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EDEXCEL INTERNATIONAL GCSE PHYSICS: QUESTIONS BY TOPIC

Radioactivity and Particles (7)

IGCSE Physics Topic 7

31 questions · 278 marks · Mark schemes included

Pearson Edexcel International GCSE (9-1) Physics 4PH1, Papers 1P/1PR & 2P/2PR, 2019-2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

31 questions · 278 marks · 4 sub-topics



SUB-TOPIC 7.1

ATOMIC STRUCTURE, ISOTOPES AND TYPES OF RADIATION

Sub-topic 7.1 · 8 questions · 73 marks · lowest tariff first



2 This question is about radioactivity.

(a) The nucleus of an atom of carbon has 6 protons and 8 neutrons.

Which row of the table shows the nucleus of an atom that is a different isotope of carbon?

(1)

	Number of protons	Number of neutrons
☐ A	6	6
☐ B	6	8
☐ C	8	6
☐ D	8	8

(b) Which type of radiation is a high-energy electron?

(1)

- ☐ A alpha
- ☐ B beta
- ☐ C gamma
- ☐ D neutron

(c) A nucleus emits radiation. This causes the mass number to decrease by one. The atomic number stays the same.

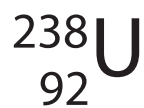
Which type of radiation does the nucleus emit?

(1)

- ☐ A alpha
- ☐ B beta
- ☐ C gamma
- ☐ D neutron



(d) The nucleus of an isotope of uranium can be represented using this symbol.



The nucleus forms part of a positively charged ion.

How many electrons could be in this ion?

(1)

- ☐ **A** 90
- ☐ **B** 92
- ☐ **C** 146
- ☐ **D** 238

(e) A radioactive isotope has an initial activity of 400 Bq.

The half-life of the isotope is 8 hours.

What is the activity of the isotope after 16 hours?

(1)

- ☐ **A** 25 Bq
- ☐ **B** 50 Bq
- ☐ **C** 100 Bq
- ☐ **D** 200 Bq

(Total for Question 2 = 5 marks)

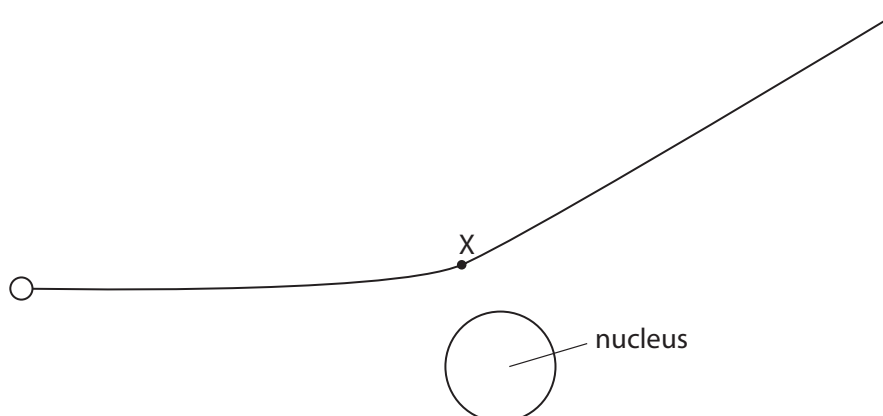


4 This is a question about alpha particles.

(a) Describe the nature of an alpha particle.

(1)

(b) The diagram shows the path of an alpha particle as it passes close to a nucleus.



(i) Draw an arrow from point X to show the force on the alpha particle due to the nucleus.
Label this force Y.

(2)

(ii) Draw an arrow to show the force on the nucleus due to the alpha particle.
Label this force Z.

(2)

(iii) Explain how the path of the alpha particle shows whether the nucleus is positive, negative or neutral.

(3)

(c) The alpha particle experiences a resultant force of 3.6 N and has a mass of 6.6×10^{-27} kg.

Calculate the acceleration of the alpha particle.

(3)

acceleration = ... m/s²

(Total for Question 4 = 11 marks)



9 A teacher investigates the penetrating ability of the gamma rays from a gamma source.

This is the teacher's method.

- place the gamma source at a distance of 25 cm from a radiation detector
- place a 1 cm thick absorbing material between the source and the detector
- measure the radiation count from the source for a time period of 3 s
- calculate the count rate in counts per second
- repeat the measurement two more times

The teacher repeats this method for different absorbing materials.

(a) Name a suitable radiation detector that the teacher could use.

(1)

(b) State the independent variable in the teacher's investigation.

(1)

(c) Explain why every absorbing material used in the investigation has a thickness of 1 cm.

(2)

(d) Suggest one improvement the teacher could make to this method.

(1)

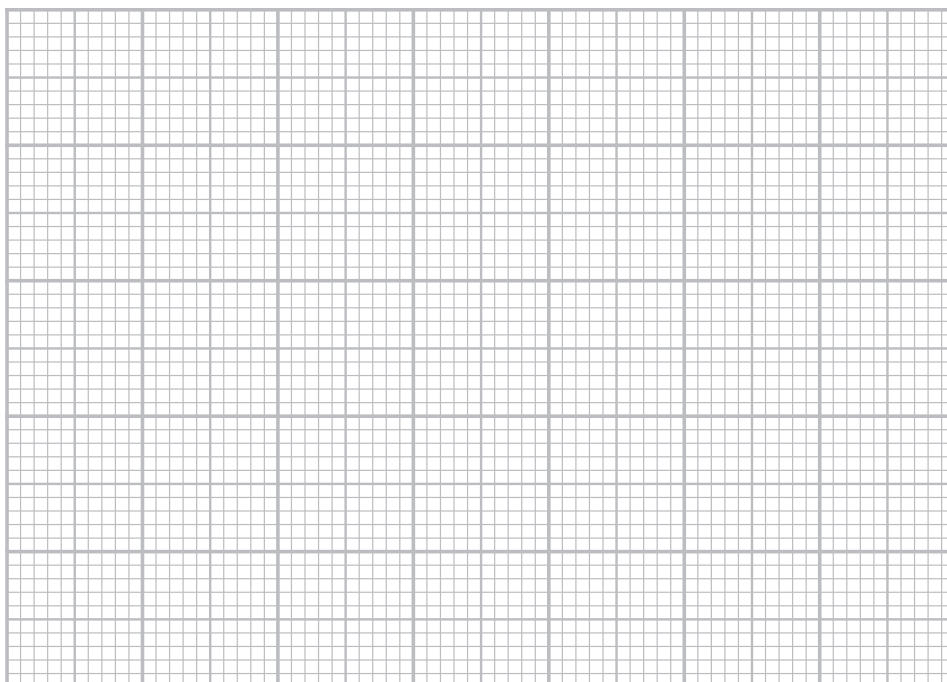


(e) The table shows the teacher's results for seven different absorbing materials.

Absorbing material	Count rate in counts per second			
	Test 1	Test 2	Test 3	Mean
plastic	248	230	226	235
copper	138	127	147	137
wood	226	231	224	227
aluminium	204	211	190	202
lead	96	102	92	97
glass	204	192	190	195
stone	205	200	205	203

(i) On the grid, plot a bar chart of the mean count rate for each absorbing material.

(3)



(ii) Why is a bar chart the correct way to display the results?

(1)

- ☐ **A** absorbing material is a continuous variable
- ☐ **B** absorbing material is not a continuous variable
- ☐ **C** count rate is a continuous variable
- ☐ **D** count rate is not a continuous variable

(iii) A student concludes that plastic is the best absorber of gamma radiation because plastic gives the largest mean count rate.

Evaluate the student's conclusion.

(2)

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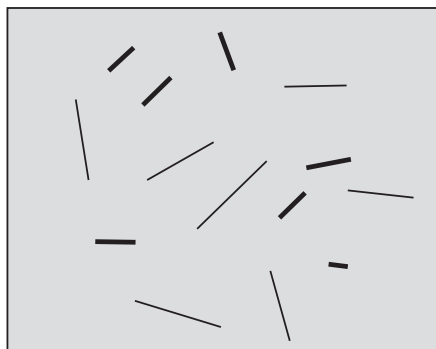
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(Total for Question 9 = 11 marks)



- 7 (a) The diagram shows tracks produced by radiation in a device called a cloud chamber.

The tracks are formed when particles ionise the material in the cloud chamber.



Alpha particles produce the shorter, thicker tracks.

Beta particles produce the longer, thinner tracks.

Explain why alpha particles produce the shorter, thicker tracks.

(2)

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- (b) Uranium-235 is an isotope of uranium that can decay by emitting an alpha particle.

(i) Describe what is meant by the term **isotope**.

(2)

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(ii) Complete the equation for the decay of uranium-235

(2)



(iii) Uranium-235 decays to thorium-231 with a half-life of 700 million years.

When a rock was formed, it contained 6400 million uranium-235 nuclei and no thorium-231 nuclei.

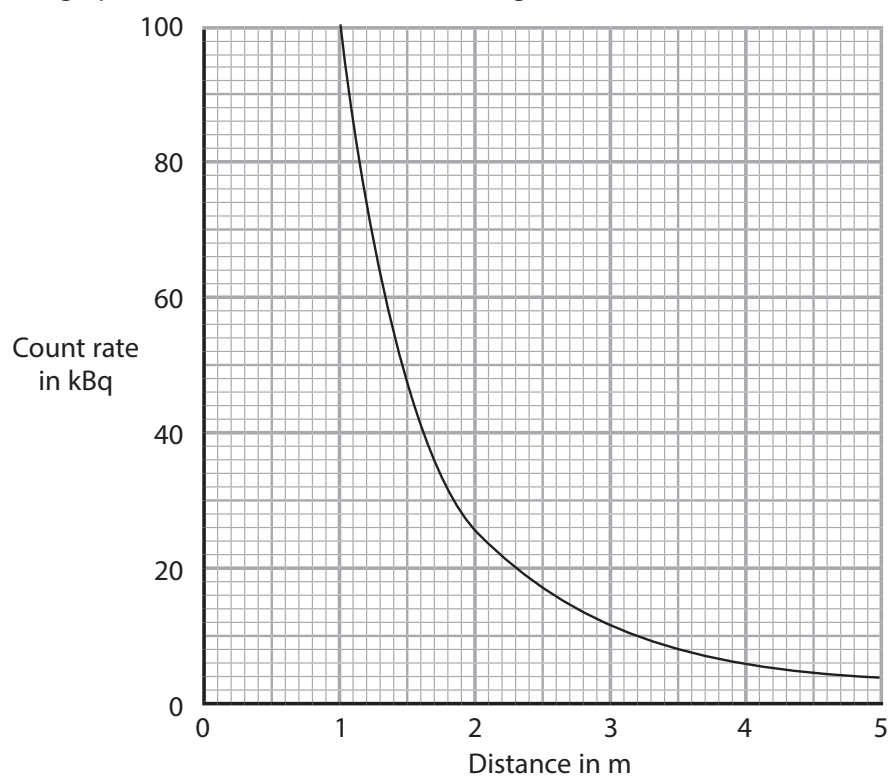
Show that after 2100 million years there are seven times more thorium nuclei than uranium nuclei in the rock.

(5)

(Total for Question 7 = 11 marks)



- (c) A scientist measures the count rate at different distances from the technetium source.
The graph shows how the count rate changes with distance from the technetium source.



The scientist suggests that the relationship between the count rate and distance is

$$(\text{distance})^2 \times \text{count rate} = \text{constant}$$

Use data from the graph to determine whether these results support this relationship.

(4)

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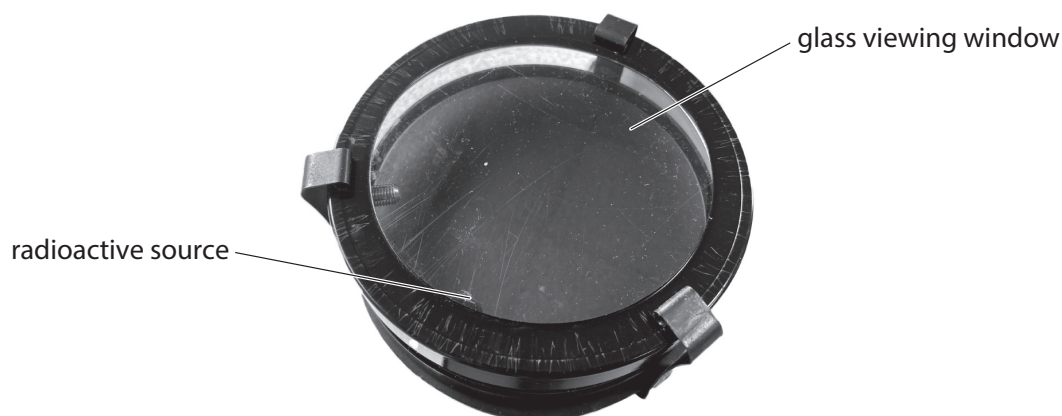
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(Total for Question 10 = 13 marks)



- 5 The photograph shows a cloud chamber, used to observe alpha radiation produced by a radioactive source. The radioactive source is inside the cloud chamber, as shown in the photograph.



- (a) Describe the structure of an alpha particle.

(2)

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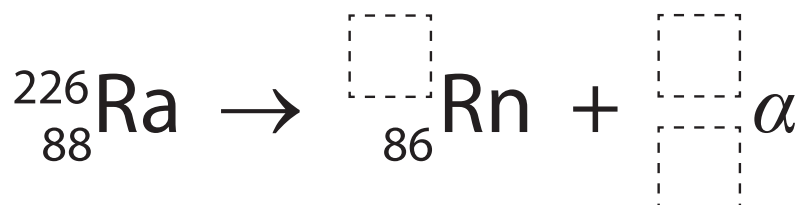
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- (b) The source used in the cloud chamber contains the isotope radium-226.

The incomplete nuclear equation shows the decay of radium-226 into an isotope of radon.

Complete the nuclear equation by writing the correct numbers in the boxes.

(3)



(c) The tracks in the cloud chamber can be seen through the glass viewing window.

Explain why the radioactive source is not a hazard to the person viewing the cloud chamber.

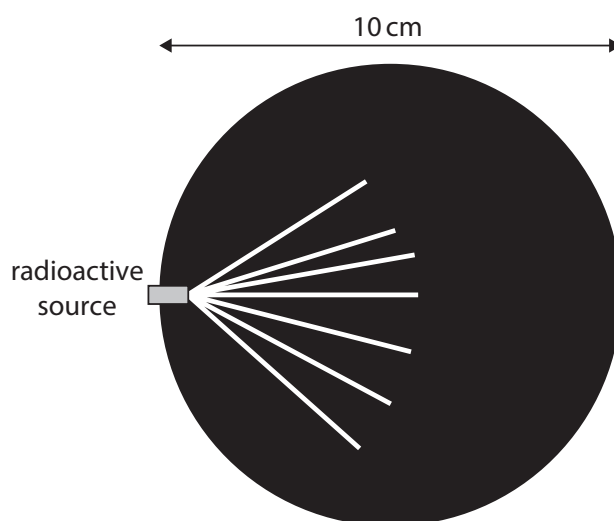
(2)



- (d) When radiation is emitted from the source a white line is produced in the cloud chamber. The white line is known as a track.

The diagram shows the tracks produced by the radiation from the source.

The diameter of the cloud chamber is also shown.



Explain the properties of alpha radiation that can be deduced from the length of the tracks.

(3)

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(Total for Question 5 = 10 marks)

6 This question is about gamma radiation.

(a) Which of these statements is correct for gamma radiation?

(1)

- ☐ **A** gamma radiation has a weaker penetrating ability than alpha radiation
- ☐ **B** gamma radiation is emitted by electrons in atoms
- ☐ **C** gamma radiation is positively charged
- ☐ **D** gamma radiation is less ionising than alpha radiation

(b) A student uses a simulation to investigate gamma radiation.

This is the student's method.

- place a Geiger-Muller (GM) tube a distance of 6 cm from a source of gamma radiation
- measure the count for a time of 10 seconds
- move the GM tube further away from the source and measure the count again.

The student measures the count three times for each distance.

(i) Give a reason why the student takes repeat readings.

(1)

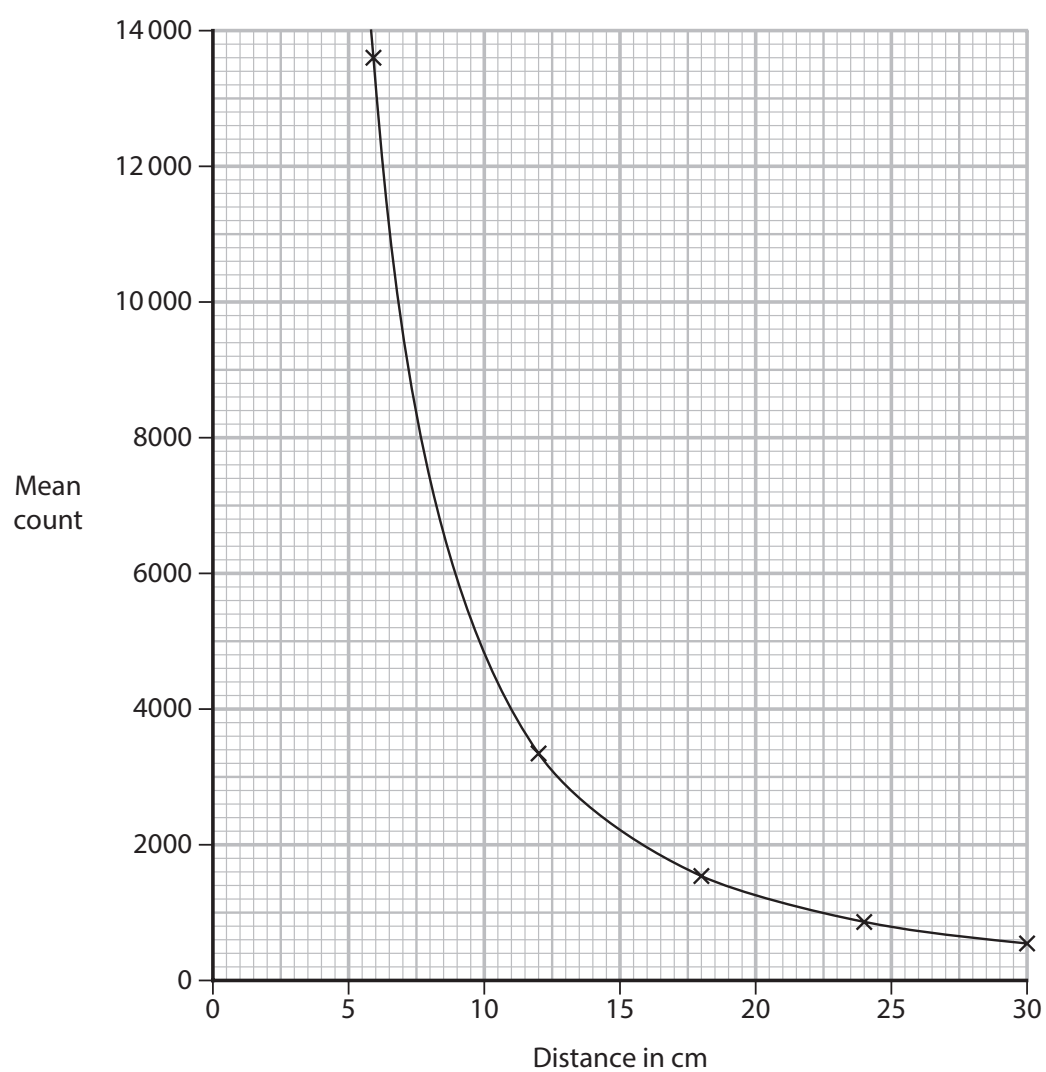
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(ii) The graph shows the student's results.



The student claims that the data obeys the formula

$$\text{count} \times \text{distance}^2 = \text{constant}$$

Evaluate the student's claim.

(3)

(Total for Question 6 = 5 marks)



(c) Uranium-239 is radioactive and decays by beta emission.

Uranium-239 has a half-life of 23 minutes.

(i) A sample of uranium-239 has an initial mass of 60 g.

Calculate the mass of uranium-239 remaining after 46 minutes.

(2)

mass = ... g

(ii) When uranium-239 undergoes beta decay, an isotope of the element neptunium, Np, is produced.

Which of these is the correct symbol for the neptunium nucleus produced in the beta decay of uranium-239?

(1)

☐ **A** ${}^{239}_{92}\text{Np}$

☐ **B** ${}^{240}_{92}\text{Np}$

☐ **C** ${}^{239}_{93}\text{Np}$

☐ **D** ${}^{240}_{93}\text{Np}$

(Total for Question 2 = 7 marks)

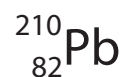
SUB-TOPIC 7.2

RADIOACTIVE DECAY, ACTIVITY AND HALF-LIFE

Sub-topic 7.2 · 8 questions · 79 marks · lowest tariff first



- 3 Lead-210 is a radioactive isotope of lead and is represented using this symbol.



- (a) State what is meant by the term **isotope**.

(2)

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- (b) How many protons are in the nucleus of lead-210?

(1)

- ☐ A 82
- ☐ B 128
- ☐ C 210
- ☐ D 292

- (c) (i) A sample of lead-210 has an initial activity of 240 Bq.

After 66 years, the activity of the sample is 30 Bq.

Calculate the half-life of lead-210.

(2)

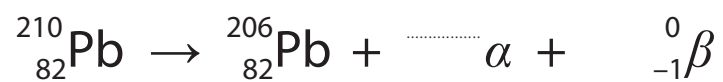
half-life = ... years



(ii) Lead-210 decays into lead-206 through a number of stages.

This involves one alpha decay and a number of beta decays.

This incomplete equation summarises these stages.



Complete the equation by giving the missing numbers.

Write your answers in the spaces provided.

(2)

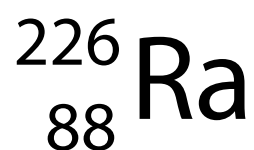
(Total for Question 3 = 7 marks)

5 A teacher uses a radioactive source containing atoms of the isotope radium-226.

- (a) Give a safety precaution that would reduce the teacher's exposure to radiation when working with the radioactive source.

(1)

- (b) Radium-226 can be represented using the symbol



How many neutrons are in the nucleus of an atom of radium-226?

(1)

- ☐ A 88
- ☐ B 138
- ☐ C 226
- ☐ D 314

- (c) The teacher investigates the type of radiation emitted from the radioactive source.

- (i) Give the name of a piece of apparatus that detects ionising radiation.

(1)

- (ii) The teacher finds that the radiation emitted from the radioactive source is not detected when the detector is more than 5 cm away from the source.

State the type of radiation emitted by the radioactive source.

(1)

(d) The number of radium-226 atoms in the source decreases over time, with a half-life of 1600 years.

(i) State what is meant by the term **half-life**.

(2)

(ii) The radioactive source contains 2.66×10^{21} atoms of radium-226.

Approximately how many atoms of radium-226 will remain in the source after 800 years?

(1)

☐ **A** 0.67×10^{21}

☐ **B** 1.33×10^{21}

☐ **C** 1.88×10^{21}

☐ **D** 2.66×10^{21}

(Total for Question 5 = 7 marks)

1 This is a question about radioactivity.

(a) Which of these is the unit of activity?

(1)

- ☐ A becquerel
- ☐ B kilogram
- ☐ C newton
- ☐ D pascal

(b) Which of these is the correct description of the term **half-life**?

(1)

- ☐ A time taken for the activity of a substance to halve
- ☐ B half of the time taken for the mass of a substance to decay
- ☐ C time taken for the activity to decay completely
- ☐ D time taken for the mass of a substance to decay twice

(c) A teacher demonstrates how the activity of a radioactive sample changes with time.

(i) The box gives the names of different pieces of equipment.

ruler	stopwatch	balance	newton meter
protractor	GM tube	voltmeter	ammeter

Complete the sentences using words from the box.

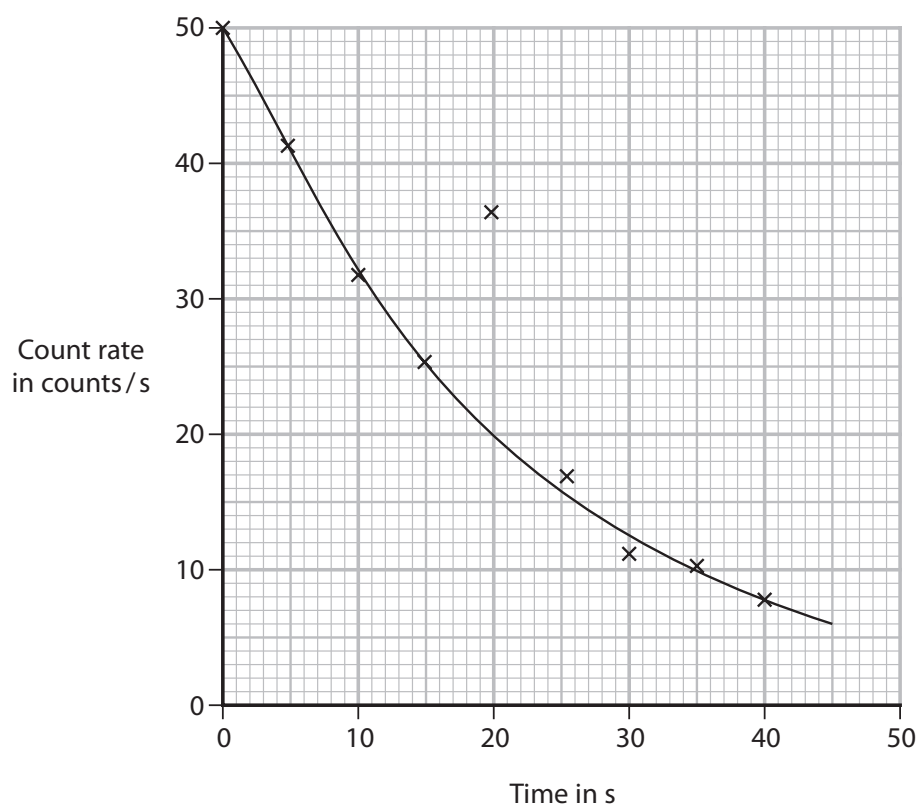
(2)

The teacher measures time with a

The teacher measures the count rate with a and a counter.



(ii) The graph shows the teacher's results.



Draw a circle around the anomalous result.

(1)

(iii) Use the graph to determine the half-life of the radioactive sample.

(2)

half-life = ... s

(iv) Give a reason why the teacher should not expect the data points to lie exactly on the curve of best fit.

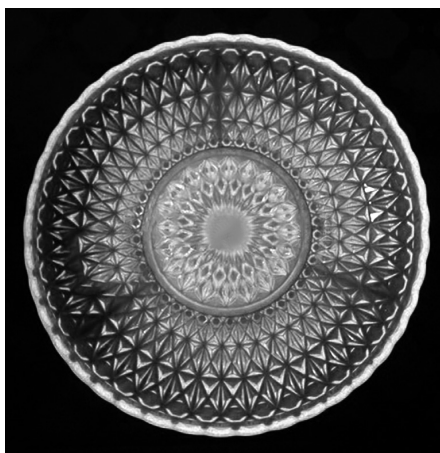
(1)

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(Total for Question 1 = 8 marks)

- 7 The photograph shows a glass plate made from uranium glass.



© Laura Healey/Shutterstock

Uranium oxide is used to give the glass a green colour.

- (a) Uranium-238 is the most common isotope of uranium and can be represented using this symbol.



- (i) State what information the numbers 92 and 238 give about the nucleus of this isotope of uranium.

(2)

92.....

238.....

- (ii) Uranium-238 decays by alpha emission.

Describe how the nucleus of a uranium-238 atom changes as a result of alpha emission.

(2)

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(b) The table gives some information about the uranium glass plate.

mass of plate	1.1 kg
percentage (%) of plate made of uranium-238 (by mass)	4.5%
mass of uranium-238 atom	$4.0 \times 10^{-27} \text{ kg}$

(i) Calculate the number of uranium-238 atoms in the plate.

(2)

number of atoms = ...

(ii) Uranium-238 is an alpha emitter and has a half-life of 4.5 billion years.

Explain why it is safe to eat food from the uranium glass plate.

(3)

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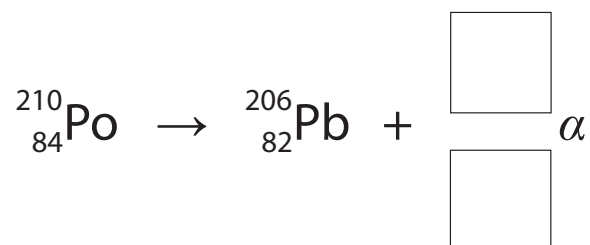
(Total for Question 7 = 9 marks)



9 A deioniser is a device used in rooms where workers build sensitive electronic circuits.

The deioniser contains a small block of polonium-210.

(a) (i) Complete the equation that shows the alpha decay of polonium-210 into lead-206. (2)



(ii) The alpha particle ionises air molecules in the room.

State what is meant by the term **ionisation**.

(1)

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(iii) Explain why workers in the same room as the deioniser are not at risk from the alpha radiation it emits.

(2)

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(b) The half-life of polonium-210 is 140 days.

(i) State what is meant by the term **half-life**.

(2)

(ii) The initial activity of the polonium-210 source in the deioniser is 70 kBq.

Calculate the activity of the source after 420 days.

(3)

activity = ... kBq

(Total for Question 9 = 10 marks)



4 Cobalt-60 is a radioactive isotope of cobalt.

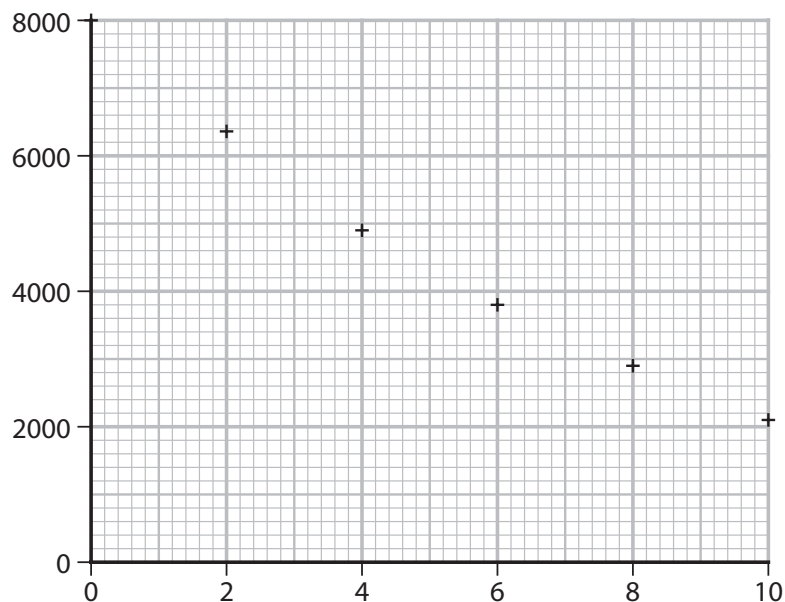
The table gives the activity of a sample of cobalt-60 over a period of 10 years.

Time in years	Activity
0	8000
2	6350
4	4900
6	3800
8	2900
10	2100

(a) Give a suitable unit for activity.

(1)

(b) The graph shows the data.



(i) Label both axes.

(1)

(ii) Draw the curve of best fit.

(1)

(iii) Use the graph to determine the half-life of cobalt-60.

(2)

half-life = ... years

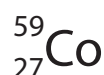
(iv) Estimate the time taken for the activity to decrease to $\frac{1}{8}$ of its initial value.

(2)

time = ... years

(c) Cobalt-60 is produced when a neutron is absorbed by the nucleus of a stable atom of cobalt-59.

The nuclei of these two isotopes can be represented as



Describe a similarity and a difference for the nuclei of these two isotopes of cobalt.

(2)

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7 Protactinium is an element with several different radioactive isotopes.

(a) Protactinium-234 has a half-life of 6.7 hours.

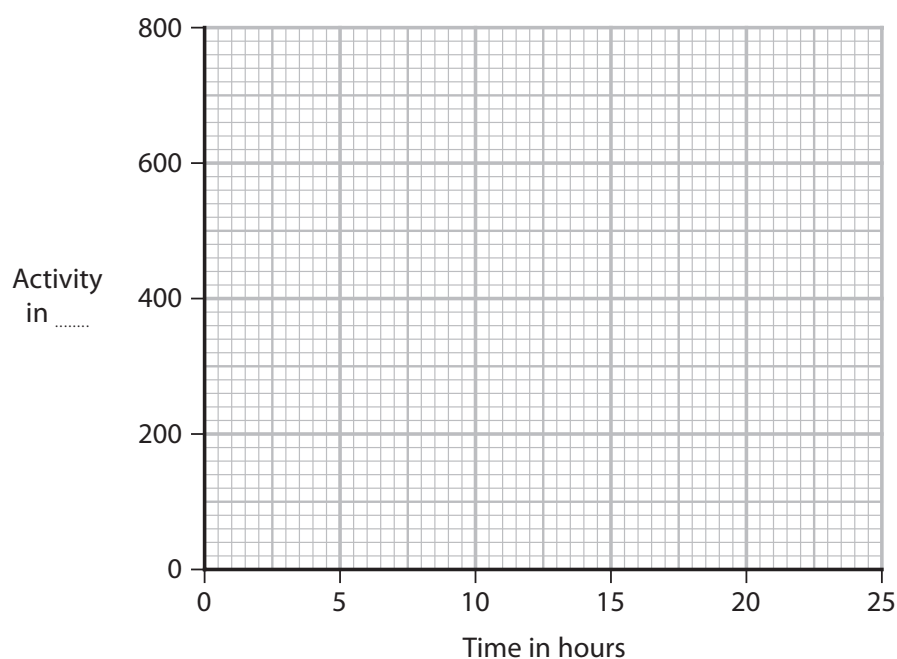
A sample of protactinium-234 has an initial activity of 800 units.

(i) Give a suitable unit for activity.

(1)

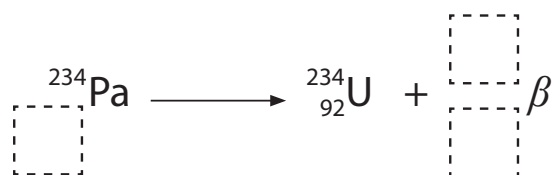
(ii) On the axes below, sketch a graph for the decay of the sample of protactinium-234 during its first three half-lives.

(3)



(iii) When protactinium-234 undergoes beta (β^-) decay it becomes uranium-234.

The incomplete nuclear equation shows this process.



Complete the nuclear equation to show the beta decay of protactinium-234.

Write your answers in the dashed boxes.

(2)

- (b) A student suggests an experiment to determine the type of radiation emitted by a different isotope of protactinium, protactinium-231.

This is the suggested method.

Step 1 connect a suitable radiation detector to a radiation counter

Step 2 place a source of protactinium-231 at a fixed distance of 3 cm from the radiation detector

Step 3 record the count of detected radiation for a time of one minute

Step 4 place a sheet of paper between the source and detector

Step 5 record the count of detected radiation for a time of one minute

Step 6 repeat Steps 4 and 5 using a sheet of aluminium and then a sheet of lead instead of the sheet of paper

The table shows the results of the investigation when it is done by a teacher.

Material between source and detector	Count
no material	261
paper	14
aluminium	11
lead	13

- (i) Which of these is the dependent variable in the investigation?

(1)

- ☐ **A** count measured by the detector
- ☐ **B** distance between source and detector
- ☐ **C** material between source and detector
- ☐ **D** time the count is measured



(ii) The student's method does not allow for background radiation.

Describe how the student's method should be modified to allow for background radiation.

(3)

(iii) Describe how the student's method could be modified to improve the reliability of the results.

(2)

(iv) Evaluate the data from the experiment to conclude the type of radiation emitted by protactinium-231.

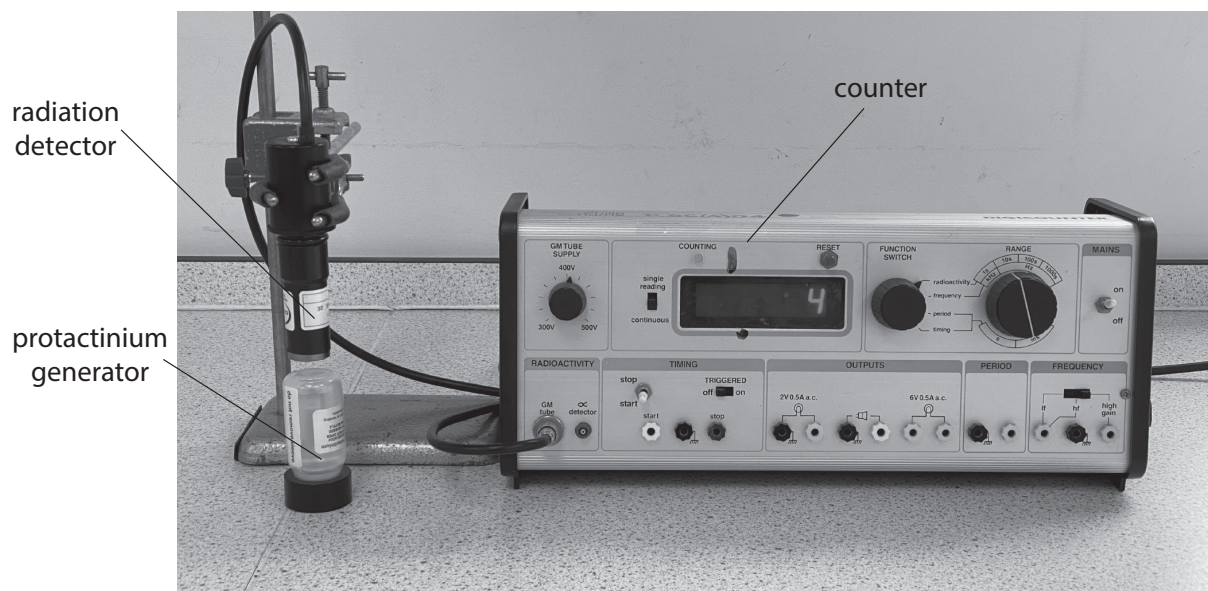
(3)

(Total for Question 7 = 15 marks)



- 9 A protactinium generator is a device that can produce samples of an isotope called protactinium-234m.

A teacher investigates the activity of protactinium-234m using the apparatus shown in the photograph.



- (a) The teacher uses a radiation detector to detect the radiation emitted from the protactinium-234m.

Give the name of a suitable radiation detector.

(1)

- (b) Give two safety precautions to minimise the risk of harm to the teacher from the radiation emitted by the protactinium generator.

(2)

1

2

(c) Protactinium-234m decays with a half-life of 70 seconds.

(i) The initial count rate is 840 counts per second.

Calculate the expected count rate after 140 seconds.

(2)

count rate = ... counts per second

(ii) The activity of an isotope is the total amount of radiation emitted each second.

The teacher estimates that only 5% of the total radiation emitted is detected by the radiation detector.

Estimate the activity of the isotope when the count rate is 840 counts per second.

Give the unit.

(3)

activity = ... unit = ...

(Total for Question 9 = 8 marks)



SUB-TOPIC 7.3

USES AND DANGERS OF RADIATION

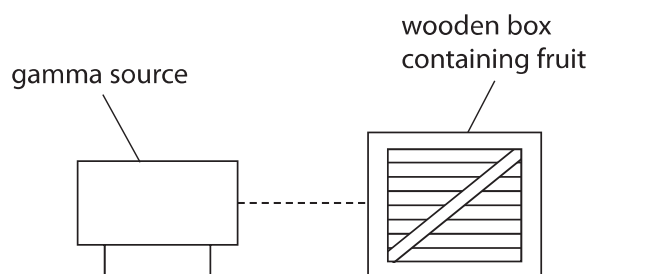
Sub-topic 7.3 · 4 questions · 34 marks · lowest tariff first



3 This question is about food preservation.

- (a) The diagram shows how gamma radiation is used to irradiate fruit stored in a wooden box.

The radiation kills bacteria on the fruit.



Explain why gamma radiation is used instead of alpha radiation to kill bacteria.

(2)

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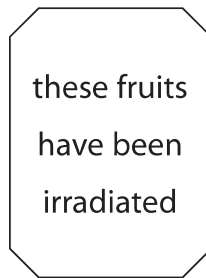
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(b) The wooden box has this label.



Explain why fruit irradiated with gamma radiation is safe to eat.

(2)

(Total for Question 3 = 4 marks)

5 An aircraft travels along a runway.

(a) The aircraft starts from rest and has a constant acceleration of 4.1 m/s^2 .

Calculate the distance required to reach take-off speed of 75 m/s .

(3)

distance = ... m

(b) The aircraft takes off and reaches its maximum height above the ground.

At maximum height, the background radiation count rate is higher than on the ground.

(i) Explain what is meant by background radiation.

(2)

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(ii) Suggest why there is a limit to the number of hours that an airline pilot can fly at maximum height.

(3)

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(Total for Question 5 = 8 marks)



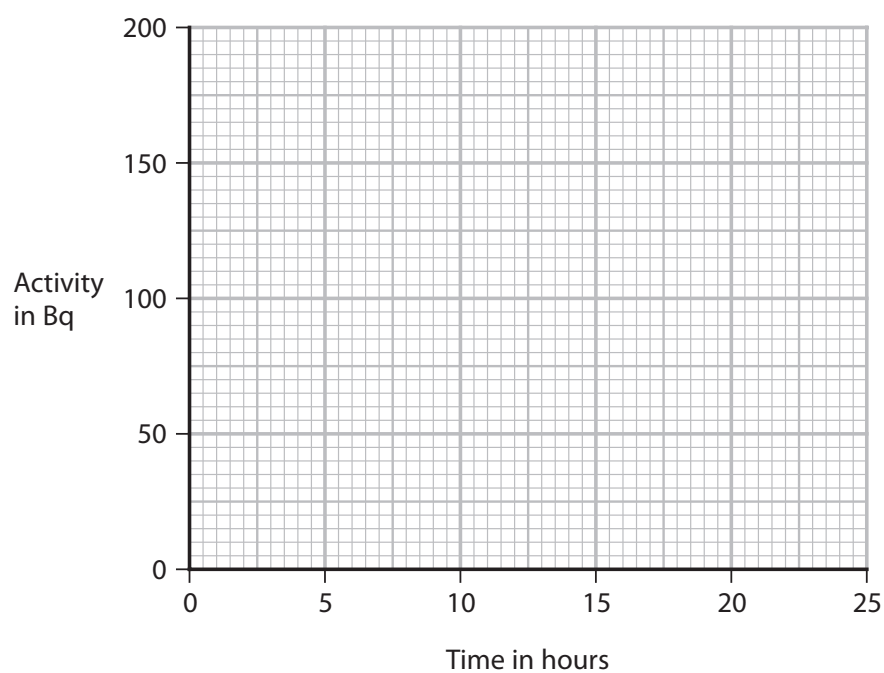
11 Technetium-99m is an isotope of the element technetium.

(a) Technetium-99m has a half-life of 6 hours.

A sample of technetium-99m has an initial activity of 160 Bq.

Complete the graph to show how the activity of this sample of technetium-99m changes over a period of 24 hours.

(3)



- (b) Technetium-99m has a half-life of 6 hours and can be used as a medical tracer.

It is injected into a patient's blood and moves around the patient's body.

Technetium-99m emits gamma radiation, which is used to locate the position of the tracer in the patient's body.

- (i) Technetium-99m does not exist naturally.

Suggest why technetium-99m is usually made at the hospital where it is used.

(1)

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- (ii) Explain why technetium-99m is an effective isotope to use as a medical tracer.

(2)

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- (c) The gamma radiation emitted by technetium-99m is potentially harmful to humans.

Discuss the risks of using technetium-99m to doctors and to patients.

(3)

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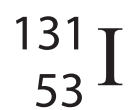
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(Total for Question 11 = 9 marks)



8 This question is about radioactive isotopes used for medical imaging.

(a) Iodine-131 is represented by this symbol.



(i) How many neutrons are in the nucleus of an atom of iodine-131?

(1)

☐ A 53

☐ B 78

☐ C 131

☐ D 184

(ii) Iodine-131 is radioactive and decays with a half-life of 8 days.

State what is meant by the term **half-life**.

(2)

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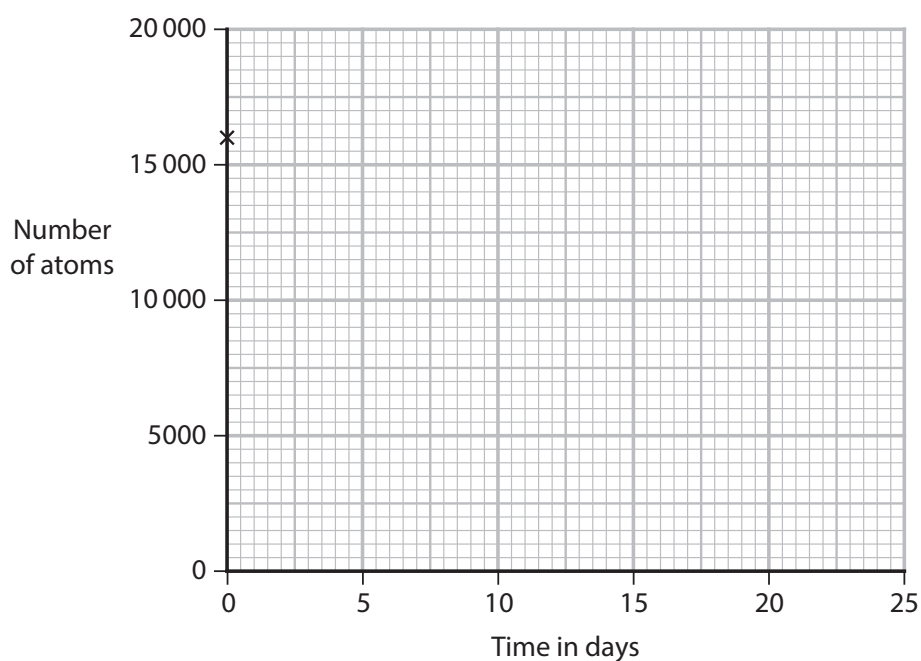
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- (iii) The cross (×) on the graph shows the initial number of atoms in a sample of iodine-131.

Draw three more crosses (×) on the graph to show how the number of atoms of iodine-131 in the sample changes during three half-lives.

[iodine-131 half-life = 8 days]

(3)



- (iv) Use a curve of best fit on the graph to estimate the time taken for the number of atoms in the sample to decrease to 5000.

(2)

time taken = ... days



(b) When iodine-131 decays, it emits beta radiation and gamma radiation.

A patient swallows a tablet containing iodine-131. The radiation emitted can be detected outside the body.

- (i) State the name of a piece of equipment that can detect the radiation emitted by iodine-131.

(1)

- (ii) Give a reason why gamma radiation is more likely to be detected outside the body than beta radiation.

(1)



(c) Technetium-99m is another radioactive isotope.

Iodine-131 and technetium-99m are both used as medical tracers. Medical tracers use radiation detected outside the body to diagnose illnesses.

The table gives information about some of the properties of iodine-131 and technetium-99m when they undergo radioactive decay.

Isotope	Type(s) of radiation emitted	Half-life
iodine-131	beta and gamma	8 days
technetium-99m	gamma	6 hours

Explain why technetium-99m is likely to be safer than iodine-131 when used as a medical tracer.

(3)

(Total for Question 8 = 13 marks)

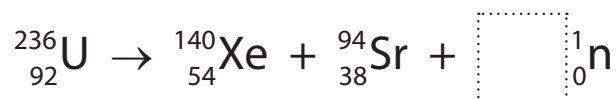
SUB-TOPIC 7.4

NUCLEAR FISSION AND FUSION

Sub-topic 7.4 · 11 questions · 92 marks · lowest tariff first



- 2 The nuclear equation shows how a nucleus of uranium-236 may undergo nuclear fission.



- (a) Determine how many neutrons are released in this fission process.

(1)

number of neutrons = ...

- (b) The table gives some of the constituents of this nuclear fission.

Complete the table by putting one tick (✓) in each row to show whether the constituent is a parent nucleus or a daughter nucleus.

(2)

Constituent	Parent nucleus	Daughter nucleus
strontium-94		
uranium-236		
xenon-140		

- (c) Describe how the neutrons released in this fission process can cause a chain reaction.

(2)

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(Total for Question 2 = 5 marks)

2 This question is about nuclear fission and nuclear fusion.

(a) The table gives some statements about nuclear fission, or nuclear fusion, or both nuclear fission and nuclear fusion.

Place ticks (✓) in the table to show which statements are about nuclear fission and which statements are about nuclear fusion.

(3)

Statement	Nuclear fission	Nuclear fusion
requires high pressure and high temperature		
energy is released		
radioactive daughter nuclei are produced		

(b) Nuclear fission reactors use control rods and a moderator.

Describe the function of the control rods and the function of the moderator in a nuclear fission reactor.

(2)

control rods

moderator

(Total for Question 2 = 5 marks)

2 This question is about a nuclear fission chain reaction.

(a) Uranium-235 is an isotope of uranium that can undergo nuclear fission.

The table gives some statements about this fission process.

Add ticks (✓) to the table to show which statements are correct.

(3)

Statement	Correct (✓)
uranium-235 loses a proton to become uranium-236	
uranium-235 absorbs a neutron to become uranium-236	
daughter cells are produced when uranium-236 splits	
the nuclear energy store of uranium-236 increases when it splits	
two or three neutrons are usually released when uranium-236 splits	
energy is transferred to the kinetic store of the fission products when uranium-236 splits	

(b) State which product of nuclear fission causes the next uranium-235 nucleus to split in the chain reaction.

(1)

(c) Uranium-235 is radioactive and emits alpha radiation.

Which of these statements describes alpha radiation?

(1)

- ☐ A an electromagnetic wave
- ☐ B a helium nucleus
- ☐ C a high energy electron
- ☐ D a high energy neutron

(d) Some of the products of nuclear fission are radioactive because their nuclei have too many neutrons.

These nuclei become more stable when a neutron changes into a proton.

State which type of radiation is emitted by radioactive nuclei with too many neutrons.

(1)

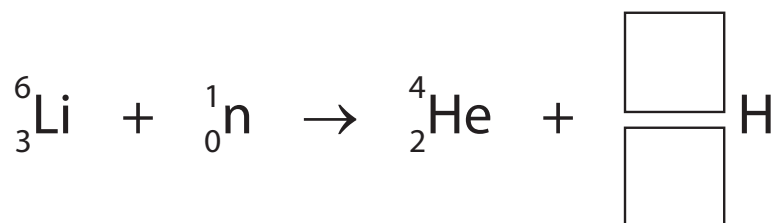
(Total for Question 2 = 6 marks)



4 In extreme conditions, the isotope lithium-6 can be made to undergo nuclear fission.

- (a) The lithium-6 nucleus absorbs a neutron and produces an alpha particle and an isotope of hydrogen.

The incomplete nuclear equation for this fission is



- (i) Complete the nuclear equation by writing the numbers in the boxes.

(2)

- (ii) Explain why this fission does not cause a chain reaction.

(2)

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- (b) Explain the difference between nuclear fission and nuclear fusion.

(2)

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(Total for Question 4 = 6 marks)

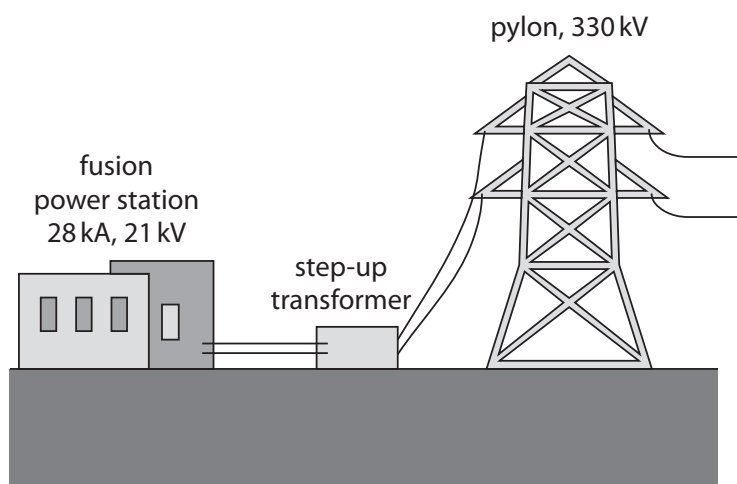


6 This is a question about a nuclear fusion power station.

(a) Explain what happens during nuclear fusion.

(3)

(b) The diagram shows how a fusion power station could supply the National Grid in the future.



(i) State the main method of energy transfer from the fusion power station generator to the primary coil of the step-up transformer.

(1)

- (ii) The fusion power station could supply the input coil of the step-up transformer with a current of 28 kA at a voltage of 21 kV.

The output coil of the transformer has a voltage of 330 kV.

Assume the transformer is 100% efficient.

Calculate the current in the output coil of the transformer.

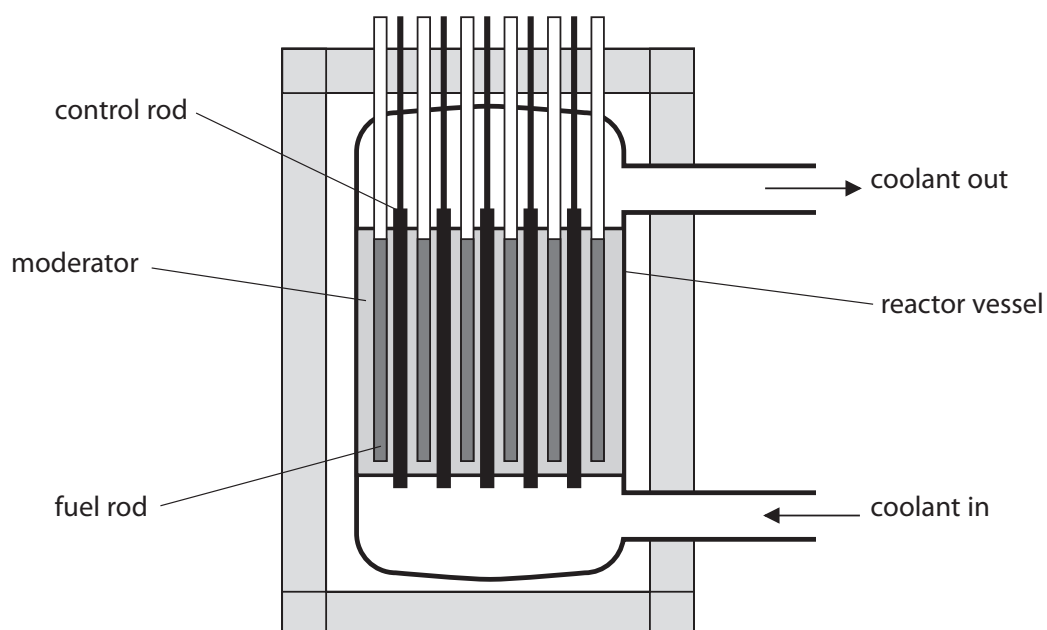
(3)

current = ... kA

(Total for Question 6 = 7 marks)



5 The diagram shows some of the components of a nuclear fission reactor.



(a) Describe how a chain reaction occurs in a nuclear fission reactor.

(3)

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(b) Describe the role of the control rods in a nuclear fission reactor.

(2)

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(c) Describe how the process of nuclear fission is different from the process of nuclear fusion.

(2)

(d) (i) Which of these is the name of the nuclear process that is the main energy source for stars?

(1)

- ☐ **A** alpha decay
- ☐ **B** fission
- ☐ **C** fusion
- ☐ **D** gamma decay

(ii) Give a reason why the nuclear process in stars does not happen at low temperatures and pressures.

(1)

(Total for Question 5 = 9 marks)

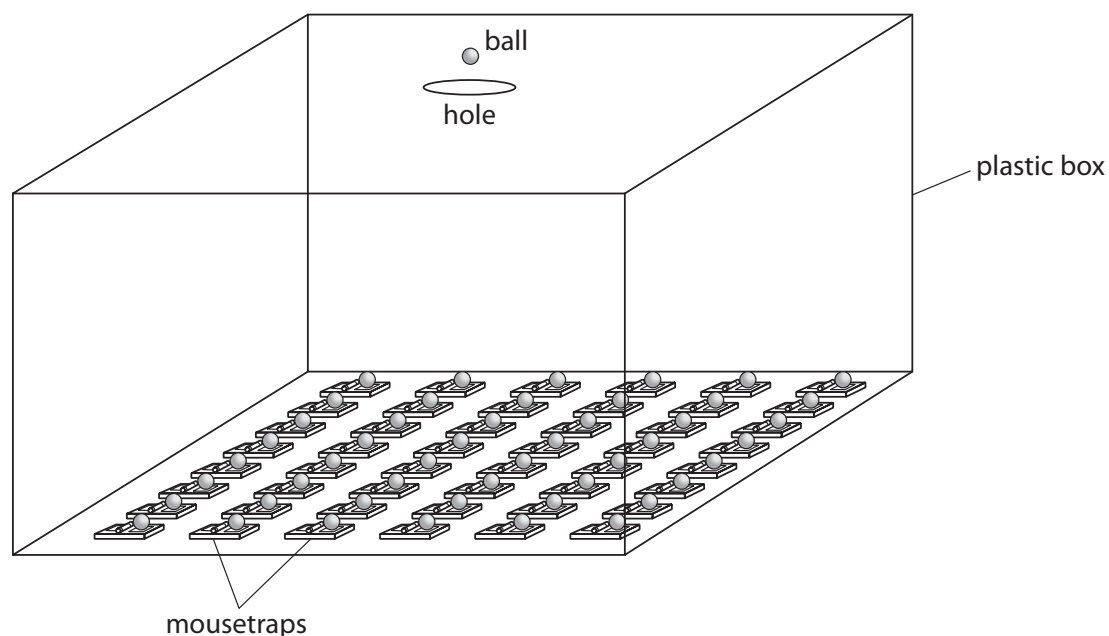


3 The diagram shows a model of a chain reaction in a nuclear fission reactor.

A ball falls through the hole and hits a mousetrap.

This mousetrap then releases another ball.

Each released ball hits a different mousetrap.



(a) Each mousetrap represents a uranium-235 nucleus.

(i) Name the particle represented by the balls.

(1)

(ii) Describe what is meant by the term **nuclear fission**.

(2)

(iii) Describe what is meant by the term **chain reaction**.

(2)

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(b) The walls of a real nuclear reactor are not made of plastic.

Give a suitable material for the walls of a real nuclear reactor.

(1)

.....

(c) Use words from the box to complete the sentences about the moderator and control rods in a nuclear reactor.

(4)

absorb	ionise	neutralise	reflect	slow
boron	granite	graphite	paper	uranium

The moderator in a nuclear reactor can be made of

The moderator is designed to neutrons.

The control rods in a nuclear reactor can be made of

The control rods are designed to neutrons.

(Total for Question 3 = 10 marks)



2 Some of the energy stored in the nuclei of atoms can be used to generate electricity.

(a) A nuclear fission power station generates electricity.

(i) State the role of the moderator in a nuclear fission power station.

(1)

(ii) Some of the daughter nuclei produced in nuclear fission are highly radioactive and emit high energy neutrons when they decay.

Explain which feature of a nuclear fission reactor reduces the risks from these high energy neutrons.

(2)

(iii) The daughter nuclei can cause contamination and irradiation.

Describe the difference between contamination and irradiation.

(2)



(b) Nuclear fusion is another process that could be used to generate electricity.

(i) Describe the process of nuclear fusion.

(2)

(ii) State where nuclear fusion occurs naturally.

(1)

(iii) Generating electricity from nuclear fusion is very difficult as the conditions needed are hard to achieve and maintain.

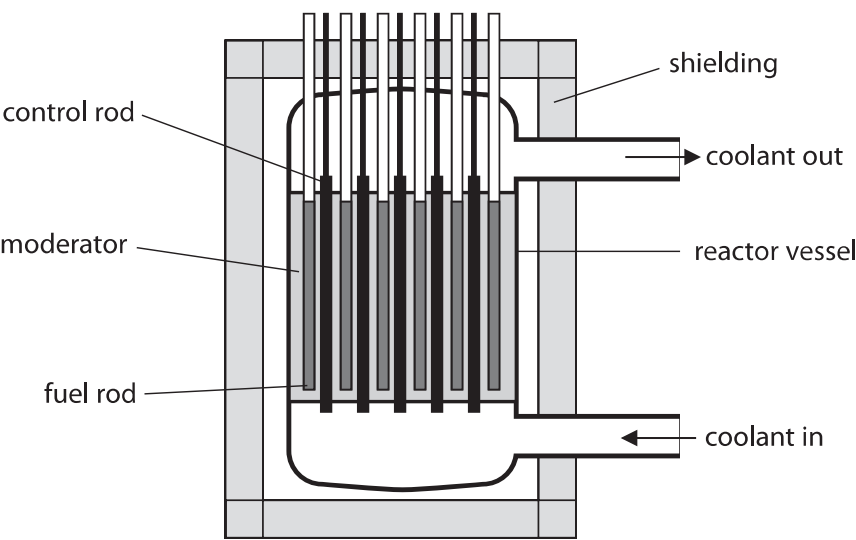
Explain the conditions required for nuclear fusion.

(3)

(Total for Question 2 = 11 marks)



9 (a) The diagram shows a nuclear reactor.



Each part of the nuclear reactor has a function and is made of a suitable material for its function.

Complete the table by giving the missing information.

(5)

Part	Function	Suitable material
control rod		boron
moderator		graphite
shielding	prevents irradiation of workers	
fuel rod		

(b) Heavy water is a compound of oxygen and an isotope of hydrogen called deuterium.

Deuterium is formed by the fusion of protons.

(i) State the meaning of the term **isotope**.

(2)

(ii) Explain the difference between nuclear fission and nuclear fusion.

(2)

(iii) State a location where nuclear fusion takes place.

(1)

(iv) Explain why fusion cannot take place at low temperature or low pressure.

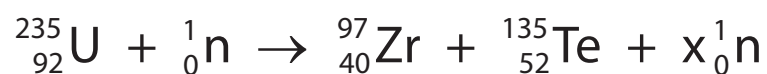
(2)

(Total for Question 9 = 12 marks)



- 10 (a) Uranium-235 captures a neutron and undergoes nuclear fission in a chain reaction.

The equation shows a possible nuclear fission reaction.



Calculate x, the number of neutrons released by this fission reaction.

(2)

x = ...

- (b) Describe what is meant by a **chain reaction**.

(3)

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- (c) Iodine-129 is an isotope found in radioactive waste from nuclear power stations.

Iodine-129 has a half-life of approximately 15 million years.

A sample of iodine-129 has an activity of 72 kBq.

Show that the time required for the sample to have an activity less than 5 kBq is approximately 60 million years.

(3)



(d) Some radioactive waste from nuclear power stations has a very long half-life.

Discuss precautions that must be taken when disposing of this radioactive waste.

(5)

(Total for Question 10 = 13 marks)



4 This question is about the process of controlled nuclear fission in a nuclear reactor.

- (a) In a nuclear reactor, uranium-235 nuclei are split to produce daughter nuclei and neutrons.

State what else is released in nuclear fission that makes the process useful in a nuclear reactor.

(1)

- (b) What is the function of the control rods in a nuclear reactor?

(1)

- ☐ A absorb excess neutrons
- ☐ B create additional neutrons
- ☐ C fuse neutrons together
- ☐ D split neutrons

- (c) What is the function of the moderator in a nuclear reactor?

(1)

- ☐ A change protons into neutrons
- ☐ B change neutrons into protons
- ☐ C slow down neutrons
- ☐ D speed up neutrons

(d) Many of the daughter nuclei produced in nuclear fission are very radioactive.

These daughter nuclei decay by emitting ionising radiation in a random process.

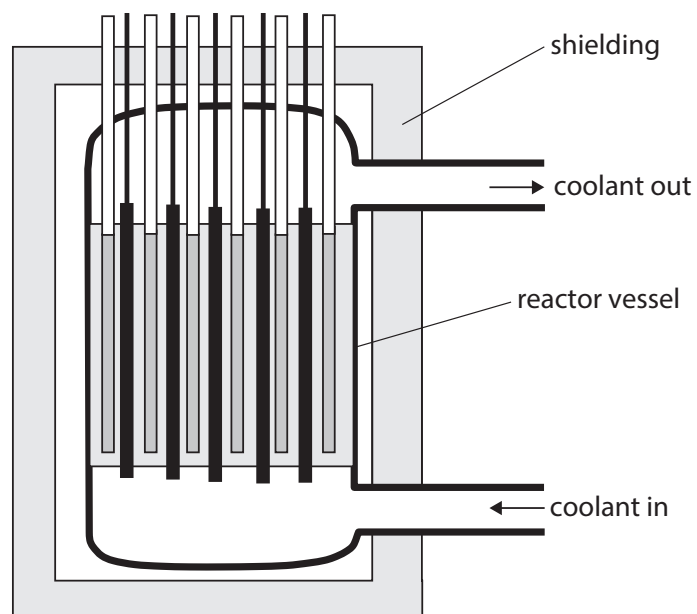
(i) State what is meant by the term **ionising radiation**.

(1)

(ii) State what is meant by the term **random process**.

(1)

(iii) The diagram shows some parts of a nuclear reactor.



Explain the role of shielding in a nuclear reactor.

(3)

(Total for Question 4 = 8 marks)

MARK SCHEMES

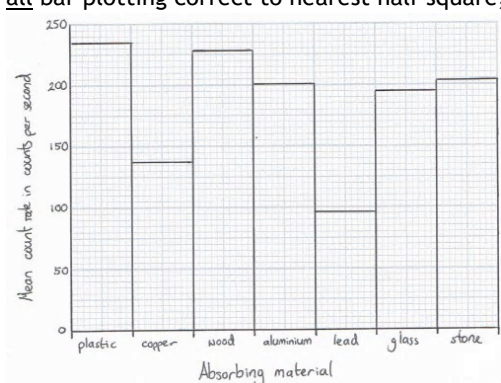
official mark schemes



Question number	Answer	Marks
2 (a)	A (6 protons, 6 neutrons); B is not the answer because it is the same isotope C is not the answer because it is a different element D is not the answer because it is a different element	1
(b)	B (beta); A is not the answer because alpha is a helium nucleus C is not the answer because gamma is a high frequency EM wave D is not the answer because it is not an electron	1
(c)	D (neutron); A is not the answer because this would decrease the atomic number and decrease the mass number B is not the answer because this would increase the atomic number and keep the mass number the same C is not the answer because this would keep the atomic number and mass number the same	1
(d)	A (90); B is not the answer because this is a neutral atom C is not the answer because it is a negatively charged ion D is not the answer because it is a negatively charged ion	1
(e)	C (100 Bq); A is not the answer because this is 4 half-lives B is not the answer because this is 3 half-lives D is not the answer because this is 1 half-life	1

Total for Question 2 = 5 marks

Question number	Answer	Notes	Marks
4 (a)	A helium nucleus / 2 protons and 2 neutrons/ 4 nucleons, 2 protons;	Ignore chemical symbol	1
(b) (i)	Arrow labelled Y, through X away from nucleus; Line of action of force would pass through centre of nucleus by eye;		2
(ii)	Arrow labelled Z, opposite direction to their answer from b) (i) by eye; Same size as their answer from b) (i) by eye;	If no arrow Y, condone correct direction for arrow Z, i.e. force arrow pointing away from point X.	2
(iii)	MP1 Force on alpha is repulsive; MP2 Alpha and nucleus must be same (type of) charge; MP3 Alpha is positive therefore nucleus is positive;	Allow 'like charges repel' for MP1 and MP2	3
4 (c)	Selection of $F = ma$; Substitution or re-arrangement; Evaluation; e.g. $a = 3.6 / 6.6 \times 10^{-27} = 5.5 \times 10^{26} \text{ m/s}^2$	Can be implied from working -1 for PoT error Allow 5.45×10^{26} , 5.454×10^{26} , $5.4545 \dots \times 10^{26}$ etc Condone 5.4×10^{26}	3

Question number	Answer	Notes	Marks																
9 (a)	Geiger-Muller tube / GM tube;	allow Geiger counter, Geiger meter, GM detector	1																
(b)	(absorbing) material;	allow absorber	1																
(c)	any two from: MP1. idea that thickness also affects the count/results; MP2. idea that thickness is a control variable; MP3. idea of making experiment valid;	allow fair test for valid	2																
(d)	measure count over longer time / take more repeats / measure background count;	allow quoted time longer than 3 seconds	1																
(e) (i)	suitable linear scale chosen (>50% of grid used); axes labelled with quantities and unit; <u>all</u> bar plotting correct to nearest half square; 	ignore orientation do not accept multiples of 30 for scale <table><tr><th>Absorbing material</th><th>Mean</th></tr><tr><td>plastic</td><td>235</td></tr><tr><td>copper</td><td>137</td></tr><tr><td>wood</td><td>227</td></tr><tr><td>aluminium</td><td>202</td></tr><tr><td>lead</td><td>97</td></tr><tr><td>glass</td><td>195</td></tr><tr><td>stone</td><td>203</td></tr></table>	Absorbing material	Mean	plastic	235	copper	137	wood	227	aluminium	202	lead	97	glass	195	stone	203	3
Absorbing material	Mean																		
plastic	235																		
copper	137																		
wood	227																		
aluminium	202																		
lead	97																		
glass	195																		
stone	203																		
(ii)	B (absorbing material is not a continuous variable); A is incorrect because absorbing material is not a continuous variable C is incorrect because line graphs are drawn for continuous variables D is incorrect because count rate is a continuous variable		1																
(iii)	idea that the lower the count, the better the absorber; lead is the best absorber;	ignore student is right/wrong allow RA allow that plastic is the worst absorber	2																

Total for Question 9 = 11 marks

Question number	Answer	Notes	Marks
7 (a)	any two from: MP1. alphas do not penetrate as far; MP2. alphas are more ionizing; MP3. alphas are more likely to collide (with material); MP4. alphas have more mass / move slower;	allow RA allow RA allow RA allow RA	2
(b) (i)	(nuclei with) same numbers of protons; (nuclei with) different numbers of neutrons;	allow (nuclei with) same atomic number allow (nuclei with) different mass number	2
(ii)	one mark for each correct number;; ${}_{92}^{235}\text{U} \rightarrow {}_{90}^{231}\text{Th} + {}_2^4\alpha$		2
(iii)	any indication that 2100 million years is 3 half-lives; evaluation of number of uranium nuclei after 1 half-life; (after 2100 million years) there are 800 million uranium nuclei; (after 2100 million years) there are 5600 million thorium nuclei; $5600 \text{ (million)} / 800 \text{ (million)} = 7$;	3200 (million) uranium nuclei after one half-life scores first three marks allow total number of nuclei is constant allow $7 \times 800 = 5600$	5

Total for Question 7 = 11 marks

Question number	Answer	Notes	Marks
10 (a) (i)	different number of neutrons; technetium-99 has 1 more neutron;	reject if number of protons is given as different DOP condone technetium-99 has 99 neutrons and technetium-98 has 98 neutrons	2
(ii)	43; -1;		2
(b)	any four max. from: MP1. use of GM tube + counter/GM tube/photographic film; MP2. measure count (rate) without source / find background count; MP3. measure count (rate) with source; MP4. (subtraction to) find corrected count (rate); MP5. repeat readings to obtain mean; MP6. idea that paper / aluminium does not affect count / reading; MP7. idea that lead reduces count rate significantly ; PLUS any safety precaution from: MP8. idea of keeping distance from source; MP9. minimise exposure time; MP10. use of shielding;	allow 'reading' for count rate allow Geiger counter; allow lead blocks (all) radiation e.g. tongs/moving away from source e.g. keeping source in lead-lined box, use of lead apron / gloves, working in a different room from source	5
(c)	use of one data point; evaluation of $\text{distance}^2 \times \text{count rate}$; second data point and second evaluation of $\text{distance}^2 \times \text{count rate}$; conclusion reached consistent with the two evaluations; e.g. (1,100) gives $1^2 \times 100 = 100$ (4,6) gives $16 \times 6 = 96$ 96 is approximately equal to 100 so relationship is verified	reject idea that evaluations are inconsistent unless there is a significant difference between them e.g. due to ECF (1,100) gives constant = 100 (2,25) gives constant = 100 (3,11) gives constant = 99 (4,6) gives constant = 96 (5,4) gives constant = 100	4

Total for Question 10 = 13 marks

Question number	Answer	Notes	Marks
5 (a)	(particle made from) contains protons and neutrons; 2 protons and 2 neutrons;	scores first MP as well ignore electrons ignore reference to helium nucleus	2
(b)	2 for proton number of alpha; 4 for nucleon number of alpha; nucleon numbers balance; e.g. ${}_{88}^{226}\text{Ra} \longrightarrow {}_{86}^{\boxed{222}}\text{Rn} + \begin{array}{c} \boxed{4} \\ \boxed{2} \end{array} \alpha$	allow ecf from incorrect nucleon number of alpha	3
(c)	any two from: MP1. alpha source is outside body / skin would absorb alpha; MP2. alpha has poor penetrating ability; MP3 idea of alpha (radiation) is absorbed by glass/cloud chamber;	condone 'highly ionising' allow idea that alpha can't penetrate glass	2

(d)	Any three from: MP1. idea that all tracks are (approximately) same length; MP2. (so) all alpha particles have the same (kinetic) energy; MP3. tracks are short / alpha radiation is short range; MP4. (so) alpha particles are highly ionising or poorly penetrating	allow sensible numerical value ignore ideas of thickness and direction of track	3
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Total for Question 5 = 10 marks



Question number	Answer	Notes	Marks																		
6 (a)	D (gamma radiation is less ionising than alpha radiation); A is incorrect because gamma radiation has a high penetrating ability B is incorrect because gamma radiation is emitted by nuclei C is incorrect because gamma radiation has no charge		1																		
(b) (i)	any one from: - to calculate a mean; - anomalies can be identified or can be removed or can be checked; - to minimise the effect of random errors or of anomalies;	allow 'average' for 'mean'	1																		
(ii)	calculation of one constant from a point on the curve; calculation of a second constant from a second point on the curve; comparison of the constants AND conclusion that is valid from the candidate's values for the 'constant'; Sample data: <table><tr><th>Count</th><th>Distance</th><th>Constant</th></tr><tr><td>13 600</td><td>6</td><td>489 600</td></tr><tr><td>3300</td><td>12</td><td>475 200</td></tr><tr><td>1600</td><td>18</td><td>518 400</td></tr><tr><td>800</td><td>24</td><td>460 800</td></tr><tr><td>600</td><td>30</td><td>540 000</td></tr></table>	Count	Distance	Constant	13 600	6	489 600	3300	12	475 200	1600	18	518 400	800	24	460 800	600	30	540 000	roughly, the constant for any count-distance pair is in range 460 000-540 000 reject this mark if there are any miscalculated constants i.e. are the constants 'the same' or not NB: ignore consistent PoT errors	3
Count	Distance	Constant																			
13 600	6	489 600																			
3300	12	475 200																			
1600	18	518 400																			
800	24	460 800																			
600	30	540 000																			

Total for Question 6 = 5 marks



Question number	Answer	Notes	Marks
2 (a)	(nuclei with) same number of protons; different number of neutrons;	ignore references to electrons allow same atomic number ignore same element allow different (atomic) mass, nucleon/mass number	2
(b) (i)	A (92); <i>B is incorrect because this is the number of neutrons</i> <i>C is incorrect because this is the number of nucleons</i> <i>D is incorrect because this is the nucleon number and proton number added together</i>		1
(ii)	neutron;	ignore n condone spelling mistakes	1
(c) (i)	recognition that 46 minutes is 2 half-lives; correct final evaluation; e.g. $46 \div 23 = 2$ OR $60 \times \frac{1}{2} \times \frac{1}{2}$ (mass =) 15 (g)	allow attempt to halve twice in calculation allow 2 half-lives seen explicitly in working	2
(ii)	C ($^{239}_{93}\text{Np}$); <i>A is incorrect because neither the number of neutrons or protons has changed</i> <i>B is incorrect because a neutron has been added with no change to the number of protons</i> <i>D is incorrect because a proton has been added with no change to the number of neutrons</i>		1

Total for Question 2 = 7 marks

Question number	Answer	Notes	Marks
3 (a)	(nuclei with) the same number of protons; (but) different number of neutrons;	allow same atomic number / same element allow different nucleon / mass number / atomic mass	2
(b)	A (82); B is incorrect because this is the number of neutrons C is incorrect because this is the number of nucleons D is incorrect because this is double the proton number + nucleon number		1
(c) (i)	evidence of 3 half-lives; correct evaluation; e.g. $240 \div 2^3 = 30$ $66 \div 3 = 22$ (years)	seen anywhere in working	2
(ii)	correct atomic and mass numbers used for alpha particle; correct evaluation of number of beta particles; e.g. atomic number of alpha = 2, mass number = 4 (therefore) 2 beta decays (to get back to 82) ${}_{82}^{210}\text{Pb} \rightarrow {}_{82}^{206}\text{Pb} + {}_2^4\alpha + 2 {}_{-1}^0\beta$	seen anywhere in working	2

Total for Question 3 = 7 marks



Question number	Answer	Notes	Marks
5 (a)	any one from: - handling source with tongs/gloves; - storing source in lead box (when not in use); - minimising time handling source; - maximising distance from source; - taking care with direction of emission from source; - use of lead apron/shielding;	ignore if mention of other room etc.	1
(b)	B (138); A is incorrect because this is the number of protons C is incorrect because this is the number of nucleons D is incorrect because this is the number of nucleons + protons		1
(c) (i)	photographic film / Geiger-Muller tube;	allow GM tube, GM detector condone Geiger counter allow spark counter	1
(ii)	alpha / α ;		1
(d) (i)	time taken; and either of - for (radio)activity to halve; - for half of the (radioactive) nuclei / atoms / isotope to decay;	allow "how long it takes" reject "half the time" allow count rate for activity	2
(ii)	C (1.88×10^{21}); A is incorrect because this is the number of atoms after 3200 years B is incorrect because this is the number of atoms after 1600 years D is incorrect because this is the initial number of atoms		1

Total for Question 5 = 7 marks



Question number	Answer	Notes	Marks
1 (a)	A (becquerel); B is incorrect because it is the unit of mass C is incorrect because it is the unit of force D is incorrect because it is the unit of pressure		1
(b)	A (time taken for the activity of a substance to halve); B is incorrect because the substance will not completely decay C is incorrect because the substance will not completely decay D is incorrect because the substance cannot decay twice		1
(c) (i)	stopwatch; GM tube;		2
(ii)	point at $t = 20\text{s}$ identified;		1
(iii)	any indication of a halving in activity; half-life = 15 (s);	e.g. $50 \rightarrow 25$ $40 \rightarrow 20$ etc. seen in working allow $\div 2$, $\times \frac{1}{2}$ seen in working allow full credit in range 14–16 (s)	2
(iv)	any indication that decay is random;	allow unpredictable allow references to background radiation/count varying	1

Total for Question 1 = 8 marks



Question number	Answer	Notes	Marks
7 (a)	(i) (92 =) number of protons (238 =) number of nucleons / number of protons <u>and</u> neutrons	ignore atomic number allow mass ignore mass number	2
	(ii) (nucleus) loses two protons; (nucleus) loses two neutrons;		2
(b) (i)	evaluation of mass of U-238 in plate; evaluation of number of atoms; e.g. mass = $(1.1 \times 0.045) = 0.0495$ kg ($n = 0.0495 / 4.0 \times 10^{-27} = 1.2 \times 10^{25}$)	accept 49.5 g or 0.0495 kg or correct standard form 1.2375×10^{25}	2
	(ii) any three from idea that food is irradiated / not contaminated; alpha cannot penetrate skin or body / range of alpha insufficient to reach body; contains low percentage of uranium(-238); (long half-life means that) activity will be very low / decays very slowly;	ignore references to paper Accept 'mass' for 'percentage'	3

Total for Question 7 = 9 marks

Question number	Answer	Notes	Marks
9 (a) (i)	4; 2;		2
	(ii) removal of electron(s) (from an atom);	allow gaining electron(s)	1
	(iii) alpha particles are absorbed by/cannot penetrate/ stopped by a few cm in air; so alphas do not reach the workers;	allow do not penetrate casing (of deioniser) condone 'do not penetrate skin/clothes'	2
(b) (i)	time taken; for (radio)activity/mass/number of (remaining) nuclei to half;	accept any synonym e.g. period/amount of time/	2
	(ii) evidence of halving of 70; 420 days means 3 half-lives; evaluation of 8.75 (kBq);	accept however presented i.e. 70→35→17.5→8.75 allow 9 (kBq)	3

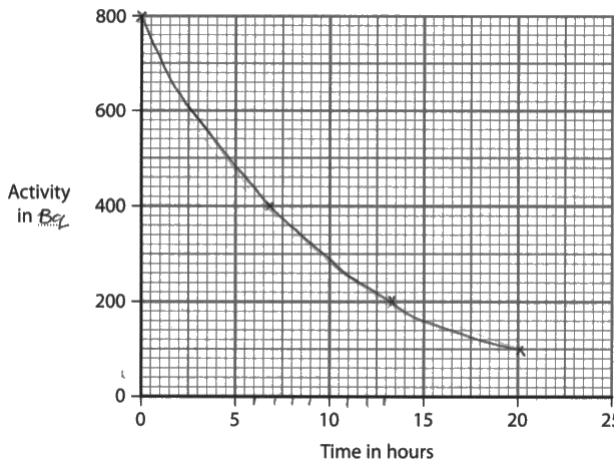
Total for Question 9 = 10 marks



Question number	Answer	Notes	Marks
4 (a)	becquerel(s) / Bq;	allow recognisable spellings allow if written in table	1
(b) (i)	vertical axis labelled “activity” AND horizontal axis labelled “time in years”;	ignore unit on vertical axis	1
(ii)	smooth curve of best fit drawn;	curve should pass within 1 small square of each data point condone curve starting at second point	1
(iii)	evidence of working on graph or in working space; half-life = 5.6 (years);	e.g. lines shown on graph or evidence of halving 8000 etc. allow range of 5.4-5.8	2
(iv)	3 half-lives; (3 × 5.6 =) 16.8 (years);	allow 16.2-17.4 (years) allow ecf from (iii)	2
(c)	both have same number of protons; cobalt-60 has one more neutron;	allow RA ignore references to atomic/mass numbers	2
(d)	nucleus loses a neutron; nucleus gains a proton;	“neutron becomes a proton” scores both marks condone plurals e.g. neutrons, protons	2
(e)	any four from: Hazards (max. 2 marks) MP1. radiation from them can cause cancer / cell damage / damage to organisms / people; MP2. radiation is highly penetrating; MP3. risk of theft / eq; MP4. remain radioactive for some time; MP5. risk of contamination of land/water; Precautions (max. 2 marks) MP6. need for shielding; MP7. use of machines to remove from reactor; MP8. need for security (to prevent public access/protect from hijacking/eq); MP9. need to be suitably protected against damage; MP10. special facilities required, not landfill; MP11. relatively short half-life means that very long-term storage is not necessary;	e.g. lead, concrete etc. e.g. from earthquakes, overheating etc. e.g. stored underground/underwater, measures to avoid leakage	4

Total for Question 4 = 15 marks



Question number	Answer	Notes	Marks
7 (a) (i)	becquerel(s);	allow kilobecquerels, Bq, kBq, curie, Ci allow recognisable spelling allow mixed case letters	1
(ii)	evidence that sketch starts at (0,800) evidence sketch passes through (6.7,400) smooth curve decreases with decreasing steepness 	accept plotted point accept plotted point	3
(iii)	both numbers for beta correct; atomic number of protactinium = 91; e.g. ${}_{91}^{234}\text{Pa} \longrightarrow {}_{92}^{234}\text{U} + {}_{-1}^0\beta$		2

(b)	(i)	A (count measured by the detector); B is incorrect because this is a control variable C is incorrect because this is the independent variable D is incorrect because this is a control variable		1
	(ii)	idea of removing source (from the experiment); measure count(for a minute); subtract background count from results;	e.g. pointing source away, keeping source in its box, (huge) increase in distance, take count before using source	3
	(iii)	idea of repeating measurements (of count); to determine a mean value;	allow idea of using repeats to identify anomalies condone average for mean	2
	(iv)	count decreases (significantly) using paper; no (additional) effect on the count when using aluminium AND lead / eq; radiation must be alpha consistent with candidate's discussion;	both must be mentioned for this mark allow idea that count with aluminium and lead is background radiation / in the range of 11-14	3

Total for Question 7 = 15 marks

Question number	Answer	Notes	Marks
9 (a)	Geiger-Muller tube;	allow GM tube, Geiger-Muller (detector), GM (detector), Geiger counter	1
(b)	any two from: MP1. increase distance from source; MP2. idea of minimising time of exposure; MP3. not pointing source at teacher/people; MP4. handle source with tongs / wear gloves; MP5. idea of shielding between teacher and source;	allow stay 2m away, don't stand too close allow keeping source in metal box (when not in use) allow idea of not touching with bare hands ignore lead vest / coat	2
(c) (i)	recognition that 140s is 2 half-lives; correct final evaluation; e.g. (140 / 70 =) 2 half-lives (840 ÷ 2 ÷ 2 =) 210 (counts per second)		2
(ii)	correct use of 5%; evaluation; unit; e.g. activity = 840 / 0.05 (activity =) 16 800 becquerels	1680, 168 scores this mark as a POT error independent mark allow Bq condone bq, BQ	3

Total for Question 9 = 8 marks

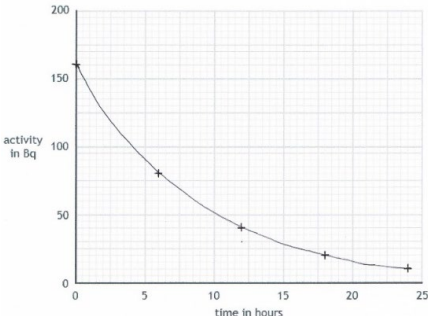
Question number	Answer	Notes	Marks
3 (a)	gamma is more penetrating (than alpha); (therefore) idea that gamma can pass through the box / fruit;	ignore references to ionising ability allow RA allow alpha has shorter range (in air) allow RA allow alpha won't reach the box	2
(b)	any two from: MP1. fruit has no bacteria / (all) bacteria on fruit have been killed; MP2. fruit has not been contaminated; MP3. fruit has not been made radioactive; MP4. radioactive source has not been in contact with the fruit;	allow fruit does not contain any radioactive isotopes allow fruit does not emit radiation	2

Total for Question 3 = 4 marks

Question number	Answer	Notes	Marks
5 (a)	substitution into $v^2 = u^2 + 2as$; rearrangement; evaluation; e.g. $75^2 = (0^2 +) 2 \times 4.1 \times s$ $s = 5625 / 8.2$ $(s =) 690 \text{ (m)}$	allow alternative method of finding the time taken and then using average speed = distance/time 1371-1372 = 2 marks allow 686, 685.9756...	3
(b) (i)	any two from: MP1. idea of radiation that is always present / present everywhere; MP2. idea of no 'obvious' source; MP3. any valid source of background radiation given e.g. radon/rocks/cosmic rays/medical or military activity/the Sun etc.;		2
(ii)	any three from: MP1. idea that excessive exposure time can be harmful/increases risk; MP2. idea that dosage is higher (at maximum height); MP3. idea that increased risk of cancer; MP4. idea that there is less atmosphere to absorb cosmic radiation; MP5. cosmic rays/radiation is increased;	allow cell mutation for cancer	3

(Total for Question 5 = 8 marks)



Question number	Answer	Notes	Marks
11 (a)	activity shown to decrease over time; descending curve getting shallower starting at (0,160); line passes through two other valid points; • (6,80) • (12,40) • (18,20) • (24,10) 		3
(b) (i)	idea that it decays very quickly / activity will be zero by the time it is injected / there will be no technetium-99m left;	ignore 'it has a short half-life'	1
(ii)	any one from: • idea that gamma can penetrate out of the body; • idea that gamma can be detected outside the body; any one from: • idea that half-life is long enough to complete the procedure; • idea that activity will fall to safe level in a day / quickly;	marks must be from separate lists allow idea that technetium will not be in body for very long	2
(c)	harmful effect of gamma radiation given; idea that patient will have procedure very rarely / only when necessary (so risk is low); idea that doctor will administer procedure regularly (so risk is higher) / doctor limits time exposure to patient (to reduce risk);	e.g. • cancer • cell damage • cell mutation allow suggestion that risk to patients is higher as they receive greater dose allow idea that doctor increases distance from patient (to reduce risk)	3

Total for Question 11 = 9 marks



Question number	Answer	Notes	Marks
8 (a) (i)	B (78); A is incorrect because this is the number of protons C is incorrect because this is the number of nucleons D is incorrect because this is the number of nucleons + protons		1
(ii)	time taken; and either of for (radio)activity to halve; for half of the (radioactive) {nuclei / atoms / isotope / mass} to decay;	allow "how long it takes" reject "half the time" allow count rate for activity ignore substance	2
(iii)	one mark for each correct cross drawn (8, 8000); (16, 4000); (24, 2000);	curve from (iv) can be used to infer correct data points	3
(iv)	smooth curve of best fit drawn; correct reading of time to decrease to 5000;	can be used to infer points in (iii) ecf candidate's curve within 1 square NB - perfect curve would give answer between 13-14 days	2
(b) (i)	Geiger(-muller) tube/ GM tube / photographic film / scintillator;	allow detector or counter for tube ignore radiation detector	1
(ii)	idea that gamma is more penetrating than beta;	RA allow gamma less ionising (power) than beta	1
(c)	any three from: MP1. gamma is less ionising than beta; MP2. beta is more likely to cause cell damage than gamma; MP3. technetium decays more quickly; MP4. technetium is in the body for less time/short time;	RA allow named damage e.g. cancer, cell mutation etc. ignore half-life of technetium is less	3

Total for Question 8 = 13 marks



Question number	Answer	Notes	Marks												
2 (a)	2;		1												
(b)	all rows correct;; any 2 rows correct; e.g. <table><tr><th>Constituent</th><th>Parent nucleus</th><th>Daughter nucleus</th></tr><tr><td>strontium-94</td><td></td><td>✓</td></tr><tr><td>uranium-236</td><td>✓</td><td></td></tr><tr><td>xenon-140</td><td></td><td>✓</td></tr></table>	Constituent	Parent nucleus	Daughter nucleus	strontium-94		✓	uranium-236	✓		xenon-140		✓		2
Constituent	Parent nucleus	Daughter nucleus													
strontium-94		✓													
uranium-236	✓														
xenon-140		✓													
(c)	any two from: MP1. neutrons absorbed by another <u>nucleus</u>; MP2. uranium-235 named; MP3. <u>nucleus</u> splits, releasing more neutrons (and process repeats);	do not penalize use of atom for nucleus for more than one mark	2												

Total for question 2 = 5 marks

Question number	Answer	Notes	Marks												
2 (a)	one mark for each correct row;;;;		3												
	<table><tr><th>Statement</th><th>Nuclear fission</th><th>Nuclear fusion</th></tr><tr><td>requires high pressure and high temperature</td><td></td><td>✓</td></tr><tr><td>energy is released</td><td>✓</td><td>✓</td></tr><tr><td>radioactive daughter nuclei are produced</td><td>✓</td><td></td></tr></table>			Statement	Nuclear fission	Nuclear fusion	requires high pressure and high temperature		✓	energy is released	✓	✓	radioactive daughter nuclei are produced	✓	
	Statement	Nuclear fission		Nuclear fusion											
	requires high pressure and high temperature			✓											
	energy is released	✓		✓											
radioactive daughter nuclei are produced	✓														
(b)	control rods absorb <u>neutron(s)</u> ; moderator reduces speed of <u>neutron(s)</u> ;	ignore controls rate of reaction condone stops <u>neutron(s)</u> allow reduces kinetic energy of <u>neutron(s)</u> ignore controls speed	2												

Total for Question 2 = 5 marks

Question number	Answer	Notes	Marks														
2 (a)	all three correct ticks = 3 marks;;; two correct ticks = 2 marks;; one correct tick = 1 mark;	-1 for 4 ticks -2 for 5 ticks 0 marks if all ticked	3														
	<table><tr><th>Statement</th><th>Correct (✓)</th></tr><tr><td>uranium-235 loses a proton to become uranium-236</td><td></td></tr><tr><td>uranium-235 absorbs a neutron to become uranium-236</td><td>✓</td></tr><tr><td>daughter cells are produced when uranium-236 splits</td><td></td></tr><tr><td>the nuclear energy store of uranium-236 increases when it splits</td><td></td></tr><tr><td>two or three neutrons are typically released when uranium-236 splits</td><td>✓</td></tr><tr><td>energy is transferred to the kinetic store of the fission products when uranium-236 splits</td><td>✓</td></tr></table>	Statement	Correct (✓)	uranium-235 loses a proton to become uranium-236		uranium-235 absorbs a neutron to become uranium-236	✓	daughter cells are produced when uranium-236 splits		the nuclear energy store of uranium-236 increases when it splits		two or three neutrons are typically released when uranium-236 splits	✓	energy is transferred to the kinetic store of the fission products when uranium-236 splits	✓		
Statement	Correct (✓)																
uranium-235 loses a proton to become uranium-236																	
uranium-235 absorbs a neutron to become uranium-236	✓																
daughter cells are produced when uranium-236 splits																	
the nuclear energy store of uranium-236 increases when it splits																	
two or three neutrons are typically released when uranium-236 splits	✓																
energy is transferred to the kinetic store of the fission products when uranium-236 splits	✓																
(b)	neutron / n / neutrons;		1														
(c)	B (a helium nucleus); A is incorrect because this describes gamma radiation C is incorrect because this describes beta radiation D is incorrect because this describes neutron radiation		1														
(d)	beta (minus);	accept β , β^- reject beta plus	1														

Total for Question 2 = 6 marks



Question number	Answer	Notes	Marks
4 (a) (i)	mass number = 3; atomic number = 1;		2
	(ii) idea that a (further) neutron is required (for further fission reactions); (but) no neutrons produced (in the fission process);		2
(b)	fission is the splitting of a <u>nucleus</u> ; fusion is the joining of two <u>nuclei</u> ;	allow “breaking down”, “dividing” for splitting allow “fusing”, “combining” for joining	2

Total for Question 4 = 6 marks



Question number	Answer	Notes	Marks
6 (a)	creation of a (large) nucleus from small nuclei; resulting in a loss of mass; and the release of energy;	condone “fusing of two nuclei” accept reference to $E=mc^2$ condone “converted to energy”	3
(b) (i)	electrical working;	condone ‘electrically’	1
(ii)	substitution in $V_{in}I_{in} = V_{out}I_{out}$; re-arrangement; evaluation; correct answer = 1.8 (kA) e.g. input power = output power $V_{in}I_{in} = V_{out}I_{out}$ $28 \times 21 = 330 \times I_{out}$ $I_{out} = (28 \times 21) \div 330$ $I_{out} = 1.7818...$	-1 POT error	3

Total for Question 6: 7 marks

Question number	Answer	Notes	Marks
5 (a)	(uranium) initial nucleus absorbs a neutron /eq ; (uranium) nucleus splits/fission releasing (further) neutron(s); idea of neutrons can be absorbed by or can cause further fissions with other (uranium) nuclei	ignore collide/hit/aimed at reject atoms/molecules/partic les etc	3
(b)	any TWO from: absorb neutron(s); idea of preventing them from causing fission; idea of slowing rate of fission;	ignore named material e.g. boron condone reduces rate of reaction condone control rate of fission/rate of reaction	2
(c)	fission is the splitting of a nucleus; fusion is the combining of nuclei;	allow reasonable alternative for split allow reasonable alternative for combining, including 'fusing' reject atoms/particles/molecu les/neutrons	2
(d) (i)	C - fusion; A cannot be correct as there are very few nuclei with $Z > 82$; B cannot be correct as there are very few nuclei with $A > 56$; D cannot be correct as fusion is required to produce excited nuclei		1
(ii)	idea of (electrostatic) repulsion of nuclei or protons (prevents fusion);		1

Total for question 5: 9 marks



Question number	Answer	Notes	Marks
3 (a)	(i) neutron;		1
	(ii) <u>nucleus/nuclei</u> splitting; releasing (two) daughter nuclei / neutrons / energy;	condone <u>nucleus/nuclei</u> breaking apart ignore daughter cells allow smaller/lighter nuclei for daughter nuclei	2
	(iii) neutrons released (by fission) are absorbed by other (uranium) nuclei; causing fission/splitting in other (uranium) nuclei;	condone atoms for nuclei condone atoms for nuclei	2
(b)	concrete / lead / (thick) steel;		1
(c)	graphite; slow; boron; absorb;		4

Total for Question 3 = 10 marks

Question number	Answer	Notes	Marks
2 (a)	(i) reduce the kinetic energy of <u>neutrons</u> ;	allow 'slow down' <u>neutrons</u>	1
	(ii) to absorb (high energy) neutrons;	allow absorb / reduce strength of neutron radiation condone "stop neutrons escaping"	2
	use of (concrete / lead) shielding;	allow "concrete walls"	
	(iii) idea that contamination is when a non-radioactive object comes into contact with a radioactive material; idea that irradiation is when radiation is present;	Condone idea of exposure for 1 mark if no other mark scored	
(b)	(i) any two from: MP1. creation of a (large) nucleus from small <u>nuclei</u> ; MP2. resulting in a loss of mass; MP3. and the release of energy;	condone "fusing of two nuclei" accept reference to $E=mc^2$ condone "converted to energy"	2
	(ii) (in) star(s);	allow named star e.g. The Sun	1
	(iii) any three from: MP1. high temperature required; MP2. to increase kinetic energy of nuclei; MP3. high pressure required; MP4. (because) <u>nuclei</u> need to be close enough to collide; MP5. (since) <u>nuclei</u> repel each other;	allow to make nuclei move faster allow particles or atoms for this MP allow higher level answers in terms of short range strong nuclear force	3

Total for Question 2 = 11 marks



Question number	Answer		Notes	Marks
9 (a)	1 mark for each correct answer in the table:,,,,;			5
	Part	Function	Suitable material	
	control rod	absorbs neutrons / regulates number of neutrons / controls rate of reaction	boron	
	moderator	slows <u>neutrons</u> / absorbs KE of <u>neutrons</u>	graphite	
	shielding	prevents irradiation of workers	concrete / lead / steel / water	
	fuel Rod	idea that it provides material for fission	uranium(-235/238) / plutonium / U / Pu	
(b)	(i)	same number of protons; different number of neutrons;	allow same atomic number, same element allow different nucleon number, different mass number, different atomic mass	2
	(ii)	fission is the splitting of a <u>nucleus</u> ; fusion is the joining of two <u>nuclei</u> ;	allow “breaking down” for splitting allow “fusing”, “combining” for joining	2
	(iii)	star / <u>fusion</u> reactor / hydrogen bomb / red giant / supernova;	allow any named star or fusion reactor, i.e. Sun, JET, ITER reject protostar, white dwarf	1
	(iv)	any two from: MP1. nuclei move (too) slowly at low temperature; MP2. nuclei interact/collide less often at low pressure; MP3. <u>nuclei</u> repel each other; MP4. <u>nuclei</u> cannot get close enough / don't have chance to undergo fusion;	allow RA in terms of high temperature and high pressure allow nuclei not having enough KE allow atoms/particles for nuclei allow atoms/particles for nuclei	2

Total for Question 9 = 12 marks



Question number	Answer	Notes	Marks
10 (a)	$236 - (97 + 135);$ $x = 4;$	answer of 4 scores 2	2
(b)	(fission) releases neutrons; neutrons can be captured by other uranium nuclei ; (these nuclei) then undergo fission;		3
(c)	evidence of halving of 72 (kBq); evidence of four half-lives required; e.g. count rate after 4 half-lives is 4.5 (kBq) evidence that four half-lives is equivalent to 60 million years;		3
(d)	Any FIVE from: MP1 idea of strong containers; MP2 idea that containers can't rust; MP3 idea that rust-proof containers expensive/difficult to manufacture; MP4 reference to security of waste site; MP5 reference to dilution in sea water; MP6 reference to leakage into water table;	accept idea of a location that prevents rust accept low earthquake risk	5

(Total for Question 10 = 13 marks)

Question number	Answer	Notes	Marks
4 (a)	(kinetic/thermal/heat) <u>energy</u> ;	condone nuclear <u>energy</u> condone <u>energy</u> as gamma waves ignore heat, radiation	1
(b)	A (absorb excess neutrons); <i>B is incorrect because neutrons cannot be created</i> <i>C is incorrect because fusion does not occur in a fission reactor</i> <i>D is incorrect because neutrons cannot be split</i>		1
(c)	C (slow down neutrons); <i>A is incorrect because this would not affect the rate of fission</i> <i>B is incorrect because this would not affect the rate of fission</i> <i>D is incorrect because faster neutrons would reduce the rate of fission</i>		1
(d) (i)	idea (that radiation can) remove electrons from atoms/molecules;	condone idea (that radiation) turns atoms/molecules into (positive) ions ignore references to α , β , γ reject if reference given to gaining electrons	1
(ii)	idea that it is not possible to know when nuclei will decay;	allow idea that decay is unpredictable / has no pattern ignore spontaneous	1
(iii)	idea that radiation (emitted in the reactor) is harmful; shielding absorbs radiation; idea that amount of radiation reaching people/workers is less/zero;	allow named harmful effect e.g. cell damage, cancer etc. allow shielding blocks radiation allow shielding prevents radiation escaping ignore protect people	3

Total for Question 4 = 8 marks

