautions which should be taken when handling radioactive sources. **2**

(7)

Section B

Answer questions in your Homework Jotter.
Show working for each question.

5. *Marks*

Companies delivering radioactive sources have to follow strict safety rules. One rule is that sources must be labelled. The following information is displayed on a label on a radioactive source.

RADIOACTIVE SOURCE	
Source:	beta and gamma emitter
Year of delivery:	2003
Half life:	10 years
Activity:	20 000 Bq

(*a*) (i) What is meant by the activity of a source? **1**

(ii) Calculate the activity of the source in year 2043. **2**

(*b*) After delivery, the source is placed in a thick walled aluminium storage box. Which type of radiation from the source, if either, could penetrate the storage box? You must explain your answer. **2**

(*c*) A technician handling an **alpha-emitting** source estimates that his hand receives an absorbed dose of 5×10^{-5} Gy. The mass of the technician's hand is 500 g.

(i) Calculate the total energy absorbed by the technician's hand. **2**

(ii) Using information from the table below, calculate the dose equivalent received by his hand.

Type of radiation	*Quality factor*
Alpha	20
Beta	1
Gamma	1
X rays	1
Slow neutrons	2·3

2

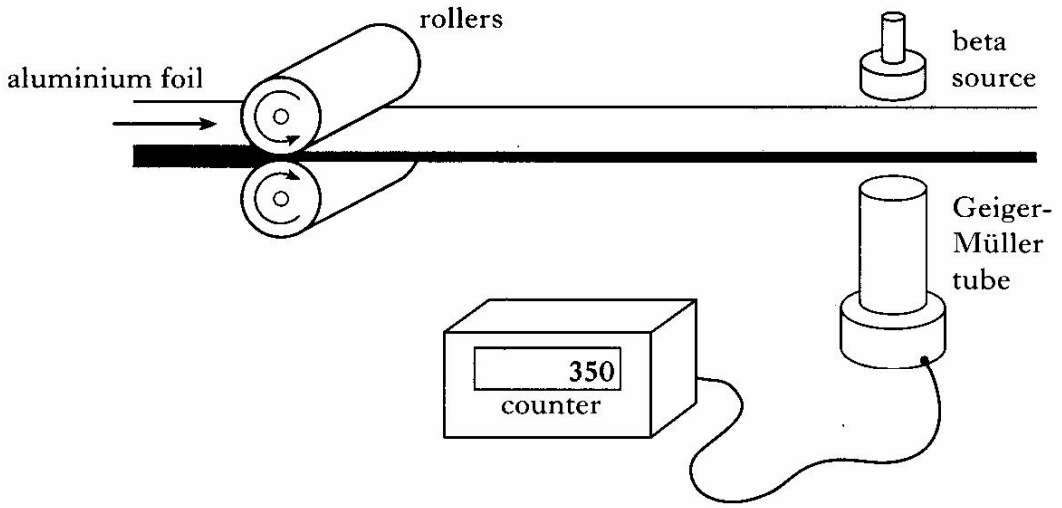
(9)

Section B

Answer questions in your Homework Jotter.
Show working for each question.

Marks

6. A roller mill produces thin sheets of aluminium foil. The thickness of the foil is checked using a source of beta radiation, a Geiger-Müller tube and a counter as shown below.



(*a*) What happens to the count rate when the thickness of the foil increases? **1**

(*b*) Why is an alpha source **not** suitable for this system? **1**

(*c*) Radioactive sources give off radiations that cause ionisation.

(i) What is meant by *ionisation*? **1**

(ii) Give **two** precautions that should be taken when handling radioactive sources. **2**

(5)

Section B
Answer questions in your Homework Jotter.
Show working for each question.

Marks

7. The table shows properties of some isotopes of the element iodine.

Isotope	*Radiation emitted*	*Half-life*
Iodine-127	none	–
Iodine-128	beta	25 minutes
Iodine-129	beta	16 million years
Iodine-131	beta	8·1 days
Iodine-135	beta	6·7 hours

(*a*) Explain what is meant by the term *half-life*. **1**

(*b*) The activity of a sample of iodine-131 is 56·0 MBq.

How long will it take for its activity to reach 1·75 MBq? **2**

(*c*) A patient suffers from cancer of the thyroid gland. This cancer is treated with an injection of a radioactive iodine isotope, which becomes concentrated in the thyroid gland. The thyroid receives a large dose of radiation for several hours, but surrounding tissues receive much less. Next day, when the activity of the isotope has decreased to a safe level, the patient can return home.

Which of the above isotopes would be the most suitable to treat the patient?

Explain your answer. **2**

(*d*) Iodine is a necessary mineral in the diet. Some people do not receive sufficient iodine in their diet to remain healthy.

Which of the above iodine isotopes should be given to such people to supplement their diet?

Explain your answer. **2**

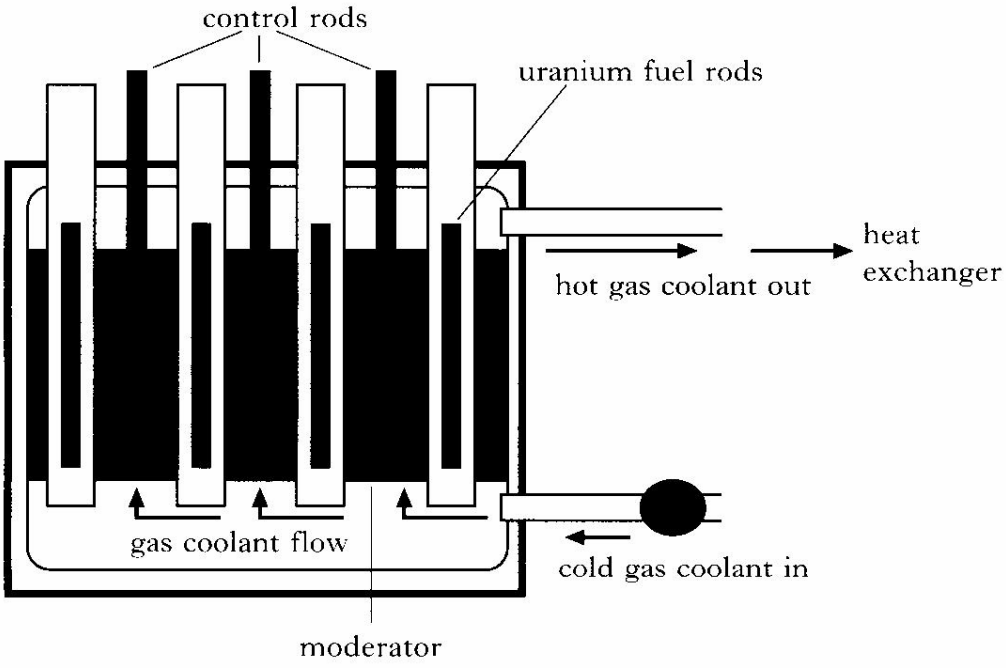
(7)

Section B

Answer questions in your Homework Jotter.
Show working for each question.

8. *Marks*

A drawing of the core of a nuclear reactor is shown below.



The fuel rods contain uranium-235.

(*a*) Describe what happens when a slow (thermal) neutron is absorbed by the nucleus of an atom of uranium-235. **2**

(*b*) The control rods are raised out of the core slightly.
Explain the effect of this action on the temperature of the coolant gas leaving the core of the reactor. **3**

(*c*) A research scientist at a nuclear reactor has a mass of 70·0 kg.
The scientist receives a dose equivalent of 336 μSv due to slow neutrons.
The energy absorbed by the scientist from the neutrons is $8{\cdot}40 \times 10^{-3}$ J.
Calculate the quality factor for slow neutrons. **3**

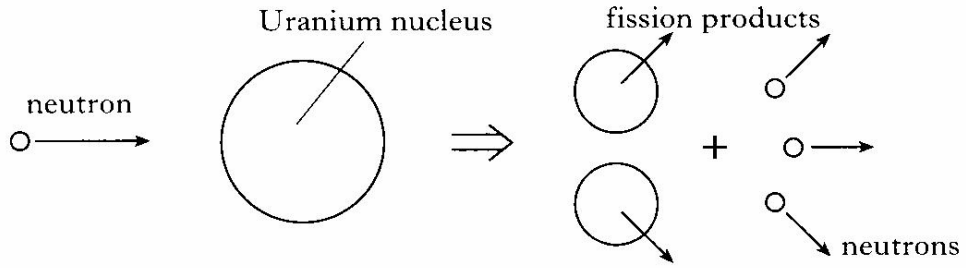
(8)

Section B

Answer questions in your Homework Jotter.
Show working for each question.

9. *Marks*

In a nuclear reactor, uranium nuclei are bombarded by neutrons. Fission products and additional neutrons are produced. Energy is also released.



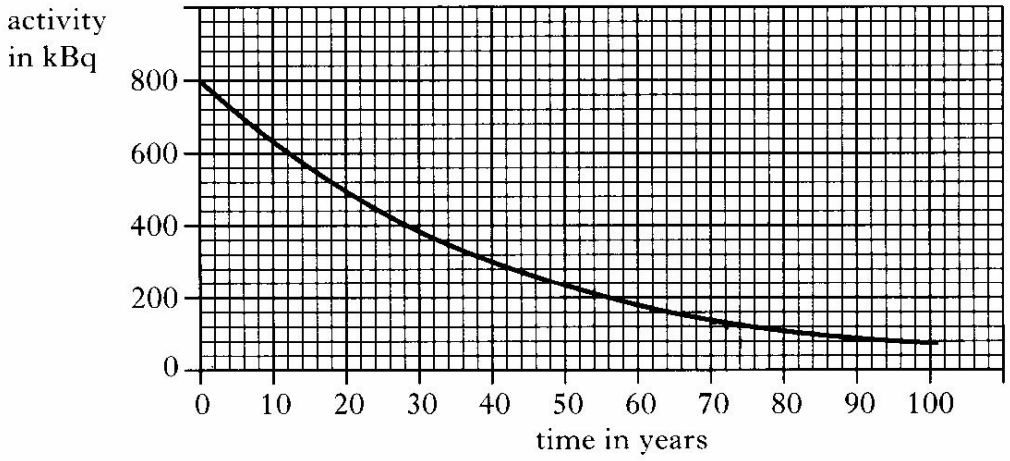
(*a*) In a reactor, what is the purpose of

(i) the coolant? **1**

(ii) the moderator? **1**

(*b*) Explain how the additional neutrons can cause a chain reaction. **2**

(*c*) A graph of activity against time for a sample of one of the fission products is shown below.



(i) From the graph, determine the half life of the fission product. **2**

(ii) A scientist states that the sample will be safe only when the activity falls to 120 kBq. How long will it take for the activity to fall to this level? **1**

(iii) State a suitable method of storing the sample during the time it takes for the activity to fall to the safe level. **1**

(8)

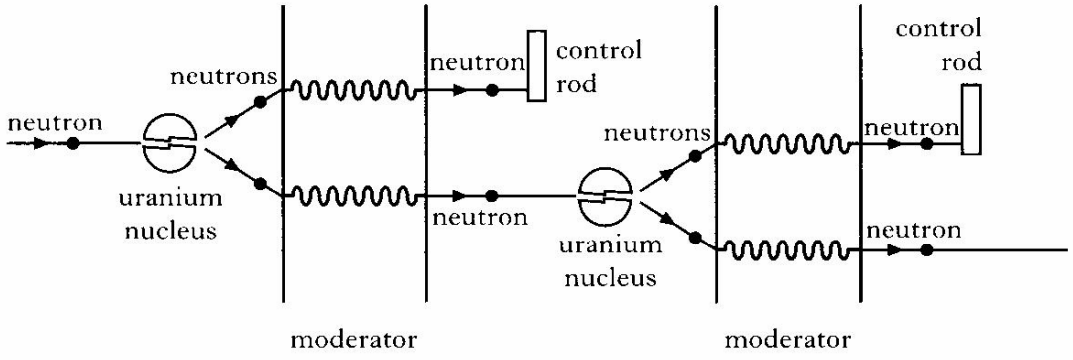
Section B

Answer questions in your Homework Jotter.
Show working for each question.

10. *Marks*

A simplified model of a controlled chain reaction in a nuclear reactor is shown below.

Controlled Chain Reaction



(*a*) (i) Name the type of nuclear reaction that takes place in the reactor. **1**

(ii) State the purpose of the moderator. **1**

(iii) How could the chain reaction process be stopped? **1**

(*b*) State **one advantage** and **one disadvantage** of using nuclear power for the generation of electricity. **2**

(5)

Section B

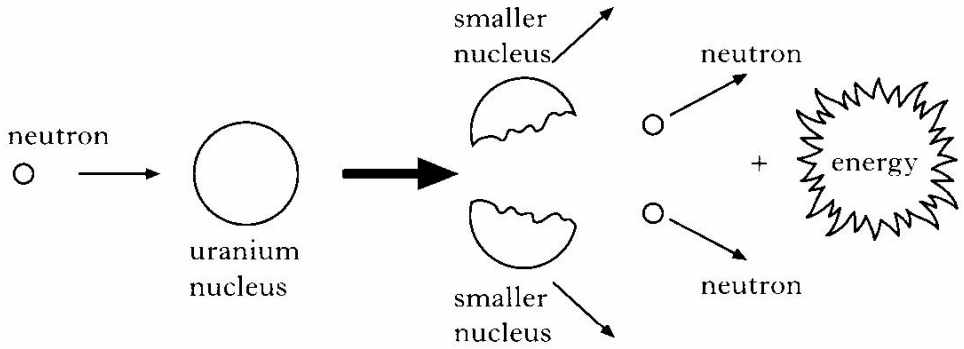
Answer questions in your Homework Jotter.

Show working for each question.

Marks

11. A student reads the following article about nuclear power.

"In a nuclear reactor, uranium nuclei in fuel rods are bombarded with neutrons. A uranium nucleus may absorb a neutron and then break up into two smaller nuclei releasing further neutrons and energy."



(*a*) (i) A **nucleus** contains 2 types of particle. Name these particles. **1**

(ii) What is the name given to the process shown in the diagram? **1**

(iii) Explain why fuel rods have to be replaced after a certain time. **1**

(iv) Explain why the fuel rods that are removed from the reactor are a safety hazard. **1**

(*b*) In a nuclear reactor, 166 MJ of energy is transferred to 2000 kg of coolant. All of this energy is absorbed by the coolant which has a specific heat capacity of 830 J/kg °C. Assuming the coolant does not change state, calculate the rise in temperature of the coolant. **2**

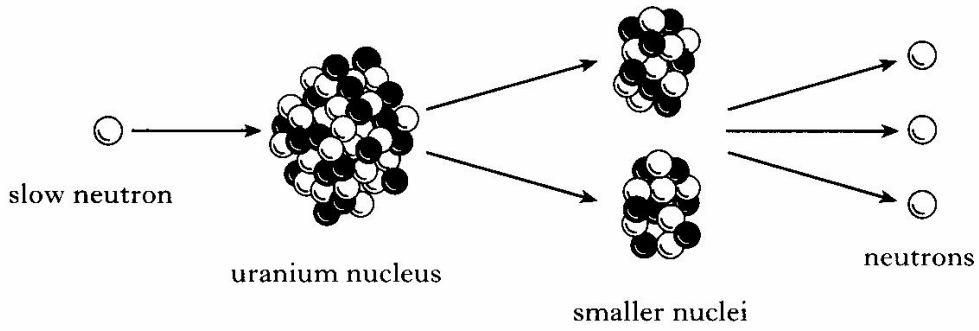
(6)

Section B

Answer questions in your Homework Jotter.
Show working for each question.

12. *Marks*

In the reactor of a nuclear power station a uranium nucleus is bombarded by a slow neutron as shown below.



(*a*) State the name of this type of nuclear reaction. **1**

(*b*) In this reaction neutrons are released.

Why are these neutrons important to the operation of the reactor? **1**

(*c*) The reactor also contains boron control rods.

Explain the purpose of these rods. **1**

(*d*) A worker in the power station is exposed to the following absorbed doses.

2·0 mGy of slow neutrons
5·0 μGy of fast neutrons

The table below gives quality factors of various types of radiations.

Radiation	*Quality factor*
X-rays	1
gamma rays	1
slow neutrons	3
fast neutrons	10
alpha particles	20

Calculate the total dose equivalent received by the worker. **3**

(*e*) (i) State **one** advantage of using nuclear power for the generation of electricity. **1**

(ii) State **one** disadvantage of using nuclear power for the generation of electricity. **1**

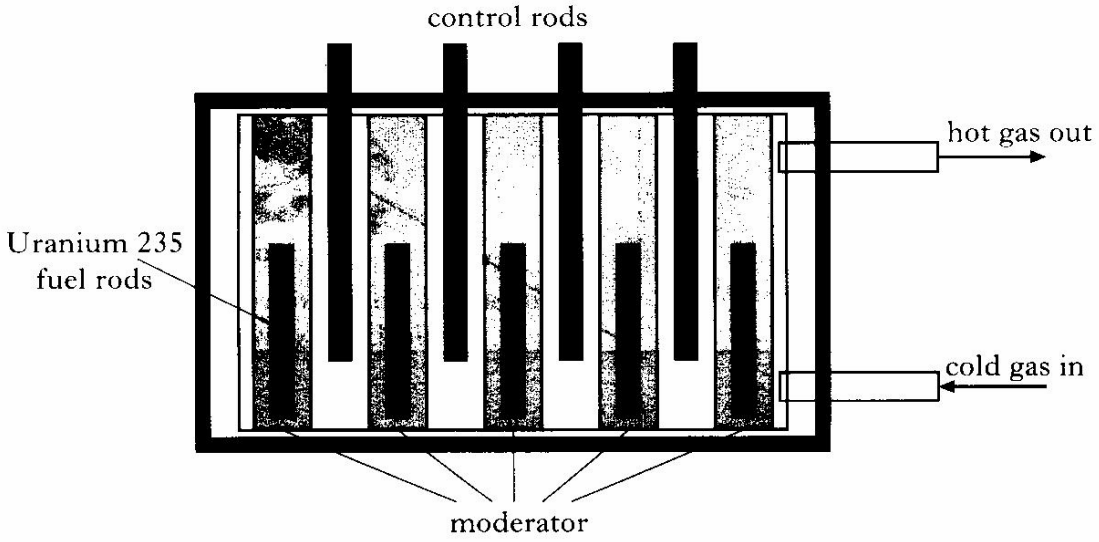
(8)

Section B

Answer questions in your Homework Jotter.
Show working for each question.

13. *Marks*

A diagram of the core of a gas cooled nuclear reactor is shown below.



(*a*) Explain the purpose of

(i) the moderator **1**

(ii) the control rods. **1**

(*b*) One of the waste products produced in the nuclear reactor is caesium.

The caesium in the waste products removed from the reactor has an activity of 16×10^{12} Bq.

Caesium has a half-life of 30 years.

(i) State what is meant by the activity of a radioactive source. **1**

(ii) State what is meant by the half-life of a radioactive source. **1**

(iii) Calculate the activity of the caesium 150 years after its removal from the reactor. **2**

(*c*) A worker at the nuclear power station has a mass of 90 kg and receives a dose equivalent of 276 μSv from slow neutrons. The quality factor for slow neutrons is 2·3.

(i) What does the quality factor tell us about a radiation? **1**

(ii) How much energy has the worker absorbed from the slow neutrons? **3**

(10)