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EDEXCEL GCSE PHYSICS: QUESTIONS BY TOPIC

Radioactivity (6)

GCSE Physics (Higher) Topic 6

15 questions · 155 marks · Mark schemes included

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

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 info@guidemygrades.com

 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

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

15 questions · 155 marks · lowest tariff first



6-MARK QUESTIONS

1 question in this booklet



1 (a) Radioactive substances are used in the generation of electricity.

State **two** other uses of radioactive substances.

(2)

1

2

(b) Figure 1 is a diagram of a nuclear reactor, used in the generation of electricity.

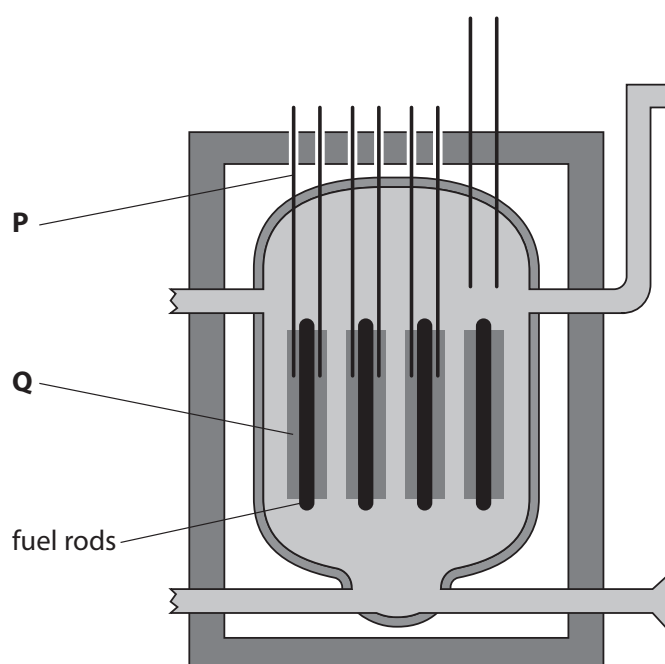


Figure 1

P may be used to shut down the reactor when necessary.

Q slows down neutrons to enable a chain reaction to take place.

State the name of the two parts labelled **P** and **Q**.

(2)

P

Q

(c) Explain how neutrons enable a nuclear chain reaction to take place.

(2)

(Total for Question 1 = 6 marks)

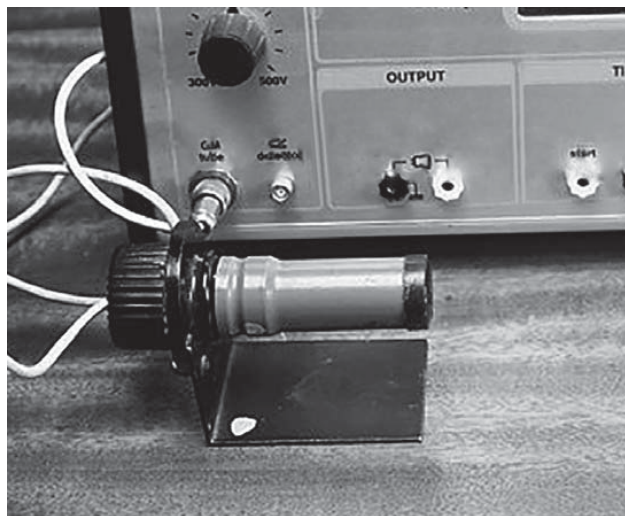


8-MARK QUESTIONS

2 questions in this booklet



- 3 Figure 4 shows a Geiger-Müller (GM) tube used for measuring radioactivity.



© Andrew Lambert Science Photo Library

Figure 4

- (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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(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.

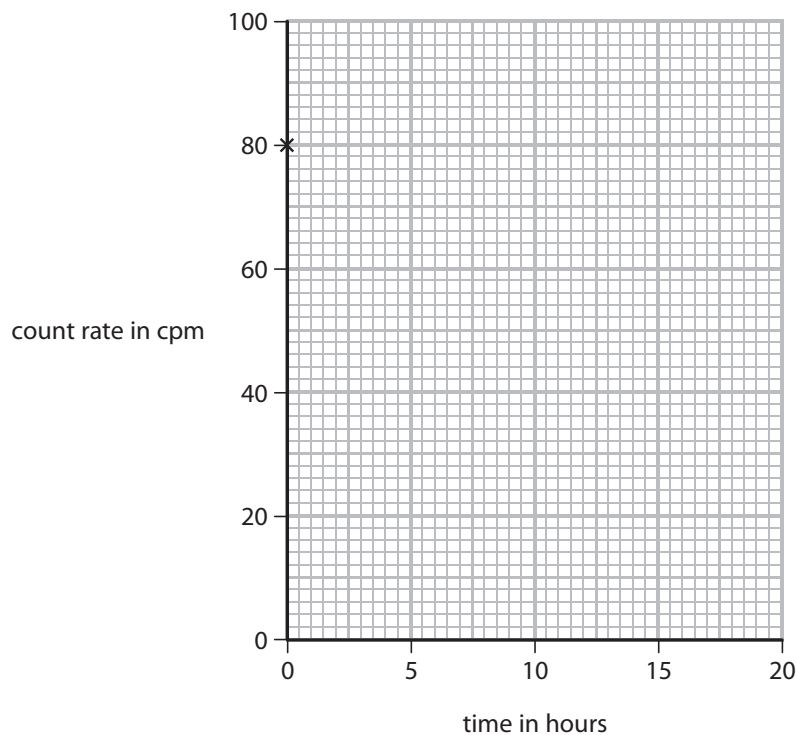


Figure 5

Complete the graph on Figure 5, 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 5.

(3)

(c) One radioactive source used in hospitals is technetium (Tc).

Technetium is produced from the radioactive decay of molybdenum (Mo).

Complete the following nuclear equation.

(1)



(Total for Question 3 = 8 marks)



- 1 (a) Nuclear fusion is a process that releases energy.

Which of these statements applies to a nuclear fusion reaction?

(1)

- ☐ **A** it emits daughter nuclei
- ☐ **B** it is a controlled chain reaction
- ☐ **C** it produces radioactive waste
- ☐ **D** it requires high temperature and pressure

- (b) In the Sun, four protons start the process of nuclear fusion.

These protons combine and finally produce a helium nucleus.

The helium nucleus has a smaller mass than the four protons.

This difference in mass is converted to energy.

Four protons have a total mass of 6.69×10^{-27} kg.

A helium nucleus has a mass of 6.64×10^{-27} kg.

Calculate the percentage of the original mass that has been converted to energy.

(3)

percentage of mass converted to energy %



- (c) Figure 1 shows the spectrum of an element detected in the light from a distant galaxy, from a nearby galaxy and from a source on Earth.

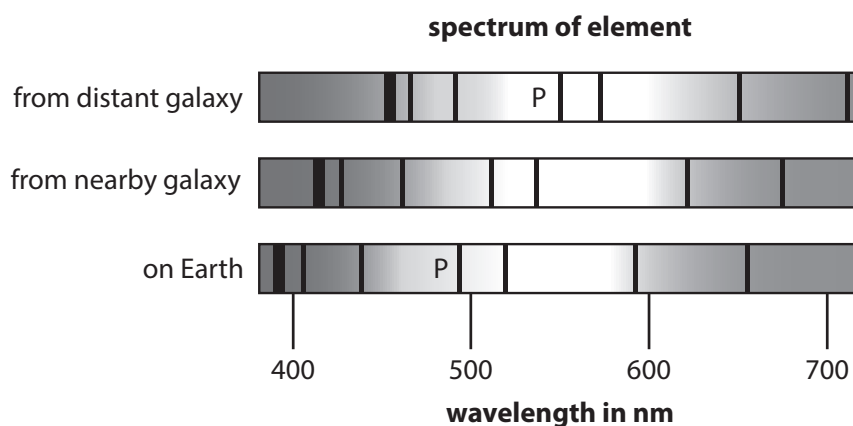


Figure 1

- (i) Estimate the difference between the wavelength of line P in the spectrum from the distant galaxy and the wavelength of line P in the spectrum on Earth.

(1)

difference in wavelength = ... nm

- (ii) Scientists have discovered that light from almost all distant galaxies has spectral lines shifted towards the red end of the spectrum.

Explain how red shift in light, received from galaxies at different distances from the Earth, supports the idea that the Universe is expanding.

(3)

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(Total for Question 1 = 8 marks)



9-MARK QUESTIONS

1 question in this booklet



3 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 3 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.

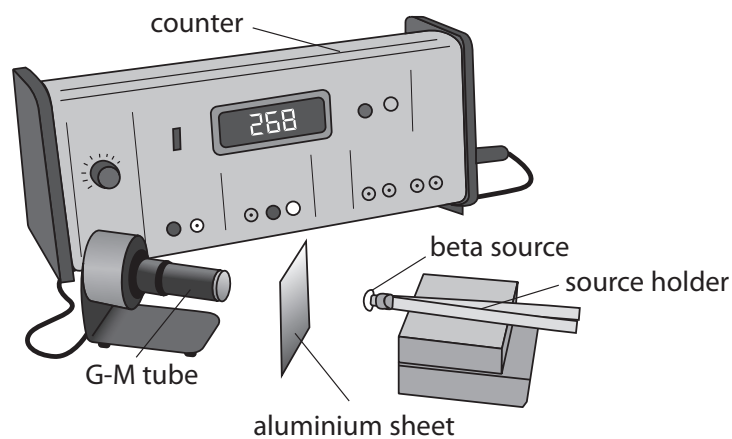


Figure 3

- (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)

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- (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) Radium-223 is a radioactive substance.

Radium-223 is an alpha emitter.

The half-life of radium-223 is 11 days.

A radioactive source contains 1.7×10^{23} nuclei of radium-223.

Calculate the number of radium-223 nuclei remaining in the source after a time of 33 days.

(2)

number of radium-223 nuclei remaining = ...

(Total for Question 3 = 9 marks)



10-MARK QUESTIONS

1 question in this booklet



- 7 (a) Figure 11 is the symbol for a nucleus of americium-241.



Figure 11

Americium-241 is a radioactive isotope of americium.

Americium-241 decays by emitting alpha (α) particles.

- (i) Which of these is the symbol for another radioactive isotope of americium?

(1)

- ☐ **A** ${}_{97}^{241}\text{Am}$
- ☐ **B** ${}_{96}^{243}\text{Am}$
- ☐ **C** ${}_{95}^{245}\text{Am}$
- ☐ **D** ${}_{94}^{247}\text{Am}$

- (ii) Which of these is the approximate maximum distance that alpha particles can travel in air at normal atmospheric pressure?

(1)

- ☐ **A** 5 mm
- ☐ **B** 5 cm
- ☐ **C** 5 m
- ☐ **D** 5 km

- (iii) Complete the equation in Figure 12 for americium-241 decaying into neptunium (Np).

(3)



Figure 12

(b) The activity of a radioactive source is measured as 128 Bq.

This is shown as a point on the graph in Figure 13.

(3)

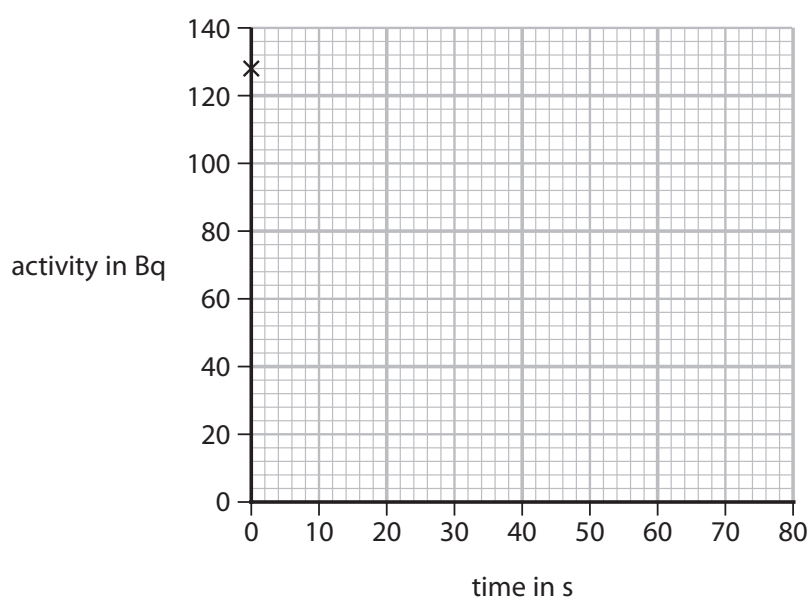


Figure 13

The half-life of this radioactive source is 17 s.

Use this information to plot three more points on the graph grid in Figure 13 to show how the activity of the source changes with time.

(c) Describe what happens in the nucleus of an atom when a positron is emitted.

(2)

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(Total for Question 7 = 10 marks)



11-MARK QUESTIONS

7 questions in this booklet



7 (a) Which of these describes isotopes of an element?

(1)

☐ A	same atomic number	different number of neutrons
☐ B	same atomic number	different number of protons
☐ C	same mass number	different number of neutrons
☐ D	same mass number	different number of protons

(b) Figure 9 represents a decay that can happen inside the nucleus of an atom.

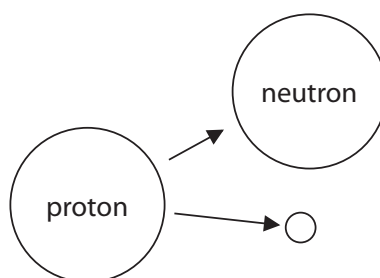


Figure 9

Which decay is represented in Figure 9?

(1)

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

(c) The half-life of cobalt-60 is 5 years.

A school cobalt source had an activity of 38.5 kBq in the year 2000.

Estimate the activity of this source in the year 2020.

(3)

activity = ... kBq

- (d) Explain what can happen to the body if a person has a prolonged exposure to gamma rays. (2)

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- (e) A G-M tube is connected to a counter.
 A teacher places the G-M tube near to a radioactive source.
 A student starts the counter and clock at the same time and writes down the readings shown on the counter every 15 s.

The student plots the readings with a line of best fit, as shown in Figure 10.

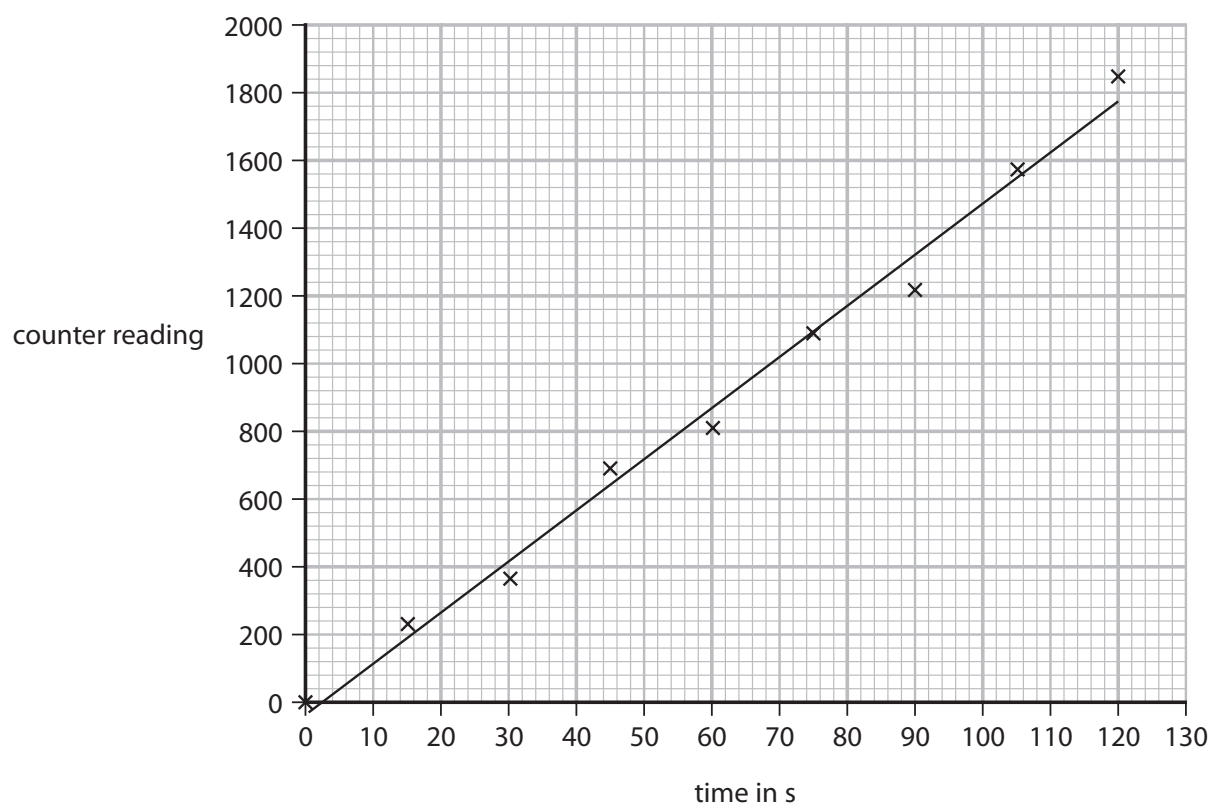


Figure 10

- (i) Calculate the average count rate, in counts/s, from the graph.

Show your working on the graph.

(2)

average count rate = ... counts/s



- (ii) The student says that the experiment must have been done carelessly because the data seemed quite scattered away from the best fit line.

The teacher claims such results should be expected in radioactivity experiments.

Justify the teacher's claim.

(2)

(Total for Question 7 = 11 marks)



- 9 (a) Sometimes food can become contaminated with radioactive substances.

Describe the harmful effects of eating food contaminated with radioactive substances.

(2)

- (b) Gamma radiation can be used in food processing to irradiate food.

Explain why some food is irradiated with gamma radiation.

(2)

- (c) Gamma radiation is part of the electromagnetic spectrum.

When the nucleus of an atom emits a gamma ray, the number of protons in the nucleus and the number of neutrons in the nucleus **do not** change.

State how the nucleus **does** change when it emits a gamma ray.

(1)

*(d) Gamma radiation is produced by radioactive decay.

Alpha radiation and beta radiation are also produced by radioactive decay.

Compare the processes of alpha decay and beta decay.

Your answer should include what each radiation is and what effect each decay has on the original nucleus.

(6)

(Total for Question 9 = 11 marks)



4 (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 6 is a diagram of a nuclear reactor.

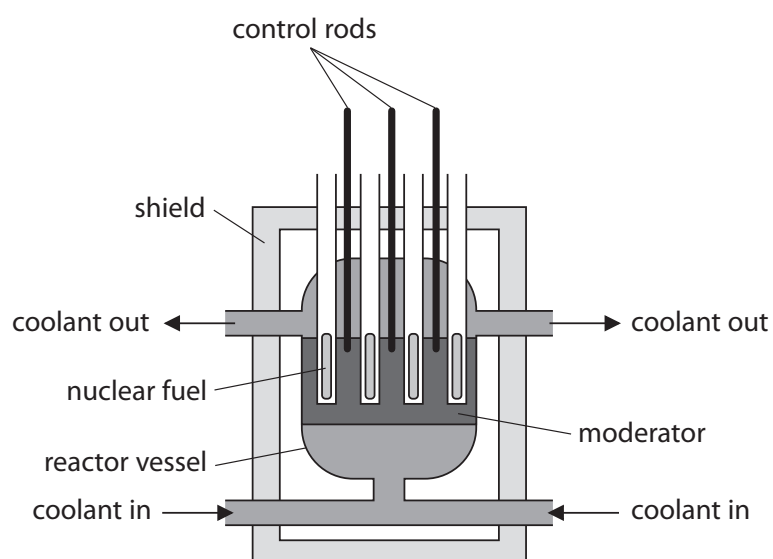


Figure 6

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

(2)

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- (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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(Total for Question 4 = 11 marks)



- 8 (a) Rutherford devised an experiment to fire alpha particles at thin gold foil.

It was found that alpha particles were scattered by the gold foil.

The gold foil was about 4.0×10^{-7} m thick.

A gold atom has a diameter of about 0.15 nm.

Estimate how many gold atoms would fit across this thickness of gold foil.

(2)

number of atoms = ...

- (b) The apparatus that was used in the experiment is shown in Figure 10.

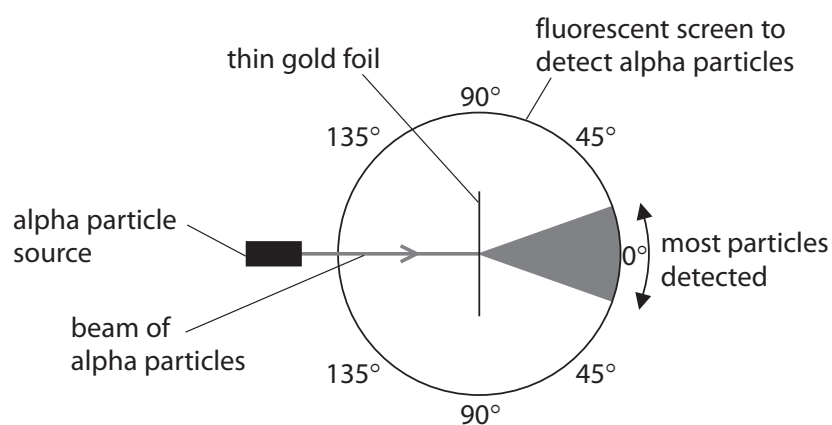


Figure 10

- (i) The number of particles detected at each angle in a given time is shown on the graph in Figure 11.

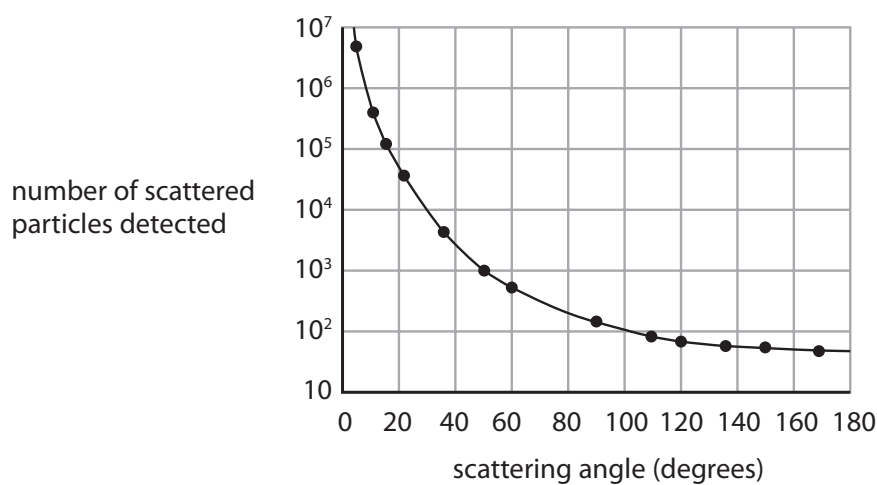


Figure 11

Use information from the graph.

Estimate the ratio of the number of particles scattered through 5° to the number of particles scattered through 100°.

(2)

ratio = ...

- (ii) Explain how the difference in the number of particles scattered at different angles gives evidence for the current model of the structure of the atom.

(4)

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(c) Students are given the apparatus shown in Figure 12 and a protractor.

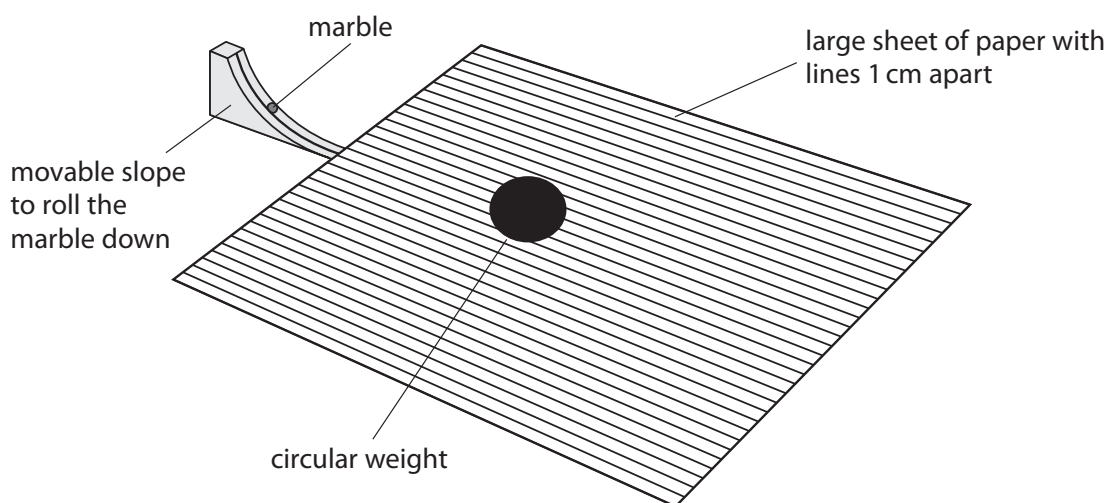


Figure 12

(i) Describe how the students could use the apparatus to model the scattering of alpha particles.

(2)

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(ii) Give **one** limitation of this model.

(1)

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(Total for Question 8 = 11 marks)

4 (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 5 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.

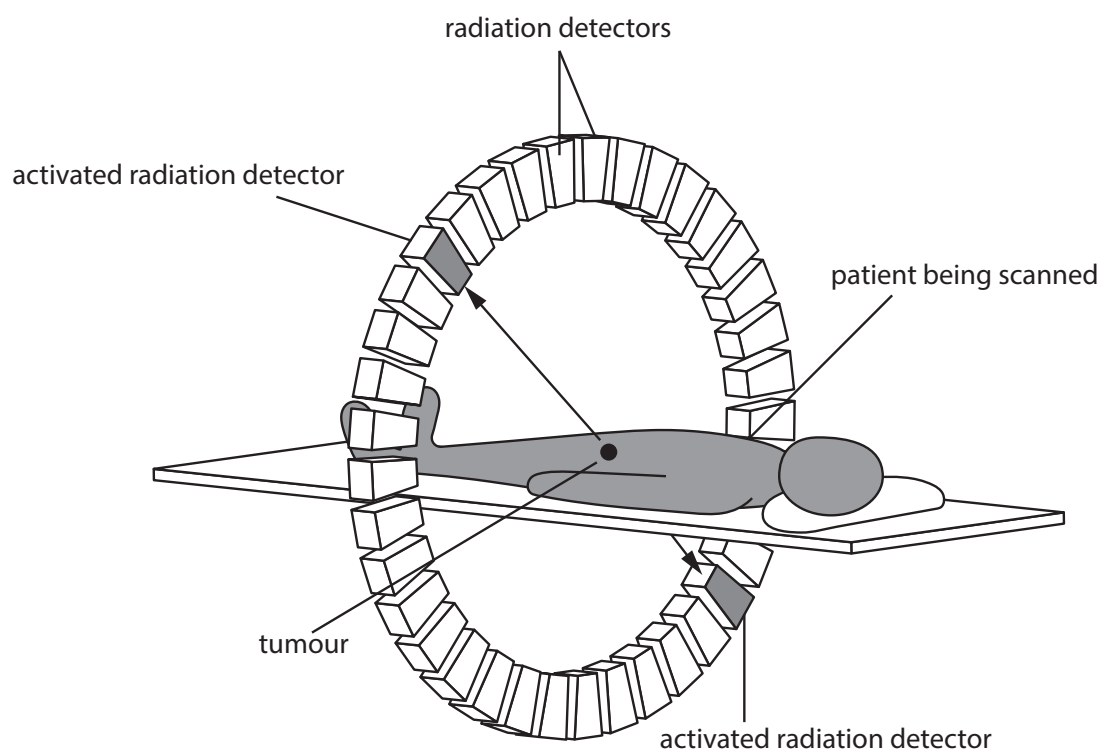


Figure 5

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

(3)

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

(2)

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(c) Radiotherapy can involve irradiation of patients.

Radioactive tracers can involve contamination of patients.

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

(2)

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(d) Figure 6 shows the decay curves of two different isotopes, Q and P.

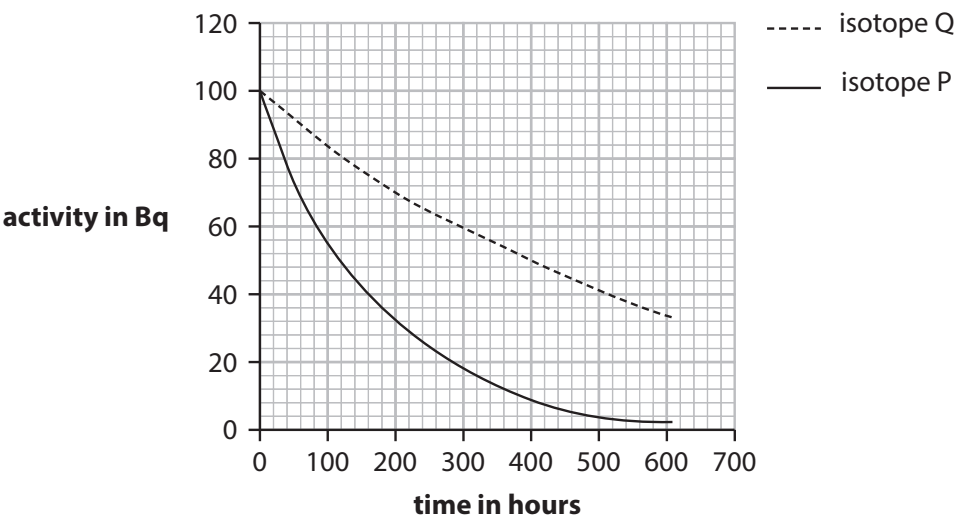


Figure 6

- (i) Use the graph in Figure 6 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)

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(Total for Question 4 = 11 marks)

- 8 (a) An electron has a charge of -1 .

The charge on an alpha particle is

(1)

- ☐ A -2
☐ B 0
☐ C $+1$
☐ D $+2$

- (b) Alpha, beta and gamma are all **ionising** radiations.

Give the meaning of the term **ionising**.

(1)

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- (c) A teacher determines the background radiation count rate in a laboratory.

Explain how to determine a value for the background radiation count rate.

(3)

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- (d) The teacher now investigates the absorption of beta radiation by different thicknesses of aluminium.

The apparatus available is

- a source of beta radiation
- a Geiger–Müller (G-M) tube and counter
- 10 pieces of aluminium, each 0.5 mm thick
- a metre rule.

- (i) Sketch a labelled diagram showing the positions of the apparatus when the measurements are being taken.

(2)

- (ii) Give the independent variable in this investigation.

(1)

- (iii) Name a quantity that must be kept constant during the investigation.

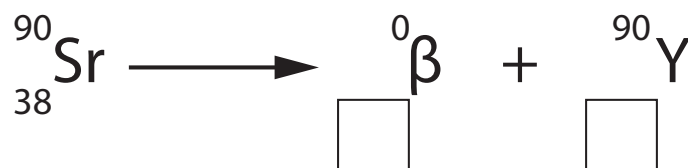
(1)



(iv) Strontium-90 is the source of beta minus radiation in this investigation.

Complete the nuclear equation for this emission of beta minus radiation.

(2)



(Total for Question 8 = 11 marks)



4 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 7 shows a radioactive decay curve for a sample of fluorine-18.

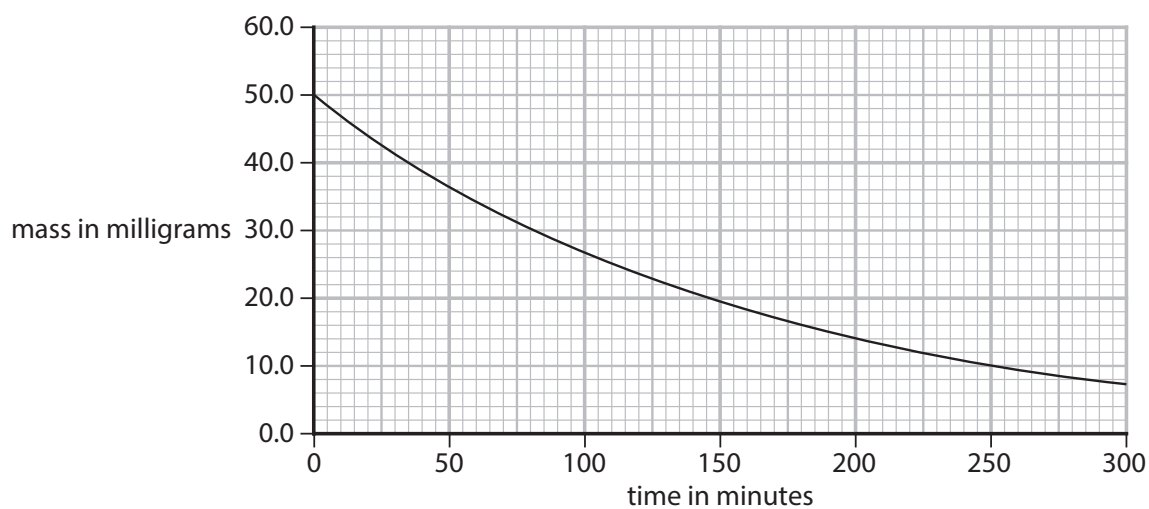


Figure 7

- (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)

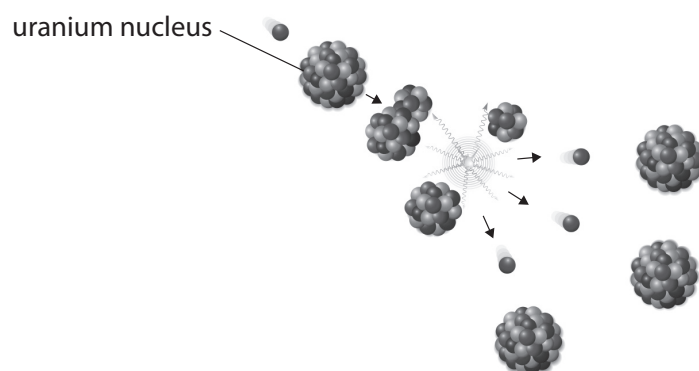
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(c) Figure 8 shows what happens during a fission chain reaction.



(Source: © Designua/Shutterstock)

Figure 8

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

(3)

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(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 4 = 11 marks)



12-MARK QUESTIONS

2 questions in this booklet



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10 Fusion and fission are nuclear reactions in which large amounts of energy are released.

- (a) (i) In a fusion reaction, two hydrogen nuclei are forced together to form a helium nucleus.

Explain why a very high temperature is needed for this reaction to happen.

(3)

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- (ii) In a fusion reaction, the combined mass of the two small nuclei is greater than the mass of the resulting nucleus.

This decrease in mass, m , appears as energy, E , according to the equation.

$$E = mc^2$$

c is the speed of light = 3.0×10^8 m/s.

The energy released in one fusion reaction is 4.5×10^{-12} J.

Calculate the decrease in mass.

(3)

decrease in mass = ... kg



*(b) Nuclear fission is used in nuclear reactors in some power stations.

In the reactor, a fission chain reaction is maintained and controlled to produce a supply of energy to generate electricity.

Figure 14 is a diagram of a nuclear reactor.

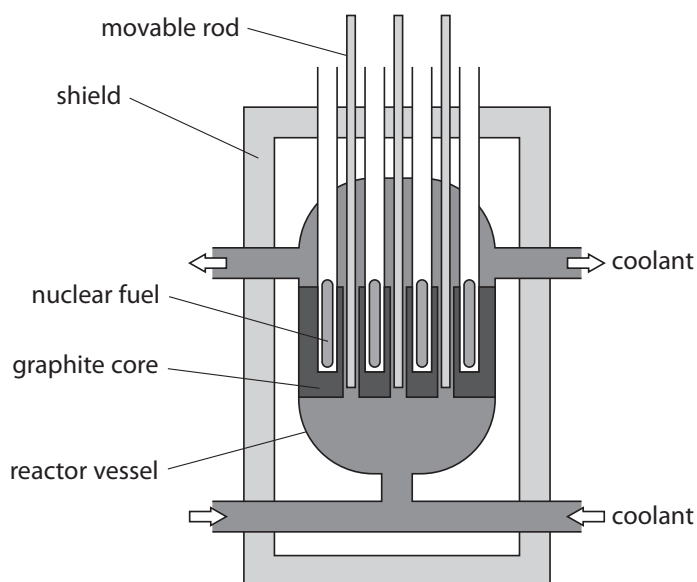


Figure 14

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AREA

Explain how the graphite core and the movable rods are used to maintain and control the chain reaction.

(6)

(Total for Question 10 = 12 marks)



9 (a) Carbon-14 is a radioactive substance that emits beta minus (β^-) particles.

(i) Which of these is the unit for the activity of a sample of carbon-14?

(1)

- ☐ A Pa
- ☐ B Nm
- ☐ C Gs
- ☐ D Bq

(ii) Which row of the table gives a correct comparison of the penetrating abilities of alpha, beta and gamma radiation?

(1)

	least penetrating → most penetrating
☐ A	alpha, beta, gamma
☐ B	alpha, gamma, beta
☐ C	gamma, beta, alpha
☐ D	gamma, alpha, beta

(iii) The mass of a beta minus particle is 9.1×10^{-31} kg.

Calculate the kinetic energy of a beta minus particle moving with a speed of 3.8×10^6 m/s.

(2)

kinetic energy = ... J



(b) Describe what happens in the nucleus of an atom when a beta plus particle is emitted.

(2)



13-MARK QUESTIONS

1 question in this booklet



- 10 (a) Figure 20 shows a Mars rover, a vehicle used for exploring the surface of the planet Mars.



(Source: © BEST-BACKGROUNDS/Shutterstock)

Figure 20

The power supply in a Mars rover is called an RTG.

The RTG contains a radioactive isotope that releases thermal energy as it decays.

The RTG uses the thermal energy released in the decay to provide electrical power for the rover.

- (i) An RTG has an efficiency rating of only 7%.

Calculate the useful energy transferred by the RTG when 1300 J of thermal energy is released in the decay.

(2)

Use the equation

$$\text{efficiency} = \frac{(\text{useful energy transferred by the device})}{(\text{total energy supplied to the device})} \times 100\%$$

useful energy transferred = ... J

- (ii) Suggest, with a reason, **one** property the isotope must have to be suitable for use in the RTG.

(2)

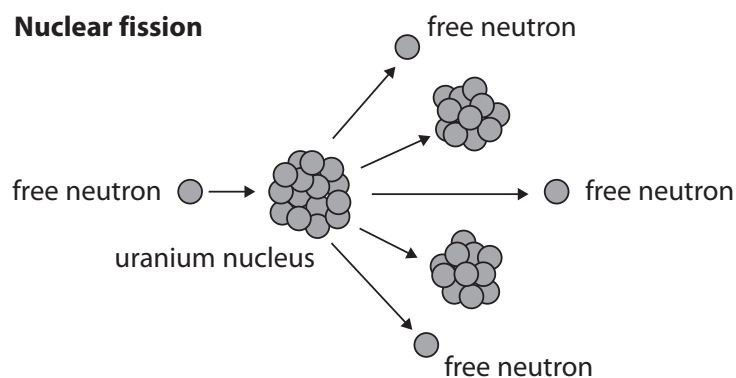
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(b) Figure 21 shows the fission of a uranium nucleus.



(Source: adapted from © 1501926062/Shutterstock)

Figure 21

The total mass of all the particles after the reaction is less than the total mass of the particles before the reaction.

The energy released in the reaction comes from the change in mass.

This is shown in the equation

$$\text{energy released} = (\text{change in mass}) \times (\text{speed of light})^2$$

The energy released in one fission reaction = $1.49 \times 10^{-10} \text{ J}$.

The speed of light = $3.00 \times 10^8 \text{ m/s}$.

Calculate the change in mass.

(3)

change in mass = ... kg

MARK SCHEMES

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Question number	Answer	Additional guidance	Mark
1 (a)	Any two from smoke alarm (1) food irradiation (1) sterilising (1) detecting leaks/cracks (1) gauging thicknesses (1) in medicine diagnostic (1) in medicine therapeutic (1) dating (archaeological samples) (1)	named named	(2)

Question number	Answer	Additional guidance	Mark
1 (b)	P – control rods (1) Q – graphite/moderator (1)	boron steel rods heavy water	(2)

Question number	Answer	Additional guidance	Mark
1 (c)	An explanation linking two of a neutron collides with/fired at a (uranium) nucleus (1) releasing (2/3) extra neutron(s) (1) which go on to collide with more nuclei (1)	neutron absorbed by nucleus. accept atom for nucleus accept atom for nucleus	(2)

Total for Question 1 = 6 marks



Question Number	Answer	Additional guidance	Mark
3(a)	a description that combines 4 points from the following: 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		Mark
3(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
3(c)	an answer containing both of the following numbers in the correct places (1) $\begin{array}{c} 99 \\ \hline 43 \end{array} \text{Tc}$	(1) AO 2 1

(Total for Question 3 = 8 marks)

Question	Answer	Additional guidance	Mark
1 (c) (i)	50-70 (nm) inclusive		1 AO1.2

Question	Answer	Additional guidance	Mark
1 (c)(ii)	explanation linking (red shift means) <u>galaxies</u> must be moving away from Earth /us (1) more distant galaxies have bigger red shift (1) more distant galaxies moving faster (1)	<u>galaxies</u> getting further apart ORA	3 AO1.1

Total Question 1 = 8 marks

Question number	Answer	Mark
3(a) CS2	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
3(b) CS2	same number of protons (1) different number of neutrons (1)	same atomic number different mass number	(2) AO2

Question number	Answer	Additional guidance	Mark
3(c)(i) CS2	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
3 c (ii) CS2	(idea of) background radiation	a named source of background radiation	(1) AO3

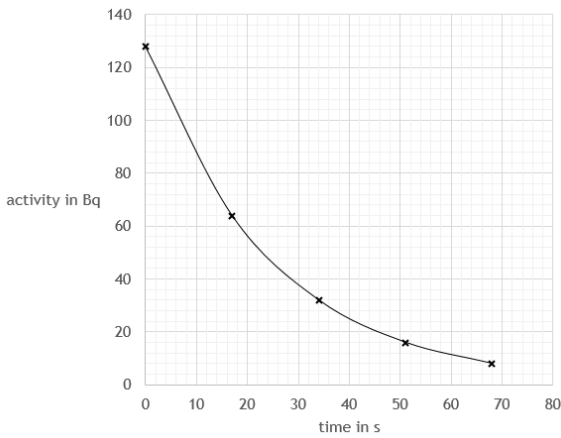
Question number	Answer	Additional guidance	Mark
3c (iii) CS2	becquerel	accept Bq accept close spelling	(1) AO1

Question number	Answer	Additional guidance	Mark
3d CS2	33 days is 3 half-lives (1) 2.1(25) × 10 ²² (1)	$\frac{1.7 \times 10^{23}}{2 (\times 2 \times 2)}$ 2.1(25) to any other power of ten scores mp1 only award full marks for correct answer without working.	(2) AO2

7(a)(i)	C $^{245}_{95}\text{Am}$ A, B and D are incorrect as these are not isotopes of americium.	(1) AO1
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	Answer	Mark
7(a)(ii)	[x] B 5 cm A, C and D are incorrect as these are not the correct range of an alpha particle in air.	(1) AO1

	Answer	Additional guidance	Mark
7(a)(iii)	$^{4}_{2}\alpha$ (1) $^{237}_{115}\text{At}$ (1) $^{93}_{43}\text{Nb}$ (1)	both correct for the mark ecf from mp1 ecf from mp1	(3) AO2

	Answer	Additional guidance	Mark
7(b)	plots at three of: 17,64 (1) 34,32 (1) 51,16 (1) 68,8 (1) tolerance ± 1 s ± 4 Bq	 allow line passing through correct point(s) ignore incorrect curve if no other marks scored allow 1 mark for evidence of halving activity e.g. 128 to 64	(3) AO3

	Answer	Additional guidance	Mark
7(c)	description to include: proton (1) becomes a neutron (1)	award 2 marks for $p \rightarrow n$ award 2 marks for answers in terms of quarks: $u \rightarrow d$ or $up \rightarrow down$ or $uud \rightarrow udd$ if no other mark scored, allow 1 mark for any one of neutron becomes proton $n \rightarrow p$ $d \rightarrow u$ decrease in atomic number <u>by one</u> mass number stays the same gains a neutron reduce charge (of nucleus) <u>by one</u> responses referring to emission of gamma or neutrino	(2) AO1

Total for Question 7 = 10 marks.

	Answer	Mark
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Question number	Answer	Mark			
7 (a)	<table border="1"> <tr> <td>A</td><td>same atomic number</td><td>different number of neutrons</td></tr> </table> Options B, C and D have wrong combinations	A	same atomic number	different number of neutrons	(1)
A	same atomic number	different number of neutrons			

Question number	Answer	Mark
7 (b)	☒ C beta plus Options A, B and D are not represented by Figure 9.	(1)

Question number	Answer	Additional guidance	Mark
7 (c)	recognition of there being 4 half lives involved (1) so fraction of 1 / 16 involved (1) evaluation (1) 2.4 (kBq)	allow 2 marks for 4.8 (kBq) (used three instead of 4 half lives) allow 1 mark for any other $(1/2)^n$ being involved i.e. for answers that round to 19.3 (kBq), 9.63 (kBq), 1.2(kBq) award full marks for the correct answer without working	(3)

Question number	Answer	Additional guidance	Mark
7 (d)	explanation linking two from: (damage to) cell(s) (1) (because gamma rays are) ionising / high frequency/very energetic (1) (causing / curing/diagnosing) cancer / mutation / chromosomal damage / dna damage/burns (1)	(rapid/unwanted) division of cells	(2)

Question number	Answer	Additional guidance	Mark
7 (e) (i)	use of gradient on graph (1) $= \frac{1480}{97}$ evaluation (1) 15.3 (counts /s)	look for a triangle / line going up allow $\frac{1480}{100}$ accept other data from the graph allow numbers between 12.0 and 16.0 award full marks for answers in the correct range without working	(2)

Question number	Answer	Additional guidance	Mark
7 (e) (ii)	explanation the process (of radioactive decay) is unpredictable / (occurs) random(ly) (1) so the count rate would not be constant / there will be variations with each reading (1)	do not allow 'difficult to predict' ignore background results (expected to) scatter	(2)

Total for Question 7 = 11 marks



9(a)	A description to include two from: (radioactive material/substances) inside the food/body (1) emit radiation from inside the body (1) damage body cells (1)	trapped in the body exposed to radioactivity cause cancer	(2) AO1
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	Answer	Additional guidance	Mark
9(b)	An explanation linking two from: to preserve food (1) by 'killing' bacteria (1) (gamma) is (very) penetrating (and so reaches all the food). (1) sterilising (1)	stop food going off	(2) AO2

	Answer	Additional guidance	Mark
9(c)	One from: rearrangement (of particles) (1) loses/emits energy (1) becomes (more) stable (1)		(1) AO1

Question number	Indicative content	Mark
9 *(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 1 (6 marks) alpha • a particle (not a wave) • made up of 4 particles • helium nucleus • has a positive charge • when emitted by a nucleus, atomic number goes down by 2 • mass number goes down by 4 beta • a particle (not a wave) • made up of 1 particle • electron (or positron) • has a negative charge • when emitted, atomic number goes up by 1 • mass number does not change Ignore references to range, penetration, ionisation.	(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 an explanation 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 an explanation 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 an explanation that has a well-developed structure which is clear, coherent and logical. (AO1)



Level	Mark	Additional Guidance	General additional guidance – the decision within levels
	0	No rewardable material.	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.
Level 1	1–2	<u>Additional guidance</u> isolated facts	<u>Possible candidate responses</u> A beta particle is an electron. An alpha particle is a helium nucleus
Level 2	3–4	<u>Additional guidance</u> effect of alpha and beta decay or nature and effect of alpha or beta	<u>Possible candidate responses</u> A beta particle is an electron. When emitted the mass number doesn't change but atomic number goes up by one
Level 3	5–6	<u>Additional guidance</u> detailed comparison that includes nature of alpha and nature of beta and effect of either alpha or beta OR effect of alpha and beta and nature of either alpha or beta	<u>Possible candidate responses</u> Alpha particle is a helium nucleus AND A beta particle is an electron. When emitted the mass number doesn't change but atomic number goes up by one

Total for Question 9 = 11 marks

	Answer	Additional guidance	Mark
10(a)i()	Two from: falling water/hydro (1) tides (1) sun/solar (1) geothermal (1) biomass (1)		(2) AO1

	Answer	Additional guidance	Mark
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Question Number	Answer	Mark
4(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
4 (a)(ii)1 CLIP with (a)(ii)2	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
4 (a)(ii)2 CLIP with (a)(ii)1	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
4(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
4(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
4(b)(ii)	$\frac{4(.0 \times 10^3)(\times 100)}{3(.0 \times 10^7)}$ (1) 1.3×10^{-2} (%) (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
4(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 if no other marks awarded allow steam transfers thermal energy/heat from reactor to kinetic energy of turbine for 2 marks	(2) AO1

Total for Question 4 = 11 marks

	Answer	Additional guidance	Mark
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8(a)	substitution (1) $\text{number of atoms} = \frac{4.0 \times 10^{-7}}{0.15 (\times 10^{-9})}$ evaluation (1) 2 700	$\frac{4.0 \times 10^{-7}}{1.5 (\times 10^{-10})}$ $\frac{0.000\ 000\ 4}{0.000\ 000\ 000\ 15}$ accept any value that rounds to 2 700 award full marks for correct answer without working	(2) AO2
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	Answer	Additional guidance	Mark
8(b)(i)	reading from graph (1) (at 5 degrees:) number between 10^6 and 10^7 AND (at 100 degrees:) 10^2 evaluation (1) $\frac{\text{number between } 10^6 \text{ and } 10^7}{10^2}$ OR between $10^4:1$ and $10^5:1$ between 10 000:1 and 100 000:1 OR between 10^4 and 10^5 between 10 000 and 100 000	(e.g. $10^{6.5}$) (e.g. $10^{4.5}:1$ or $10^7:10^2$) allow any correct ratio not in its simplest form (e.g. $10^{4.5}$) award full marks for correct answer without working inverted ratio scores 1 mark maximum	(2) AO2

	Answer	Additional guidance	Mark
8(b)(ii)	an explanation including any four from: Observations most (alpha particles) pass (straight) through the foil (with little deflection) (1) some (alpha particles) are {scattered / deflected} through {small angles / less than 90 degrees} (1) (very) few (alpha particles) are {scattered / deflected} through {large angles / greater than 90 degrees} (1) Conclusions atoms are mainly empty space (1) there must be a nucleus / something inside the atom (1) (nucleus / something) must be {small / heavy / dense / concentrated / charged / positive} (1)	ignore electrons ignore refracted allow repelled allow rebound / reflect / back scattering / bounce back ignore electrons	(4) A01,A03

	Answer	Additional guidance	Mark
8(c)(i)	A description including: roll / release / drop a marble (down the slope) (1) and one from record where the marbles go (1) OR measure the angle of path (1)	allow alpha particle for marble allow any method of recording	(2) AO3

	Answer	Additional guidance	Mark
8(c)(ii)	any one from marble / weight has no charge (1) the edge of the paper is not far enough away from the weight (1) the marble / weight is too big / small (1) there is only one marble / weight (1) it is 2 dimensional / not 3D (1) all marbles have the same speed / alpha particles different speed to marbles (1) marbles (only deflect on) hitting / contact with weight (1)	not to scale allow marble cannot pass through the weight (1)	(1) AO3

Total for Question 8 = 11 marks

4(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
4(b)(i)	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
4 (c)	any two from :- irradiation does not make an object radioactive (1) irradiation can be stopped by shielding (1) irradiation source is outside the object (1) irradiation stops when the source is removed (1)	ORA ORA source of contamination is in or on the object effect of contamination is continuous allow you can move away from irradiation	2 AO1.1

Question	Answer	Additional guidance	Mark
4(d)(i)	correct use of the graph (1)	horizontal line in range 48-52 Bq to line for either isotope allow two horizontal lines showing halving	2 AO2.1

Question	Answer	Additional guidance	Mark
4 (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 A02.2

Total question 4 = 11 mark

8(a)	D +2 A , B and C do not apply to an alpha particle	1 AO1.1
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Question	Answer	Additional guidance	Mark
8(b)	loss / gain of electrons (from atoms)	accept knock electrons out (of atoms)	1 AO1.1

Question	Answer	Additional guidance	Mark
8(c)	an explanation linking three from use of G-M tube (with counter) (1) no (obvious) radioactive sources present (1) measure (number of) counts in a given time (1) divide number of counts by time (1) repeat readings (1) calculate the average value (1)	allow Geiger counter / rate meter allow measure count rate / activity if rate meter used take readings in different positions in laboratory	3 AO3.3

Question	Answer	Additional guidance	Mark
8(d)(i)	sketch with at least three objects labelled (1) allowed labels: G-M tube counter aluminium piece(s)/sheet(s)/foil (metre) rule β/beta/source aluminium / sheets between source and G-M tube with all three labelled (1)	ignore beta particles / beta drawn as particles or waves	2 A03.3

Question	Answer	Additional guidance	Mark
8(d)(ii)	one from number of pieces/sheets (of aluminium/foil)(1) thickness of aluminium (between source and G-M tube) (1)	allow amount for number	1 A03.3

Question	Answer	Additional guidance	Mark
8(d)(iii)	one from distance between the source and the G-M tube (1) distance between source and aluminium pieces (1) distance between G-M tube and pieces of aluminium (1) activity of source (1) direction / angle of source (1) duration/time of measurement (1)	ignore background radiation / temperature accept beta / beta radiation for source for 1st, 2nd and 4th marking points do not allow 'distance of aluminium' accept (same) strength/intensity of source	1 A03.3

Question	Answer	Additional guidance	Mark
8(d)(iv)	-1 for beta β (1) correctly balanced equation with numbers in boxes adding to 38 (1) ${}_{38}^{90}\text{Sr} \longrightarrow {}_{\boxed{-1}}^0\beta + {}_{\boxed{39}}^{90}\text{Y}$		2 A01.1

Total question 8 = 11 marks

Question	Answer	Mark
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Question number	Answer	Mark
4 (a) (i)	B ionising radiation (1) A is incorrect because gamma rays are not considered as particles in this context C and D are incorrect: the gamma rays are ionising, not non-ionising	(1) AO1.1

Question number	Answer	Mark
4 (a) (ii)	A control rods (1) B,C and D do not absorb neutrons	(1) AO1.1

Question number	Answer	Additional guidance	Mark
4(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 inclusive allow values between 38(%) and 40(%) inclusive award full marks for correct answer without working.	(2) AO2.1

Question number	Answer	Additional guidance	Mark
4(b)(ii)	a description to include any two from they collide (1) annihilate (1) (releasing a pair of) gamma ray(s) (1)	ignore interact / combine / attract /meet allow (charges) cancel / neutralise / become neutral photons release energy ignore light	(2) AO1.1

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

Question number	Answer	Additional guidance	Mark
4 (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(.0) accept 1(.0) : 0.49 award full marks for correct answer without working.	(2) AO2.1

Total for Question 4 = 11 marks

	Answer	Additional guidance	Mark
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Question Number	Answer	Additional guidance	Mark
10(a)(i)	an explanation linking: (high temperature means) high energy (1) (needed) to overcome (force of) repulsion (1) between nuclei / because they both have the same charge (1)	accept "them" / hydrogen for nuclei	(3) AO 2 1

Question Number	Answer	Additional guidance	Mark
10(a)(ii)	substitution (1) $4.5 \times 10^{-12} = m (3.0 \times 10^8)^2$ rearrangement (1) $(m =) \frac{4.5 \times (10^{-12})}{9.0 \times (10^{16})}$ evaluation (1) $5.0 \times 10^{-29} \text{ (kg)}$	accept substitution and rearrangement in either order ignore POT errors until evaluation award full marks for the correct answer with no working	(3) AO 2 1

Question Number	Answer	Mark
10(b)*	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 • neutrons released in a chain reaction • slow(er) neutrons needed for fission • (some) neutrons are too fast • control rods can be moved in and out • control rods control speed of the reaction AO2 • graphite core is the moderator • graphite core slows down the neutrons • moveable rods absorb neutrons • moveable rods make more or fewer neutrons available for fission	(6) AO 1 1 AO 2 1

Level	Mark	Descriptor
	0	No awardable content
Level 1	1-2	- An explanation that demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) - 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	- An explanation that demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) - 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	- An explanation that demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) - 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)

Total for Question 10 = 12 marks)



Question Number	Answer	Mark
9(a)(i)	The only correct answer is D Bq <i>A is not correct because it is the unit of pressure</i> <i>B is not correct because it is the unit of moment</i> <i>C is not correct because it is the unit of time</i>	(1) AO1.1

Question Number	Answer	Mark
9(a)(ii)	The only correct answer is A <i>C and D are not correct because they start with most penetrating</i> <i>B is not correct because gamma is more penetrating than beta</i>	(1) AO1.1

Question Number	Answer	Additional guidance	Mark
9(a)(iii)	selection of (KE =) $\frac{1}{2} mv^2$ (1) evaluation (1) 6.6×10^{-18} (J)	$\frac{1}{2} \times 9.1 \times 10^{-31} \times [3.8 \times 10^6]^2$ allow values that round to 6.6×10^{-18} (J) e.g. 6.5702×10^{-18} (J) award full marks for the correct answer without working	(2) AO2.1

Question Number	Answer	Additional guidance	Mark
9(b)	description to include proton (1) becomes a neutron (1)	charge decreases by 1 atomic number decreases by 1 mass (number) stays the same neutron number increases by 1 award 2 marks for $p \rightarrow n$ award both marks for answers in terms of quarks: $up \rightarrow down$ or $u \rightarrow d$ or $uud \rightarrow udd$ if no other mark scored award 1 mark for $n \rightarrow p$	(2) AO1.1

Question Number	Indicative content	Mark
9c*	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 alpha nature (may be in context of emitted from nucleus) - made up of 4 particles / 2 protons and 2 neutrons - helium nucleus - is positively charged (+2) alpha decay effect on nucleus - when emitted, atomic/proton number of nucleus goes down by 2 - when emitted, mass/nucleon number of nucleus goes down by 4 - element changes - charge goes down by 2 - mass goes down by 4 gamma nature (considered to be) a (electromagnetic / EM) wave - photon (very) high frequency / short wavelength - no charge / no mass gamma decay effect on nucleus - nucleus does not change (in atomic number or mass number) - nucleus undergoes rearrangement / becomes more stable / loses energy / mass converts to energy - element does not change Ionisation / penetration - gamma is weakly ionising / highly penetrating / stopped by (thick) lead - alpha is highly ionising / weakly penetrating / stopped by paper / few cm of air	(6) AO1.1



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 comparison 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 comparison 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 comparison that has a well-developed structure which is clear, coherent and logical. (AO1)



Level	Mark	Additional Guidance	General additional guidance – the decision within levels
	0	No rewardable material.	e.g. - At each level, as well as content, the scientific coherency of what is stated will help place the response at the top, or the bottom, of that level. At each level ionising/penetrating ability may be used instead of a nature or an effect to place the response in the lower end of that level.
Level 1	1–2	<u>Additional guidance</u> isolated facts: related to alpha or gamma	<u>Possible candidate responses</u> alpha is a helium nucleus OR gamma is a wave
Level 2	3–4	<u>Additional guidance</u> Limited comparison that includes nature of both or effect of decay of both or nature and effect of one or nature of one and effect of other	<u>Possible candidate responses</u> Alpha is a helium nucleus and gamma is a wave. OR When alpha emitted the mass number decrease by 4 and when gamma emitted nucleus doesn't change. OR Gamma is a wave and when gamma is emitted the nucleus loses energy. OR Alpha is positively charged and when gamma is emitted nucleus undergoes rearrangement.
Level 3	5–6	<u>Additional guidance</u> detailed comparison that includes nature and effect of either alpha or gamma AND nature or effect of the other	<u>Possible candidate responses</u> Alpha is helium nucleus. When alpha emitted the mass number decreases by 4. When gamma emitted nucleus doesn't change.

Total for Question 9 = 12 marks



10(a)(i)	substitution and rearrangement (1) useful energy transferred = $\frac{7(\%) \times 1300}{100}$ evaluation (1) 90 (J)	useful energy transferred = 0.07×1300 allow 91 (J) 0.91 or 0.9 scores 1 mark award full marks for the correct answer without working	(2) AO2
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	Answer	Additional guidance	Mark
10(a)(ii)	statement plus reason for example: long half-life (1) with one from: the rover takes a long time (to get to Mars) (1) rover needs to operate for a long time (on Mars) (1) (once on Mars) cannot be replaced (1)	Allow other relevant properties for MP1 with reason for MP2, for example: high melting point ... to maintain RTG integrity not chemically reactive ... to prevent corrosion	(2) AO3

	Answer	Additional guidance	Mark
10(b)	substitution (1) $1.49 \times 10^{-10} = \text{change in mass} \times (3 \times 10^8)^2$ rearrangement (1) (change in mass $\Rightarrow$) $\frac{1.49 \times 10^{-10}}{9 \times 10^{16}}$ evaluation (1) $1.66 \times 10^{-27} \text{ (kg)}$	$\frac{1.49 \times 10^{-10}}{(3 \times 10^8)^2}$ allow $m = E/c^2$ Accept values that round to 1.7×10^{-27} if no other marks scored 1.66 or 1.7 to any other power of ten scores 1 mark award full marks for the correct answer without working	(3) AO2

Question number	Indicative content	Mark
10c	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 chain reaction - neutrons emitted in one fission go on to hit other U-235 nuclei - neutrons emitted in one fission go on to cause a chain reaction control rods - rods absorb/capture/stop neutrons - limit/control number of fissions - varies rate of (thermal) energy released moderator - slows down neutrons - makes them more likely to cause fission	(6) AO1

Level	Mark	Descriptor
	0	No rewardable material. relevant
Level 1	1-2	- Demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) - Presents an explanation 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 an explanation 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 an explanation 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 statements	<u>Possible candidate responses</u> Mention of 2 of: chain reaction OR control/boron rods OR moderator
Level 2	3–4	<u>Additional guidance</u> limited explanation detail of 1 of chain reaction/ control rods/ moderator and mention at least 1 other	<u>Possible candidate responses</u> neutrons emitted in one fission go on to hit other U-235 nuclei and mention control rods
Level 3	5–6	<u>Additional guidance</u> detailed explanation detail of 2 of chain reaction/ control rods/ moderator and mention the other one	<u>Possible candidate responses</u> neutrons emitted in one fission go on to hit other U-235 nuclei AND control rods absorb neutrons to reduce number of fissions AND mention of moderator

