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EDEXCEL GCSE PHYSICS: QUESTIONS BY TOPIC

Radioactivity (6)

GCSE Physics (Foundation) Topic 6

14 questions · 153 marks · Mark schemes included

Pearson Edexcel GCSE (9-1) Physics 1PH0, Foundation Tier, June 2018 - June 2025

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HOW TO USE THIS BOOKLET

Questions run from the lowest mark tariff to the highest, so similar questions sit together.

Click any row below to jump straight to that 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

14 questions · 153 marks · lowest tariff first



9-MARK QUESTIONS

3 questions in this booklet



3 This question is about nuclear reactions.

(a) When a uranium-235 (U-235) nucleus absorbs a neutron, the nucleus splits into smaller parts.

This reaction is called nuclear fission.

How many daughter nuclei are produced from the fission of one nucleus of uranium-235 (U-235)?

(1)

- ☐ **A** two
- ☐ **B** three
- ☐ **C** four
- ☐ **D** six

(b) (i) When a uranium-235 (U-235) nucleus splits, neutrons are also emitted.

The neutrons may start a chain reaction.

Describe what is meant by a chain reaction.

You may draw a diagram to help with your answer.

(2)

.....

.....

.....

.....

(ii) In the nuclear reactor of a power station, the chain reaction has to be controlled.

Explain the action of a moderator in a nuclear reactor.

(2)

.....

.....

.....

.....



(iii) In a nuclear reactor there are 2.0×10^{17} fission reactions each second.

Each fission reaction releases 4.0×10^{-11} J of energy.

Calculate the energy released in 1 second.

(2)

energy released in 1 second = ... J

(c) Nuclear fusion is a nuclear reaction that takes place in the Sun.

Describe what happens during a nuclear fusion reaction.

(2)

.....

.....

.....

.....

(Total for Question 3 = 9 marks)



4 An atom has a central nucleus containing neutrons and protons.

Electrons orbit the nucleus.

(a) (i) Which row of the table gives the relative mass and charge of a proton?

(1)

		relative mass	charge
☐	A	0	+1
☐	B	0	-1
☐	C	1	+1
☐	D	1	-1

(ii) An atom has a radius of 1.0×10^{-10} m.

A nucleus has a radius of 1.0×10^{-15} m.

Calculate the ratio of the radius of the atom to the radius of the nucleus.

(2)

ratio of radius of atom to radius of nucleus = ...

(iii) Explain why an atom has no charge overall.

(2)

.....

.....

.....

.....



(b) One isotope of carbon is carbon-14.



(i) State the number of protons in one atom of carbon-14.

(1)

number of protons = ...

(ii) State the number of neutrons in one atom of carbon-14.

(1)

number of neutrons = ...

(iii) Figure 6 shows a graph for the decay of the radioactive isotope carbon-14.

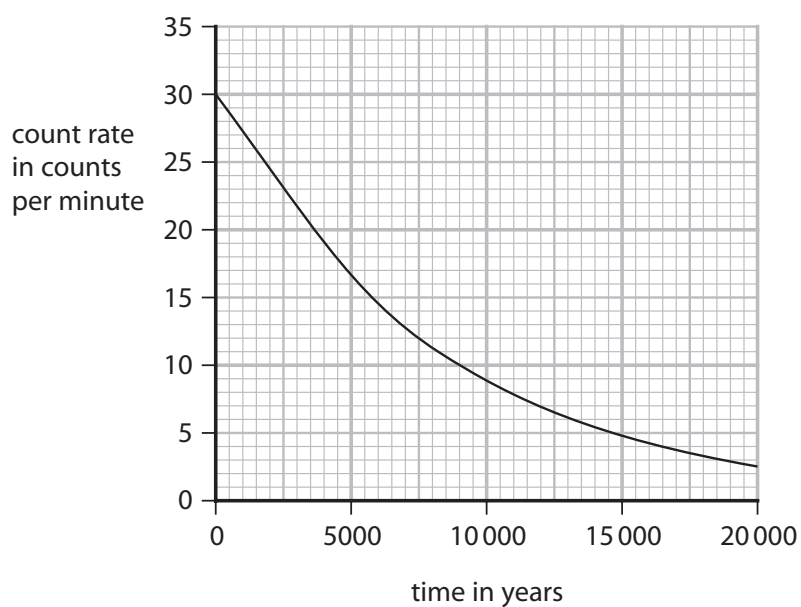


Figure 6

Use the graph to estimate the half-life of carbon-14.

(2)

half-life = ... years

(Total for Question 4 = 9 marks)



4 (a) Figure 6 shows a diagram of a helium atom.

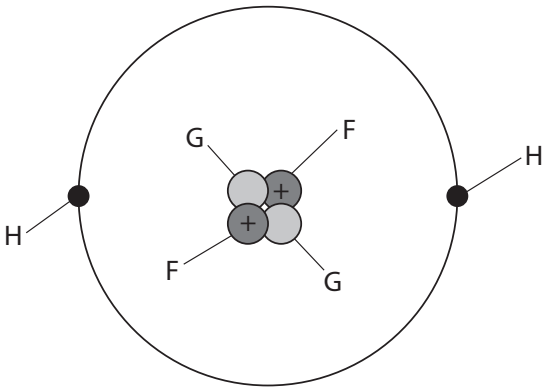


Figure 6

Complete the table for particles G and H, as shown in Figure 6.

(4)

particle	name of particle	charge
F	proton	positive
G		
H		

(b) An atom of beryllium has the symbol



The beryllium atom has 4 protons.

(i) Determine the number of neutrons in this atom.

(1)

number of neutrons

(ii) Determine the number of electrons in this atom.

(1)

number of electrons



(c) (i) Which of these is the unit for the activity of a radioactive isotope?

(1)

- ☐ **A** second (s)
- ☐ **B** kilogram (kg)
- ☐ **C** kelvin (K)
- ☐ **D** becquerel (Bq)

(ii) The isotope nitrogen-13 (N-13) has a half-life of 10 minutes.

A sample of N-13 has an initial mass of 120 g.

Calculate the mass of N-13 that remains after 30 minutes.

(2)

mass remaining = ... g

(Total for Question 4 = 9 marks)



10-MARK QUESTIONS

3 questions in this booklet



5 Figure 8 shows a helium nucleus.

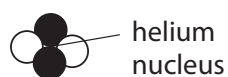


Figure 8

(a) Two of the particles in the helium nucleus are neutrons.

State the name of the other two particles in the helium nucleus.

(1)

(b) (i) Describe the difference between a fusion reaction and a fission reaction.

(2)

(ii) Nuclear fusion does not happen at low temperatures because of electrostatic repulsion between

(1)

- ☐ A beta particles
- ☐ B electrons
- ☐ C neutrons
- ☐ D protons

(c) The energy released per kilogram of fuel in a fusion reaction is 845 000 GJ.

The energy released per kilogram of fuel in burning oil is 0.0394 GJ.

- (i) Calculate the ratio of the energy released in fusion compared with the energy released in burning oil.

Use the equation

$$\text{ratio} = \frac{\text{energy released from fusion}}{\text{energy released by burning oil}} \quad (2)$$

ratio = ...

- (ii) State **two** advantages of using a fusion reactor rather than burning oil in a power station.

(2)

1

2

- (iii) State **two** of the difficulties that need to be overcome to produce a fusion reactor.

(2)

1

2

(Total for Question 5 = 10 marks)



- 6 (a) Figure 10 shows a safety sign on the door of a laboratory where radioactive materials are used.



Figure 10

- (i) State **one** way that radioactivity can be dangerous to humans.

(1)

.....

.....

- (ii) State **one** piece of equipment that can be used to measure radioactivity.

(1)

.....

.....

- (iii) Alpha (α) radiation and ultraviolet (UV) radiation are ionising radiations.

Give **two** other ionising radiations.

(2)

1

.....

2

.....

(b) Sulfur-35 is a radioactive isotope of sulfur.

Figure 11 represents a nucleus of sulfur-35.



Figure 11

Draw one line from each type of particle to the number of that type of particle in a nucleus of sulfur-35.

(3)

type of particle

number of particles

proton

35

neutron

16

nucleon

51

19



(c) A sample of a radioactive isotope has a mass of 520 g.

The half-life of the radioactive isotope is 18 days.

(i) Calculate the mass of the original radioactive isotope remaining after 18 days.

(1)

mass after 18 days g

(ii) Calculate the mass of the original radioactive isotope remaining after 54 days.

(2)

mass after 54 days g

(Total for Question 6 = 10 marks)



6 Figure 12 is a diagram representing an atom.

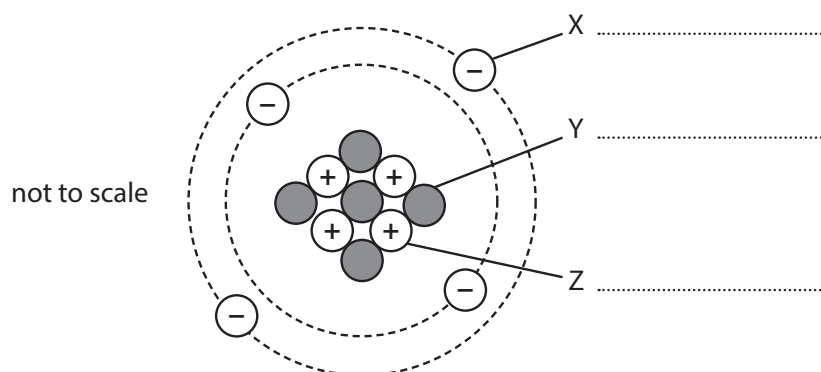


Figure 12

(a) Write the names of the particles X, Y and Z on the lines next to each letter in Figure 12.

(3)

(b) The nucleus of a different atom emits a gamma ray.

What happens to the number of particles in the nucleus?

(1)

- ☐ **A** it decreases by one
- ☐ **B** it decreases by two
- ☐ **C** it decreases by four
- ☐ **D** it does not change

(c) A teacher demonstrates a radioactivity experiment to a class of students.

The teacher places a radioactive source in front of a radiation detector.

(i) State **one** safety precaution the teacher should take.

(1)

(ii) The teacher uses the detector to measure the activity of the source several times.

Figure 13 shows the results.

	1st measurement	2nd measurement	3rd measurement	4th measurement
activity in Bq	21	23	19	22

Figure 13

The teacher tells the class that radioactive decay is random.

State how the data in Figure 13 supports this statement.

(1)

(iii) Calculate the mean of the **four** measurements in Figure 13.

(1)

mean = ... Bq



- (d) The teacher moves the radiation detector to different distances from the radioactive source.

The teacher determines the mean detector reading at each distance from the source.

The teacher plots the results on graph paper, as shown in Figure 14.

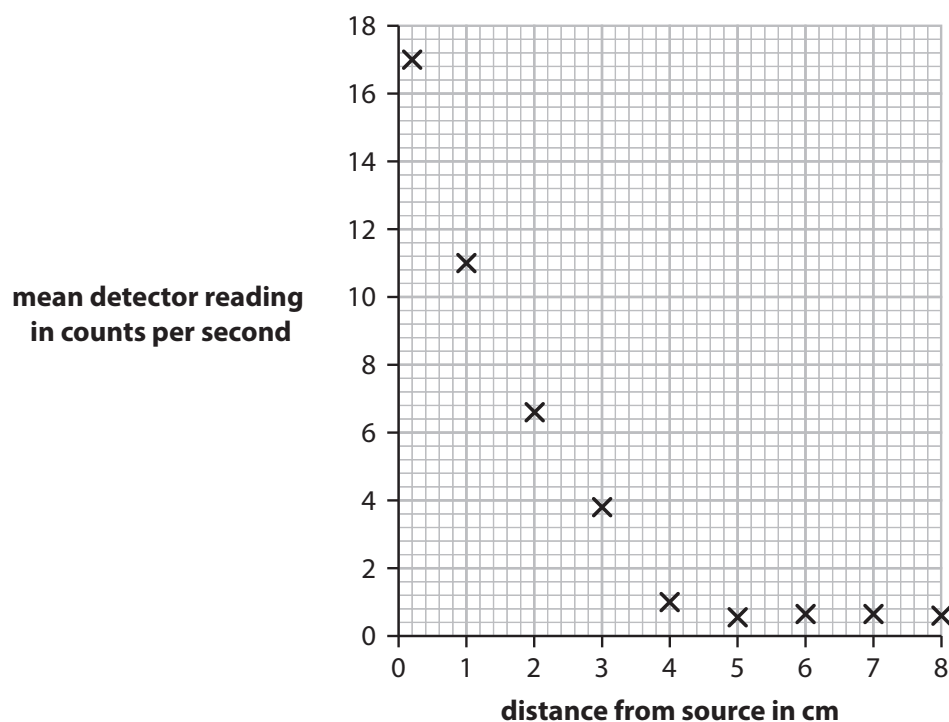


Figure 14

- (i) The source emits alpha radiation **only**.

Explain how the graph in Figure 14 shows that the source only emits alpha radiation.

(2)

.....

.....

.....

- (ii) Give a reason why the mean detector reading in Figure 14 does not fall to zero in this experiment.

(1)

.....

.....

(Total for Question 6 = 10 marks)



11-MARK QUESTIONS

4 questions in this booklet



- 5 (a) Figure 8 shows the symbol for the nucleus of an atom of strontium-90.



Figure 8

- (i) How many protons are in the nucleus of an atom of strontium-90?

(1)

- ☐ A 38
☐ B 52
☐ C 90
☐ D 128

- (ii) How many neutrons are in the nucleus of an atom of strontium-90?

(1)

- ☐ A 38
☐ B 52
☐ C 90
☐ D 128



- (b) The half-life of strontium-90 is 29 years.

The table in Figure 9 gives some information about how the mass of a sample of strontium-90 changes with time.

mass of strontium-90 in g	time in years
1600	0
.....	29
400	

Figure 9

Complete the table in Figure 9.

(2)

- (c) A teacher sets up an experiment to show some students how far beta particles travel in air.

Figure 10 shows some of the equipment she uses.



(Source: www.einstein.yu.edu)

Figure 10

- (i) State the scientific name for the radioactivity detector shown in Figure 10.

(1)

.....

The teacher also has:

- a radioactive source that emits only beta particles
- a metre rule.

(ii) State **two** precautions the teacher must take to protect herself from the effects of radioactivity.

(2)

1.....

.....

2.....

.....

(iii) Describe how the teacher could show how far beta particles travel in air.

(4)

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(Total for Question 5 = 11 marks)



10 (a) Radioactive tracers can be used when scanning a person's kidneys.

A radioactive isotope is injected into a person's blood stream.

The isotope emits radiation.

As the blood flows through the kidneys, this radiation is detected outside the body by a scanner.

(i) What type of radiation travels from the kidney to the scanner?

(1)

- ☐ **A** alpha
- ☐ **B** beta plus
- ☐ **C** beta minus
- ☐ **D** gamma

(ii) During the scan, a technician needs to take readings for about 30 minutes.

The half-life of the isotope used is about 6 hours.

1. State why an isotope with a half-life of about 6 minutes is **not** suitable.

(1)

.....

.....

2. State why an isotope with a half-life of about 6 days is **not** suitable.

(1)

.....

.....

(iii) State **two** ways of reducing the radiation risks to the technician.

(2)

1.....

.....

2.....

.....



(b) Figure 17 is a diagram of a nuclear reactor.

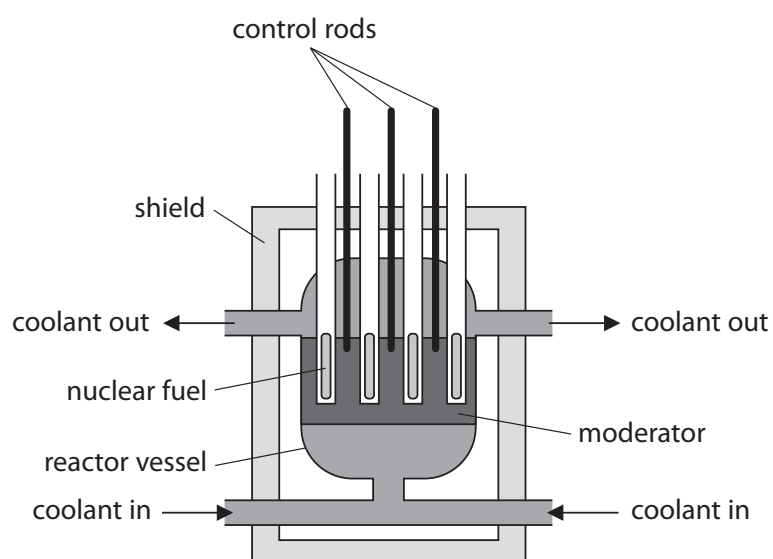


Figure 17

(i) Explain how pushing the control rods further into the reactor slows down the nuclear chain reaction.

(2)

.....

.....

.....

.....

- (ii) The moderator in a nuclear reactor slows down the neutrons so that the neutrons are more likely to start other fission reactions.

In a nuclear reactor,

- the average speed of the fast neutrons is 3.0×10^7 m/s
- the average speed of the slow neutrons is 4.0×10^3 m/s

Calculate the average speed of the slow neutrons as a percentage of the average speed of the fast neutrons.

(2)

.....%

- (iii) The nuclear reaction is the first stage in the process of generating electricity.

Describe how energy is transferred from the nuclear reaction to the next stage in the process.

(2)

.....

.....

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.....

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.....

(Total for Question 10 = 11 marks)



10 (a) Radiation is used to treat tumours (cancer).

The source of the radiation can be inside or outside the human body.

Which of these has a radiation source that can be positioned inside the body to treat tumours?

(1)

- ☐ **A** gamma rays
- ☐ **B** x-rays
- ☐ **C** radio waves
- ☐ **D** microwaves

(b) Figure 22 shows a PET scanner used to detect cancerous tumours.

A radioactive isotope is injected into a patient.

The isotope is absorbed by the tumour.

The isotope emits positrons from the location of the tumour.

The ring of radiation detectors rotates around the person.

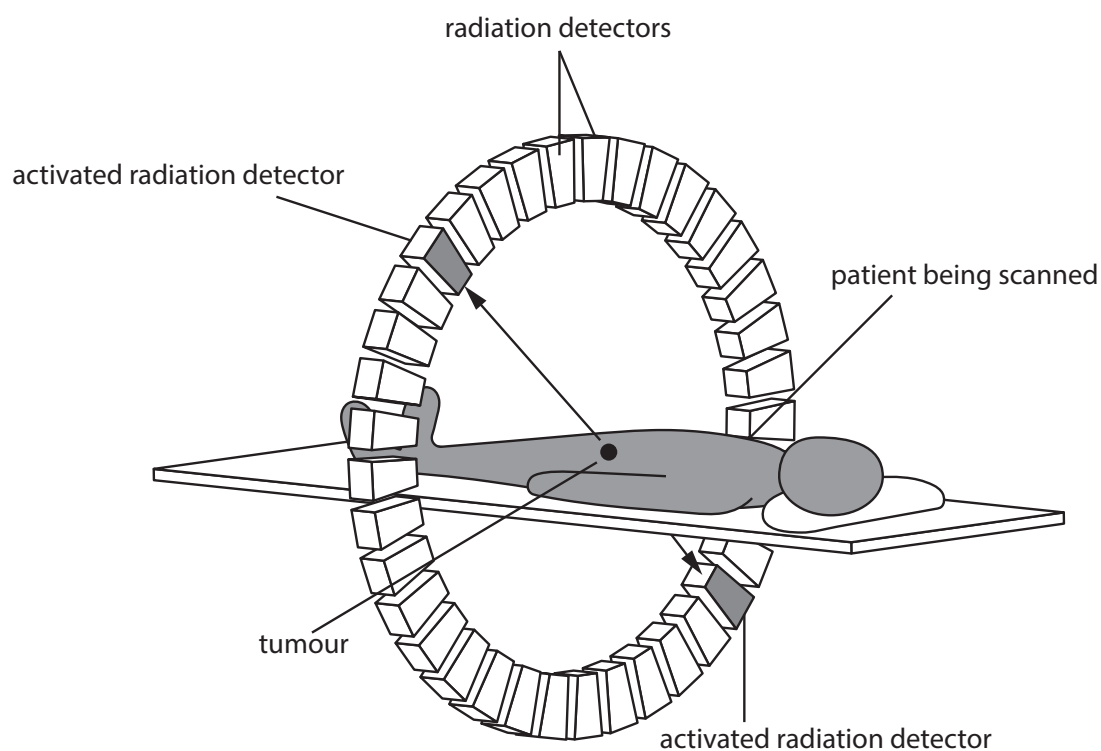


Figure 22

(i) Explain how the scan can give the location of the tumour.

(3)

.....

.....

.....

.....

.....

.....

(ii) Explain why the radioactive isotope injected into the patient must be produced near to the place where it is to be used.

(2)

.....

.....

.....

.....

(c) Radiotherapy can involve irradiation of patients.

Radioactive tracers can involve contamination of patients.

State **two** differences between irradiation and radioactive contamination.

(2)

1

.....

2

.....



(d) Figure 23 shows the decay curves of two different isotopes, Q and P.

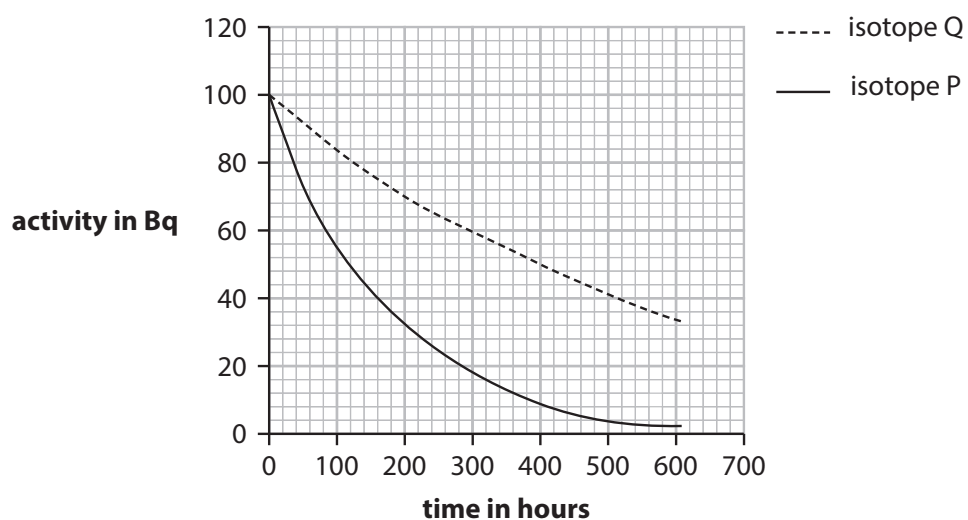


Figure 23

(i) Use the graph in Figure 23 to determine the half-life of isotope P.

(2)

half-life of isotope P = ... hours

(ii) Suggest a reason why the sample of isotope Q could be more dangerous to humans than the sample of isotope P.

(1)

(Total for Question 10 = 11 marks)

10 This question is about using radioactivity and nuclear energy.

(a) (i) Gamma ray irradiation of food kills harmful bacteria by using

(1)

- ☐ **A** ionising particles
- ☐ **B** ionising radiation
- ☐ **C** non-ionising particles
- ☐ **D** non-ionising radiation

(ii) Which part of a nuclear reactor is used to absorb neutrons?

(1)

- ☐ **A** control rods
- ☐ **B** coolant
- ☐ **C** moderator
- ☐ **D** PET scanner

(b) The isotope fluorine-18 is used in PET scans, which help to detect cancers.

Figure 20 shows a radioactive decay curve for a sample of fluorine-18.

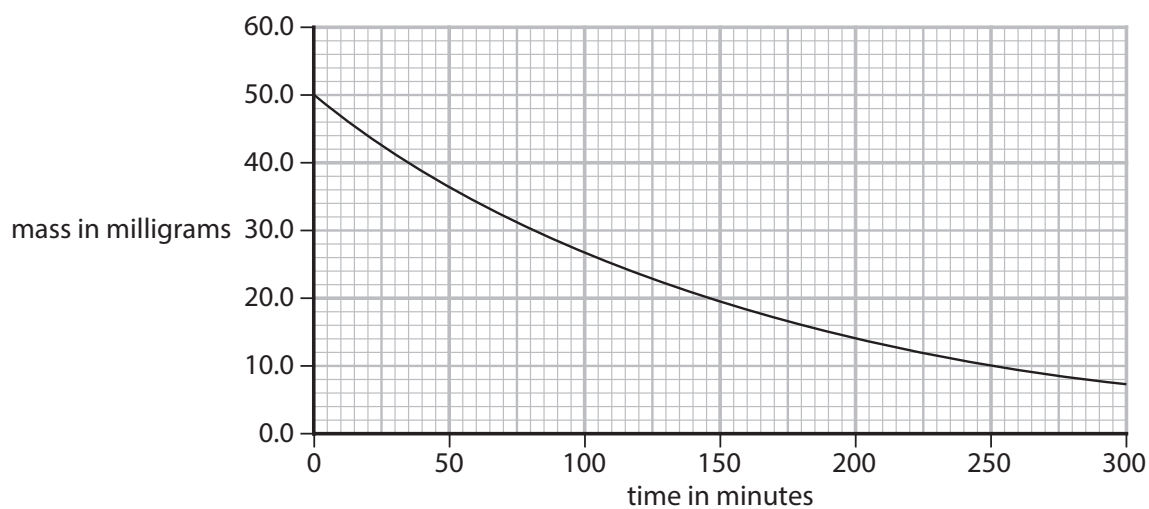


Figure 20

- (i) Use the graph to calculate the percentage of fluorine-18 remaining after 150 minutes.

(2)

percentage of fluorine-18 remaining after 150 minutes = ... %

- (ii) Fluorine-18 releases positrons.

Describe what happens when positrons meet electrons.

(2)

.....

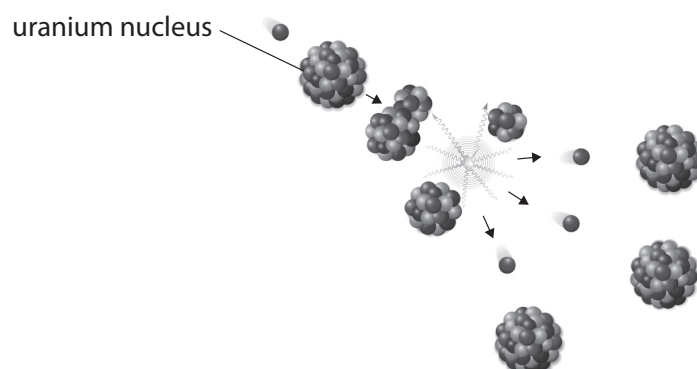
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(c) Figure 21 shows what happens during a fission chain reaction.



(Source: © Designua/Shutterstock)

Figure 21

Explain what happens when **one** neutron interacts with **one** uranium nucleus.

(3)

.....

.....

.....

.....

.....

.....

(d) In 2023, Finland produced 4.4 GW of power from nuclear power plants.

The UK produced 8.9 GW of power from nuclear power plants.

Calculate the ratio of nuclear power produced in Finland compared with the UK as

$$\frac{\text{power production in Finland}}{\text{power production in the UK}}$$

Give your answer to 2 significant figures (2 s.f.).

(2)

ratio = ...

(Total for Question 10 = 11 marks)

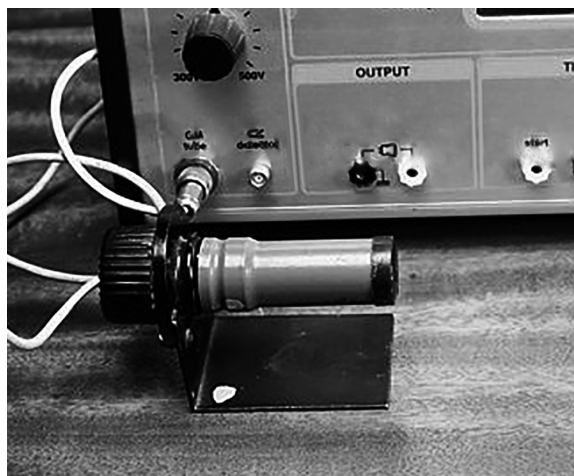


13-MARK QUESTIONS

4 questions in this booklet



- 9 Figure 17 shows a Geiger-Müller (GM) tube used for measuring radioactivity.



©Andrew Lambert Science Photo Library

Figure 17

- (a) Describe how a teacher should use a Geiger-Müller (GM) tube to compare the count-rates from two different radioactive rocks.

(4)

.....

.....

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.....

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.....

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.....

(b) A hospital uses a radioactive isotope with a half-life of 6 hours.

A technician measures a count rate of 80 counts per minute (cpm) from this isotope.

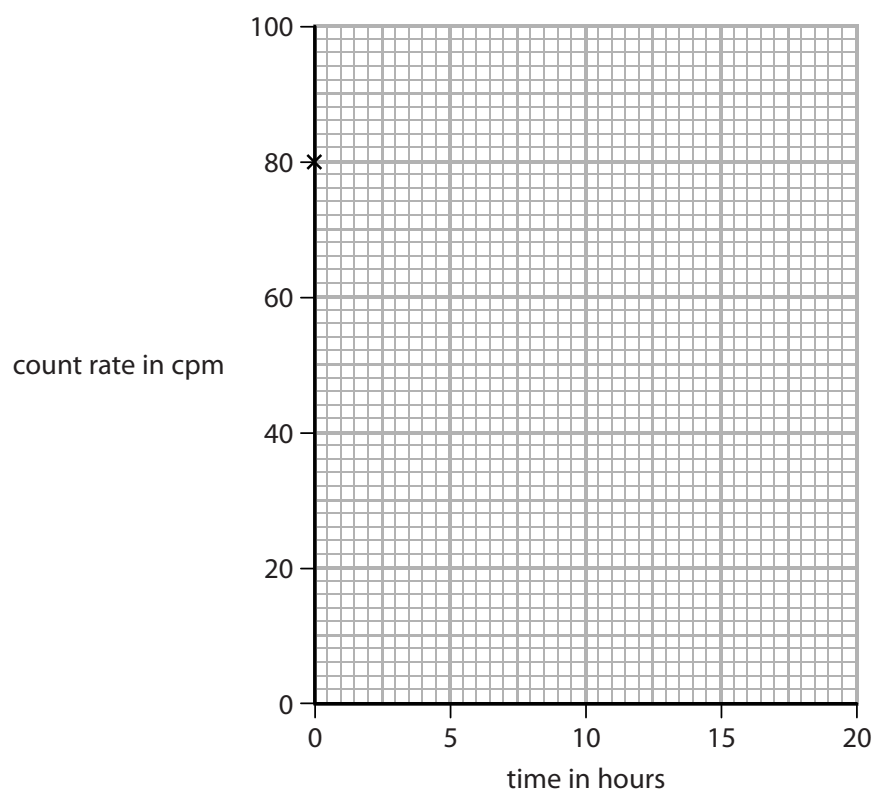


Figure 18

Complete the graph on Figure 18, as accurately as possible, to show how the count-rate from this isotope will change from the time of the first measurement.

The first point is already drawn in Figure 18.

(3)



- 7 (a) Use words from the box to complete the sentences about nuclear fission of uranium-235 (U-235).

chain	chemical	fuse
neutrons	protons	split

(3)

A neutron hits a nucleus of U-235 and causes the nucleus to

Each fission releases energy, two daughter nuclei and some

In a nuclear reactor, one fission can set off a controlled reaction.

- (b) Both U-235 and oil can be used as energy sources for generating electricity.

1 kg of natural uranium can result in the generation of 45 000 units of electricity.

1 kg of oil can result in the generation of 5.0 units of electricity.

Calculate the mass of oil needed to generate the same amount of electricity as 1 kg of natural uranium.

(2)

mass of oil = ... kg

- (c) Both using nuclear fuel and burning oil produce harmful waste products.

State **one** harmful waste product from each process.

(2)

using nuclear fuel

.....

burning oil

.....

*(d) Figure 14 shows a household smoke alarm that uses radioactivity to detect smoke.



Courtesy NASA/JPL-Caltech

Figure 14

The radioactive source in the smoke detector is americium-241.

The table in Figure 15 shows some information about americium-241 and two other radioactive sources.

radioactive source	type of radiation	half-life
americium-241	alpha	433 years
actinium-225	alpha	10 days
cobalt-60	gamma	5.27 years

Figure 15

Explain why americium-241 is the best of these three sources to use in this smoke detector.

Use information from Figure 15 and your own knowledge about radiation.

Your answer should refer to

- properties of alpha and gamma radiation
- half-life.

(6)

(Total for Question 7 = 13 marks)

9 This question is about radioactivity.

(a) Alpha (α), beta (β) and gamma (γ) are three types of radioactive emissions.

Which statement describes **all** of these radioactive emissions?

(1)

- ☐ **A** ionising and emitted by stable nuclei
- ☐ **B** ionising and emitted by unstable nuclei
- ☐ **C** neutral and emitted by stable nuclei
- ☐ **D** neutral and emitted by unstable nuclei

(b) Fluorine-19 is a stable isotope of the element fluorine.

The element fluorine also has several radioactive isotopes.

Describe **one** similarity and **one** difference between the numbers of particles in one nucleus of fluorine-19 and one nucleus of a radioactive isotope of fluorine.

(2)

similarity

.....

difference

.....



- (c) Figure 14 shows a Geiger-Muller (G-M) tube attached to a counter. The G-M tube is used to measure the activity of a source of beta (β) radiation. There is an aluminium sheet between the beta source and the G-M tube. The counter is switched on and after 1 minute shows a count of 268.

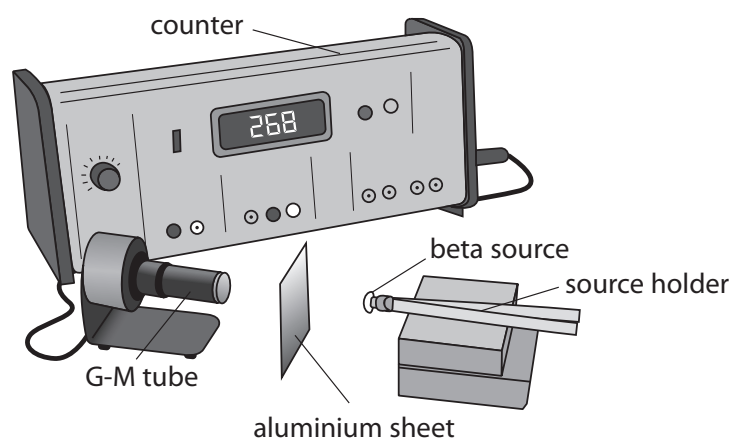


Figure 14

- (i) The aluminium sheet is taken away. The counter is reset to zero and then switched on again. A new count is taken for 1 minute.

Explain why the new count is greater than 268.

(2)

.....

.....

.....

.....

- (ii) The beta source is then also taken away.
The counter is reset to zero and switched on again.
A new count is taken for 1 minute.

Give a reason why there would now be a reading on the counter.

(1)

- (iii) State the SI unit for the activity of a radioactive source.

(1)

- *(d) Exposing people to radioactive sources can be dangerous.

Describe the dangers of exposure to radioactive sources and what can be done to protect hospital staff when they are working with radioactive sources.

(6)

(Total for Question 9 = 13 marks)



7 This question is about radioactivity and its uses.

(a) Which of these radiations does **not** have a charge?

(1)

- ☐ A alpha
- ☐ B beta minus
- ☐ C beta plus
- ☐ D gamma

(b) Which of these radiations is used in smoke detectors?

(1)

- ☐ A alpha
- ☐ B beta minus
- ☐ C beta plus
- ☐ D gamma

(c) The diagram in Figure 13 shows a radioactive source used to check the thickness of paper.

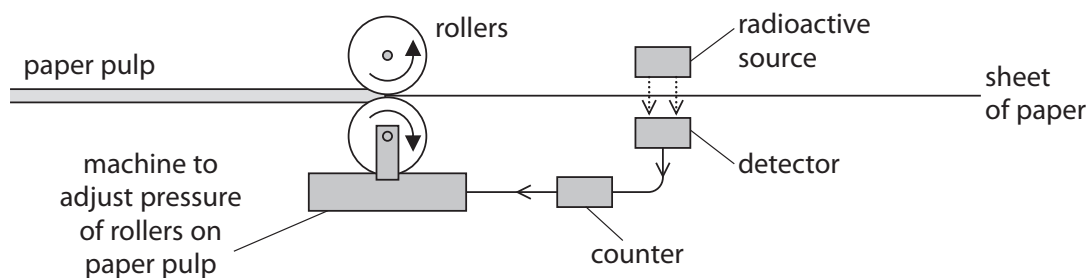


Figure 13

(i) Name the type of radiation used to check the thickness of the paper.

(1)

(ii) Give the name of **one** device which could detect this type of radiation.

(1)

When the paper is the correct thickness, the count rate is 4000 counts per minute.

(iii) The count rate increases when the paper gets thinner.

Give **one** reason for this increase.

(1)

(iv) The rollers need to be adjusted if the count rate increases by 5%.

Calculate the maximum count rate that would be allowed before the rollers need to be adjusted.

(2)

maximum count rate = ... counts per minute



*(d) Radioactivity from radioactive sources can be used in the diagnosis and treatment of cancer.

Describe **one** way radioactivity can be used in the diagnosis of cancer and **one** way radioactivity can be used in the treatment of cancer.

(6)

(Total for Question 7 = 13 marks)

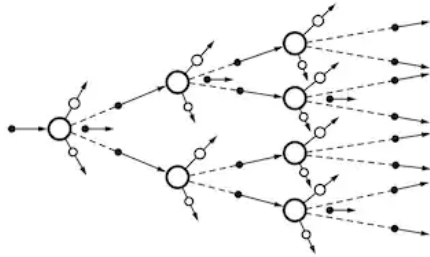


MARK SCHEMES

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Question number	Answer	Additional guidance	Mark
3a	A two B is not correct as a uranium nucleus does not split to give 3 daughter nuclei C is not correct as a uranium nucleus does not split to give 4 daughter nuclei D is not correct as a uranium nucleus does not split to give 5 daughter nuclei		(1) AO1

Question number	Answer	Additional guidance	Mark
3bi	A description including: EITHER neutrons are absorbed by uranium nuclei/atoms (1) more neutrons are produced/emitted (which are absorbed by uranium nuclei) (1) OR diagram (no labels needed) two nuclei/atoms splitting (1) four or more nuclei/atoms splitting (1)  shutterstock.com • 1177431790	ignore any reference to bonds accept hit /collide with accept a controlled chain reaction diagram for 2 marks	(2) AO1

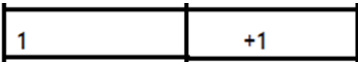
Question number	Answer	Additional guidance	Mark
3bii	An explanation linking: (because the moderator/it) slows down/increases the chance of absorption of(1) neutrons (1)		(2) AO1

Question number	Answer	Additional guidance	Mark
3biii	substitution(1) $2(.0 \times 10^{17}) \times 4(.0 \times 10^{-11})$ evaluation (1) $8(.0) \times 10^6$ (J)	accept 8000000(J) accept 8MJ 8 to any other power of ten scores 1 mark award full marks for correct answer without working.	(2) AO2

Question number	Answer	Additional guidance	Mark
3c	A description including one from hydrogen nuclei/atoms join (1) helium is produced (1) one from lost (total) mass (1) mass is converted to energy (1)	nuclei/atoms join larger/heavier nucleus produced energy is released	(2) AO1

Total marks for question 3 = 9



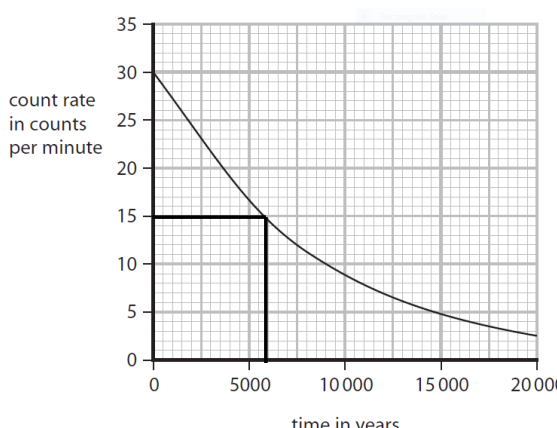
Question Number	Answer	Mark
4 a (i)	C  A is incorrect the proton has a mass of 1 not 0 B is incorrect the proton has a mass of 1 not 0 D is incorrect the proton has a charge of +1 not -1	(1) AO1

Question Number	Answer	Additional guidance	Mark
4 a(ii)	substitution (1) ratio = $\frac{10^{-10}}{10^{-15}}$ evaluation (1) 10^5	$10^{-10} : 10^{-15}$ accept suitable equivalent ratios e.g. $1 \times 10^5 : 1$ $1 : 10^{-5}$ or $10^5 : 1$ $1 : 0.00001$ or $100000 : 1$ allow 1 mark for inverted ratios e.g. $10^{-15} : 10^{-10}$ $0.00001 : 1$ or $1 : 100000$ award full marks for the correct answer with no working	(2) AO2

Question Number	Answer	Additional guidance	Mark
4 a(iii)	an explanation linking same number / amount of (1) electrons and protons (1)	equal number / amount of allow balanced (number / amount of) negative and positive charges ignore (neutral) neutrons reject positive/negative neutrons for 2nd marking point	(2) AO1

Question Number	Answer	Additional guidance	Mark
4 (b)(i)	6 / six		(1) AO1

Question Number	Answer	Additional guidance	Mark
4 (b)ii	8 / eight		(1) AO2

Question Number	Answer	Additional guidance	Mark
4 (b)(iii)	indication of horizontal line between 14 and 16 and / or vertical line between 5250 and 6250 (1)  value between 5250 (years) and 6250 (years) inclusive (1)	accept alternative indications e.g. cross on curve accept any halving pairs e.g. going between 20 cpm and 10 cpm award full marks for the correct answer with no working	(2) AO3

Total for question 4 = 9 marks

Question number	Answer	Mark
4 (a)	1 mark for answer in each box, marked independently:	(4) AO1.1

Question number	Answer	Additional guidance	Mark
4 (b) (i)	5 (1)	five	(1) AO1.1

Question number	Answer	Additional guidance	Mark
4 (b) (ii)	4 (1)	four	(1) AO1.1

Question number	Answer	Additional guidance	Mark
4 (c) (i)	D becquerel (Bq) A, B and C are not units for activity		(1) AO1.1

Question number	Answer	Additional guidance	Mark
4 (c) (ii)	Identification of 3 half-lives OR $\frac{1}{8}$ left (1) evaluation (1) 15 (g)	evidence of halving a number 3 times evidence of halving 120(g) award full marks for correct answer without working award one mark only for 40(g) (thinking three half lives means $\div 3$)	(2) AO2.1

Total for Question 4 = 9 marks



Question Number	Answer	Mark
5(a)	proton(s)	(1) AO 1 1

Question Number	Answer	Additional guidance	Mark
5(b)(i)	a description referring to: fusion involves coming together / joining of particles / nuclei / atoms (1) fission involves (larger) particle(s) / nuclei / atoms breaking up (1)	not just 'fuse together' that's just restating – more explanation needed particles etc. coming apart / separating no marks if just objects / things joining / coming apart	(2) AO 1 1

Question Number	Answer	Mark
5(b)(ii)	D protons The only correct answer is D <i>A 'beta particles' is incorrect, they are not found in nuclei to facilitate that repulsion</i> <i>B 'electrons' is incorrect, for the same reason as A</i> <i>C 'neutrons' is incorrect as they don't repel each other</i>	(1) AO 1 1

Question Number	Answer	Additional guidance	Mark
5(c)(i)	substitution (1) <u>845 000</u> 0.0394 evaluation (1) 21 000 000	answers that round to 21 000 000 $2.1(45) \times 10^7$ etc. award full marks for the correct answer without working	(2) AO 2 1

Question Number	Answer	Additional guidance	Mark
5(c)(ii)	any two from: - fusion power gives (many) more times the energy output (for the same mass used) - no greenhouse gases / CO₂ emissions (produced with the fusion alternative) - does not lead to global warming - no (radioactive) waste - does not deplete / use up a finite resource (e.g. oil)	may quote numbers here accept no or less pollution / no or less harmful gases etc. sustainable reference oil is running out ignore references to costs	(2) AO 1 1

Question Number	Answer	Additional guidance	Mark
5(c)(iii)	any two from: - problem of containment (the fusion gases / isotopes at high temperatures) (maintaining) high temperature (maintaining) high pressure		(2) AO 2 1

(Total for Question 5 = 10 marks)



6(a)(i)	One from: cell damage (1) cancer (1) radiation sickness / poisoning (1) mutation (1) chromosomal damage (1) dna damage (1) skin damage (1) (named) organ damage (1) burns (1) releases ionising radiation (1)	allow ionises / kills cells	(1) AO1
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	Answer	Additional guidance	Mark
6 (a)(ii)	any one from: Geiger (Muller) (tube/counter) photographic film dosimeter	accept recognisable spellings GM film badge	(1) AO1

	Answer	Additional guidance	Mark
6(a)(iii)	any two from: beta(minus)/ $\beta(-)$ (1) beta + (1) x-rays (1) gamma/ γ (1)	accept positron in place of beta + accept proton beam accept electron beam maximum of 1 mark if one incorrect radiation given zero marks if two incorrect radiations given	(2) AO1

Question number	Answer	Additional guidance	Mark
6(a)	X: electron (1) Y: neutron (1) Z: proton (1)	accept recognisable spellings. accept Y and Z in the wrong order for 1 mark independent of any mark for X	3 AO1.1

Question number	Answer	Additional guidance	Mark
6(b)	D it does not change A, B and C are incorrect because the number of nucleons does not change in gamma emission		1 AO1.1

Question number	Answer	Additional guidance	Mark
6(c)(i)	any one from: keep a safe distance (1) point the source away from people (1) handle the source with tongs/at a distance (1) limit exposure time/return source to store (asap) (1) use shielding (1) use of gloves / mask (1) protective clothing (1) wear a film badge/monitor (1)	(store in) lead-lined box use of screen PPE ignore goggles	1 AO1.2

Question number	Answer	Additional guidance	Mark
6(c)(ii)	the activity varies (slightly) (1)	numbers / counts / results / measurements are different no pattern increases and decreases ignore random(ly)	1 AO1.1

Question number	Answer	Additional guidance	Mark
6(c)(iii)	21 (1)	$\frac{21+23+19+22}{4}$ or $\frac{85}{4}$ accept 21.3 or 21.2 or 21.25 do not accept 21.5 (median)	1 AO3.2

Question number	Answer	Additional guidance	Mark
6(d)(i)	an explanation linking any two from readings fall (to almost zero) (1) radiation is (all) absorbed (1) after a few cm (of air) (1)	accept graph / activity / measurements for readings stopped by air in a short distance (in air) reverse arguments must include beta and gamma	2 AO2.1

Question number	Answer	Additional guidance	Mark
6(d)(ii)	background radiation (1)	or words to that effect accept named examples ignore reference to original alpha source	1 AO2.1

Total for question 6 = 10 marks



Question number	Answer	Mark
5(a)(i)	☒ A 38 B is number of neutrons C is mass number D is an irrelevant addition of two numbers	(1)

Question number	Answer	Mark
5(a)(ii)	☒ B 52 A is number of protons C is mass number D is an irrelevant addition of two numbers	(1)

Question number	Answer	Additional guidance	Mark								
5(b)	<table><tr><th>mass in g</th><th>time in days</th></tr><tr><td>1600</td><td>0</td></tr><tr><td>800 (1)</td><td>29</td></tr><tr><td>400</td><td>58 (1)</td></tr></table>	mass in g	time in days	1600	0	800 (1)	29	400	58 (1)	numbers in correct boxes	(2)
mass in g	time in days										
1600	0										
800 (1)	29										
400	58 (1)										

Question number	Answer	Additional guidance	Mark
5(c)(i)	Geiger-Müller tube	accept Geiger (counter) geiger (counter) GM (tube) gm(tube) accept any recognisable (phonetic) spelling	(1)

Question number	Answer	Additional guidance	Mark
5(c)(ii)	any two from: keep a safe distance (1) point the source away from people (1) handle the source with tongs/at a distance (1) limit exposure time/return source to store (asap) (1) use shielding (1) use of gloves (1) use of mask (1) protective clothing (1) wear a film badge/monitor (1)	use of screen Do not credit goggles	(2)

Question number	Answer	Additional guidance	Mark
5(c)(iii)	a description to include four from: take measurement without source (1) place source in front of/near/close to detector (1) increase the distance (between source and detector) (1) measure distance (from source to detector) (1) take reading from the screen/counter (1) until reading gets to background value /constant value (1) use same time for each count (1) repeat / check when down to low values (1)	measure/account for background (count) DO NOT allow 'inside' allow reverse argument by starting with detector long way away from source allow zero as constant value mention of (count) <u>rate</u>	(4)

(Total for Question 5 = 11 marks)

Question Number	Answer	Mark
10 (a)(i)	D gamma <i>A is not correct because alpha cannot pass through and out of the body</i> <i>B is not correct because beta plus cannot pass through and out of the body</i> <i>C is not correct because beta minus cannot pass through and out of the body</i>	(1) AO1

	Answer	Additional guidance	Mark
10(a)(ii)1	decays too quickly to give a reading (1)	accept (half-life) not long enough for reading to be taken Ignore disappear after 12 min	(1) AO1

	Answer	Additional guidance	Mark
10(a)(ii)2	stays in the body too long (1)	accept could harm/damage other organs patients stay radioactive for too long so the patient does not get too high a dose of radiation	(1) AO1

	Answer	Additional guidance	Mark
10(a)(iii)	Two from: shielding (1) time limiting exposure (1) distance limiting exposure (1) wear PPE / protective clothing (1)	accept stand behind barriers / store (source) in lead box radiation monitoring badges leave the room/ go outside/stay away from the patient / use tongs lead aprons / gloves ignore goggles / masks	(2) AO1

	Answer	Additional guidance	Mark
10 (b)(i)	an explanation linking: (control rods) absorb <u>neutrons</u> (1) (so) fewer (neutrons) available for chain reaction (1)	ignore slow down the nuclear chain reaction accept (control rods) block <u>neutrons</u> accept <u>neutrons</u> can't pass through (control rods) fewer fission(s) (reactions)	(2) AO1

	Answer	Additional guidance	Mark
10 (b)(ii)	$\frac{4(.0 \times 10^3)(\times 100)}{3(.0 \times 10^7)} \quad (1)$ $1.3 \times 10^{-2} (\%) \quad (1)$	 0.013 (%) allow 0.01 (%) power of ten error scores 1 mark maximum award full marks for the correct answer without working	(2) AO2

	Answer	Additional guidance	Mark
10 (b)(iii)	A description to include: (from) kinetic energy (of fission fragments) (1) (transferred to) thermal energy (of coolant) (1)	accept references to energy stores accept energy in nuclear store accept nuclear energy / gamma radiation energy / binding energy / mass (to) thermal store (in coolant) accept heat for thermal allow steam transfers thermal energy/heat from reactor to kinetic energy of turbine for 2 marks	(2) AO1

Total Question 10 =11 marks

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10 (a)	A gamma rays B X-rays, C ultraviolet, D microwaves, all applied externally	1 AO1.1
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Question	Answer	Additional guidance	Mark
10(b)(i)	an explanation linking any 3 from positrons and electrons annihilate (1) (two) gamma rays produced/emitted (1) in opposite directions /at 180° (1) detected by radiation detector/ gamma cameras/scintillation counters (1) at (almost) the same time (1) time difference gives distance difference (1)	 ignore positrons for this marking point allow triangulation	3 AO2.2

	activity decreases rapidly/decays rapidly (1)	accept decays before use / does not last long	
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Question	Answer	Additional guidance	Mark
10 (d)(ii)	one suggestion from: (Q) has longer half-life (1) (Q) does not decay as quickly/ takes longer to decay (1) (Q) (maintains) a higher (level of) activity (1) (Q) gives a higher <u>dose</u> (1) (Q) emits more ionising (type of) radiation (1)	allow reverse arguments activity decreases more slowly (always) more (radio)active / more decays per second	1 AO2.2

Total for question 10 = 11 marks

Question number	Answer	Mark
10 (a) (i)	B ionising radiation (1) A is incorrect because gamma rays are considered as radiation in this context C and D are incorrect because gamma rays are ionising	(1) AO1.1

Question number	Answer	Mark
10 (a) (ii)	A control rods (1) B is incorrect because the coolant is used for the purpose of cooling C is incorrect because the moderator is used to slow neutrons down D is incorrect because a PET scanner is not part of a nuclear reactor.	(1) AO1.1

Question number	Answer	Additional guidance	Mark
10(b) (i)	reading from graph and substitution (1) $= \frac{19.5}{50} (\times 100)$ evaluation (1) 39 (%)	allow use of values between 19 and 20 allow values between 38(%) and 40(%) award full marks for correct answer without working.	(2) AO2.1

Question number	Answer	Additional guidance	Mark
10(b)(ii)	an explanation linking two from they collide (1) annihilate (1) (releasing a pair of) <u>gamma</u> ray(s) (1)	ignore interact/combine allow (charges) cancel/neutralise/become neutral photons ignore light	(2) AO1.1

Question number	Answer	Additional guidance	Mark
10 (c)	an explanation linking any three from neutron absorbed (into uranium) (1) (causing) nucleus becomes unstable (1) (so nucleus) breaks up/splits (into two nuclei) (1) (then) releasing (more) neutron(s)(1) releases gamma rays / energy (1)	allow collides/hits/joins with do not allow atoms for this mark allow daughter/smaller if no other marks scored award 1 mark for neutrons go onto hit other nuclei	(3) AO1.1

Question number	Answer	Additional guidance	Mark
10 (d)	substitution (1) $= \frac{4.4 (\times 10^9)}{8.9 (\times 10^9)}$ evaluation to 2 s.f.(1) 0.49	0.49438 allow 4.4:8.9 allow 44:89 allow 0.49:1 accept 1(.0): 0.49 award full marks for correct answer without working.	(2) AO2.1

Total for Question 10 = 11 marks



Question Number	Answer	Additional guidance	Mark
9(a)	a description to include: 1. put rock(s) in front of/near tube (1) 2. measure (count rate) separately for the two different rocks (1) 3. measure each count for the same time period (1) 4. keep source-detector distance the same for both rocks (1) 5. take (into account)/measure background count (1) 6. repeat readings and take average(s) (1)	not 'in' tube keep rocks apart	(4) AO 2 2

Question Number	Answer	Additional guidance	Mark
9(b)	- point after first half-life - 6, 40 (1) - point after second half-life - 12, 20 (1) - point after third half-life - 18, 10 (1)	within 1 small square by eye smooth curve starting at 80, with a decreasing gradient passing through one correct half-life point scores 2 marks smooth curve starting at 80, with a decreasing gradient passing through two correct half-life points scores 3 marks if no other mark scored smooth curve showing decreasing gradient but not going through any correct points scores 1 mark	(3) AO 3 1a

Question Number	Answer	Mark
9(c)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive, and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. A03 Strand 2a and 2b (6 marks) • shows some idea that the data can support arguments about alpha, beta and gamma radiation being present • argues that there is some evidence that alpha might be emitted (count rate going down with paper interposed) • argues that there is a lot of evidence that beta particles are emitted (count rate goes down a lot when the aluminium is inserted) • argues that there might be some gamma getting through (lead stopping everything apart from gamma) OR that with the lead present the count rate has gone down to a level consistent with background, so no gamma was present a level 3 answer will use data effectively	(6) AO 1 1

Level	Mark	Descriptor
	0	• No rewardable material.
Level 1	1-2	• Deconstructs scientific information but understanding and connections are flawed. An unbalanced or incomplete argument that provides limited synthesis of understanding. • Judgements are supported by limited evidence. (AO3)
Level 2	3-4	• Deconstructs scientific information and provides some logical connections between scientific concepts. An imbalanced argument that synthesises mostly relevant understanding, but not entirely coherently. • Judgements are supported by evidence occasionally. (AO3)
Level 3	5-6	• Deconstructs scientific information and provide logical connections between scientific concepts throughout. A balanced, well-developed argument that synthesises relevant understanding coherently. • Judgements are supported by evidence throughout. (AO3)

(Total for Question 9 = 13 marks)



Question number	Answer	Additional guidance	Mark
7(a)	split (1) neutrons (1) chain (1)	in this order	(3)

Question number	Answer	Additional guidance	Mark
7(b)	$\frac{45\,000}{5}$ (1) 9000 (kg) (1)	award full marks for the correct answer without working	(2)

Question number	Answer	Additional guidance	Mark
7(c)	using nuclear fuel: radioactive substances (1) burning oil: carbon dioxide (1)	named radioactive substance / nuclear waste greenhouse gases named pollutant toxic/poisonous gases atmospheric pollutant / acid rain	(2)

Question number	Indicative content	Mark
*7(d)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. AO3 strand 1 (3 marks) • americium emits alpha • cobalt emits gamma • americium has long(est) half-life • actinium has short(est) half-life AO2 strand 1 (3 marks) • alpha is the better ioniser • gamma is weakly ionising • alpha allows electricity to flow • alpha cannot get out of detector • gamma can get out of detector • americium won't run out • actinium would run out	(6)

Level	Mark	Descriptor
	0	• No awardable content
Level 1	1–2	• Interpretation and evaluation of the information attempted but will be limited with a focus on mainly just one variable. Demonstrates limited synthesis of understanding. (AO3) • The explanation attempts to link and apply knowledge and understanding of scientific ideas, flawed or simplistic connections made between elements in the context of the question. (AO2)
Level 2	3–4	• Interpretation and evaluation of the information on both variables, synthesising mostly relevant understanding. (AO3) • The explanation is mostly supported through linkage and application of knowledge and understanding of scientific ideas, some logical connections made between elements in the context of the question. (AO2)
Level 3	5–6	• Interpretation and evaluation of the information, demonstrating throughout the skills of synthesising relevant understanding. (AO3) • The explanation is supported throughout by linkage and application of knowledge and understanding of scientific ideas, logical connections made between elements in the context of the question. (AO2)



SUMMARY, for guidance

Level	Mark	Additional Guidance	General additional guidance – the decision within levels e.g. - At each level, as well as content, the scientific coherency of what is stated will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	<u>Additional guidance</u> Elements of physics, i.e. isolated fact from knowledge or table	<u>Possible candidate responses</u> americium emits alpha OR alpha needed for smoke detector
Level 2	3–4	<u>Additional guidance</u> Some understanding shown, i.e. link between fact from table and fact from knowledge	<u>Possible candidate responses</u> americium emits alpha that can't get out of the detector OR two facts (from either table of knowledge) americium emits alpha and has the long(est) half-life
Level 3	5–6	<u>Additional guidance</u> Understanding is detailed and fully developed, i.e. link between fact from table and fact from knowledge AND second fact (from either table or knowledge	<u>Possible candidate responses</u> americium emits alpha that can't get out of the detector AND americium has the long(est) half-life

(Total for Question 7 = 13 marks)

Question number	Answer	Mark
9(a)	B ionising and emitted by unstable nuclei A is incorrect stable nuclei do not give radioactive emissions C is incorrect not all radioactive emissions are neutral D is incorrect not all radioactive emissions are neutral	(1) AO1

Question number	Answer	Additional guidance	Mark
9(b)	same number of protons (1) different number of neutrons (1)	same atomic number different mass number	(2) AO2

Question number	Answer	Additional guidance	Mark
9(c)(i)	An explanation to include; there is no aluminium to absorb β particles (1) (therefore) more β particles reach the G-M tube (1)	aluminium absorbs/stops/blocks beta particles accept reverse arguments accept radiation for beta particles	(2) AO2

Question number	Answer	Additional guidance	Mark
9 c (ii)	(idea of) background radiation	a named source of background radiation	(1) AO3

Question number	Answer	Additional guidance	Mark
9c (iii)	becquerel	accept Bq accept close spelling	(1) AO1

Question number	Indicative content	Mark
9d*	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. Dangers of exposing people to radioactive sources / radiation. • it is ionising • may cause cancer • may destroy /kill cells • can mutate DNA • can burn the skin Protection of hospital staff using radioactive sources / radiation. • use tongs to carry radioactive sources • use lead containers to store sources • stay at a distance from radioactive sources • use sources for as short a time as possible • wear (lead lined) protective clothing (PPE) • give treatments from behind a shield /wall • wear a radiation badge (dosimeter)	(6) AO1

Level	Mark	Descriptor
	0	No rewardable material.
Level 1	1–2	Demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific, enquiry, techniques and procedures lacks detail. (AO1) Presents a description which is not logically ordered and with significant gaps. (AO1)
Level 2	3–4	Demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas, enquiry, techniques and procedures is not fully detailed and/or developed. (AO1) Presents a description of the procedure that has a structure which is mostly clear, coherent and logical with minor steps missing. (AO1)
Level 3	5–6	Demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas, enquiry, techniques and procedures is detailed and fully developed. (AO1)

		Presents a description that has a well-developed structure which is clear, coherent and logical. (AO1)
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Level	Mark	Additional Guidance	General additional guidance – the decision within levels e.g. - At each level, as well as content, the scientific coherency of what is stated will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	<u>Additional guidance</u> At least one isolated fact about the dangers of radiation and/or protection from radiation	<u>Possible candidate responses</u> it's ionising causes cancer burns you kills cells mutates DNA wear a radiation badge use tongs work from behind a shield use protective clothing
Level 2	3–4	<u>Additional guidance</u> simple explanation of the dangers of radiation and a fact about protection or reverse OR detailed explanation of the dangers of radiation or protection from radiation	<u>Possible candidate responses</u> radiation is ionising and can kill cells so wear a radiation badge or use tongs and stay at a distance from radiation source as it can cause cancer or use tongs to stay at a distance from radiation sources and wear a radiation badge
Level 3	5–6	<u>Additional guidance</u> detailed explanation of the dangers of radiation and protection from radiation	<u>Possible candidate responses</u> radiation is ionising and can kill cells and use tongs and stay at a distance from the radiation source

7 (a)	D gamma A,B and C all carry a charge	(1) AO1
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	Answer	Mark
7 (b)	A alpha B,C, and D travel too far in air and are not sufficiently ionising	(1) AO1

	Answer	Additional guidance	Mark
7 (c)(i)	beta, beta (minus), β , β^-	accept beta(plus), β^+	(1) AO1

	Answer	Additional guidance	Mark
7 (c)(ii)	Geiger-Muller (tube)/ G-M (tube)/ GM (tube)/ Geiger (counter)	accept ratemeter do not accept radiation meter accept phonetic spellings e.g. Giga	(1) AO1

	Answer	Additional guidance	Mark
7 (c)(iii)	one from more (radiation) passes through (the paper) (1) OR less (radiation) is absorbed (by the paper) (1) OR less paper (for radiation) to pass through/penetrate(1)	penetrates/gets through allow easier to pass through Ignore name of particle if given	(1) AO2

	Answer	Additional guidance	Mark
7 c(iv)	Calculation of 5% of count rate (1) $\frac{4000 \times 5}{100} \text{ or } 4000 \times 0.05$ $= 200$ evaluation (1) $4000 + 200 = 4200$	accept use of any percentage between 4% and 5% accept any value between 160 and 200 ecf for addition of incorrect calculated percentage and 4000 award full marks for any answer that rounds to 4200 without working	(2) AO2

Question number	Indicative content	Mark
7*(d)	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. AO1 Diagnosis Tracers - radioactive sources - swallowed by or injected into patients - travel around the body - emit gamma radiation (from radioactive decay) - gamma radiation passes out through the body - detected outside the body with a gamma camera PET Scanner (more of) the tracer goes to the cancer cells - gamma radiation is emitted (gamma rays) from/in different directions - gamma detected by gamma cameras (3D) pictures produced on a computer screen Named tracer, e.g. technetium, iodine, fluorine Treatment - Radiotherapy - Use of gamma rays/x-rays - kills cancer (cells) - radiating small area of body (with gamma rays/X rays) - radiation used for a short time (gamma rays) from/in different directions - brachytherapy - radioactive sources - inside the body - may not be removed - put close to cancerous tumour Ignore references to chemotherapy	(6) AO1

Level	Mark	Descriptor
	0	No rewardable material.
Level 1	1-2	- Demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) - Presents a description with some structure and coherence. (AO1)
Level 2	3-4	- Demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) - Presents a description that has a structure which is mostly clear, coherent and logical. (AO1)
Level 3	5-6	- Demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) - Presents a description that has a well-developed structure which is clear, coherent and logical. (AO1)



Level	Mark	Additional Guidance	General additional guidance – the decision within levels e.g. - At each level, as well as content, the scientific coherency of what is stated will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	<u>Additional guidance</u> isolated facts about cancer diagnosis or cancer treatment using radioactivity OR limited description about cancer diagnosis or limited description about cancer treatment using radioactivity OR allow isolated facts about cancer diagnosis using x-rays, C(A)T scans, MRI, ultrasound for level 1 if no other mark scored	<u>Possible candidate responses</u> Uses/emits gamma (rays) can kill cancer(ous) cells radiotherapy Cancer is treated using gamma rays CT scan is used to find tumours
Level 2	3–4	<u>Additional guidance</u> limited description about cancer diagnosis and limited description about cancer treatment using radioactivity OR detailed description of either cancer diagnosis or treatment using radioactivity	<u>Possible candidate responses</u> PET scans are used in diagnosis and radiotherapy is used to treat cancer OR Cancer is treated using gamma rays, the gamma rays kill the cancer cells
Level 3	5–6	<u>Additional guidance</u> detailed description about either diagnosis OR cancer treatment using radioactivity AND limited description about either cancer treatment OR diagnosis using radioactivity	<u>Possible candidate responses</u> Tracers are used in diagnosis and radiotherapy uses gamma rays to kill cells. OR Tracers emit gamma rays which pass out through the body and radiotherapy uses x-rays

Total Question 7 =13marks