Questions

Q1.

In 2011, a nuclear accident happened at Fukushima in Japan.

This released radioactive materials into the environment.

A month later, the radioactivity of seaweed on the west coast of USA was tested.

The seaweed was found to contain radioactive iodine-131.

The half-life of iodine-131 is 8.0 days.

(a) Three samples of the same mass of seaweed were taken.

The number of counts in 10 minutes of the samples are shown in the table.

	sample 1	sample 2	sample 3
number of counts in 10 minutes	3970	3970	3985

Explain why three separate samples were used.

(2)

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(b) Iodine-131 emits beta particles.

There was not a high risk to the public from the iodine-131 in the seaweed.

Explain **one** reason why the risk was not high.

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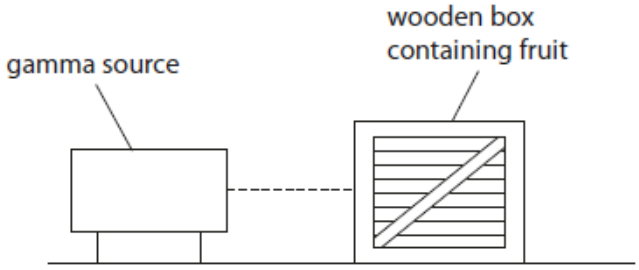
(Total for question = 4 marks)

Q2.

This question is about food preservation.

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

The radiation kills bacteria on the fruit.



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

(2)

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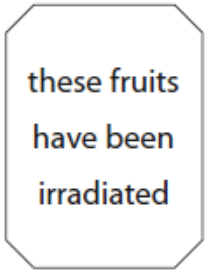
(b) The wooden box has this label.



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

(2)

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(Total for question = 4 marks)

Q3.

A scientist wants to determine the half-life of a radioactive isotope.

The scientist measures the count rate from the radioactive isotope.

(a) State how the scientist should correct the count rate for background radiation.

(1)

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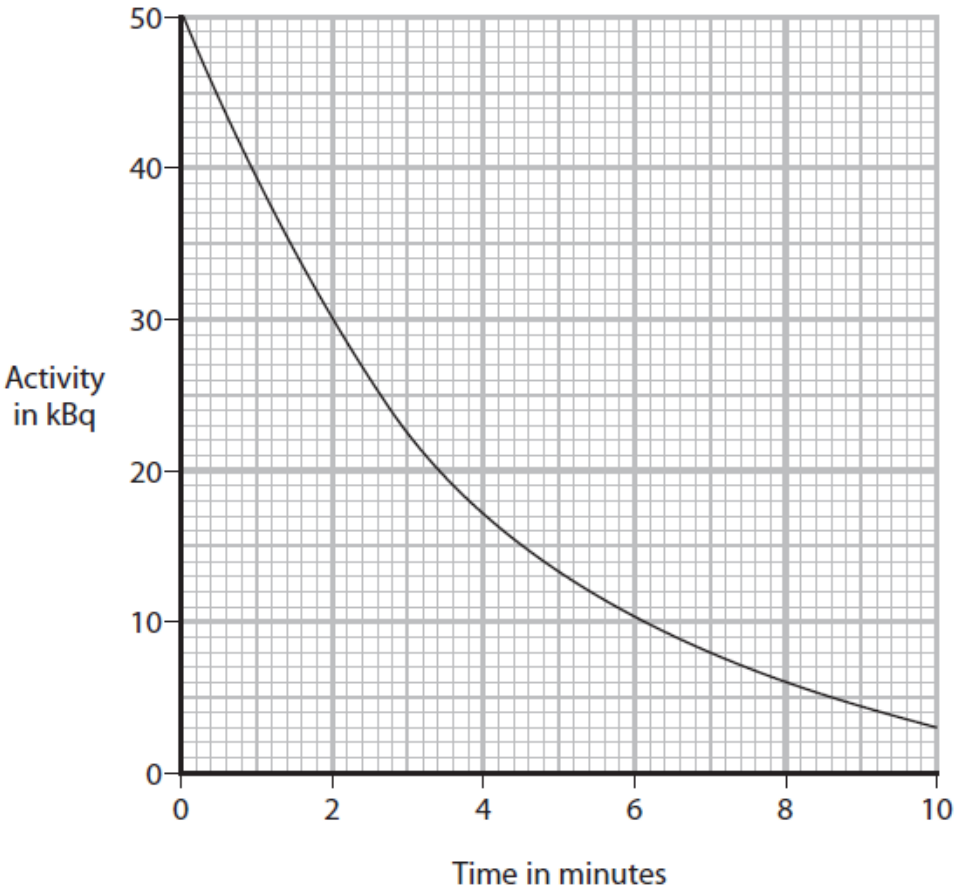
(b) The graph shows how the activity of the radioactive isotope varies with time.



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

(2)

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(ii) Use the graph to determine the half-life of this isotope.

(2)

half-life = ... minutes

(Total for question = 5 marks)

Q4.

(a) Bismuth-207 is a gamma emitter and is represented by the symbol

$^{207}_{83}Bi$

How many neutrons are in the nucleus of an atom of bismuth-207?

(1)

☒ **A** 83

☒ **B** 124

☒ **C** 207

☒ **D** 290

(b) Which of these gives the best description of gamma radiation?

(1)

☒ **A** a helium nucleus

☒ **B** a high energy electron

☒ **C** a high frequency electromagnetic wave

☒ **D** a subatomic particle with mass, but with no charge

(c) A technician uses this method to investigate the penetration power of gamma radiation.

- place a gamma emitting source at a fixed distance from a radiation detector
- measure the count using the detector, for a period of one minute
- place a thin sheet of lead between the source and the detector
- measure the new count using the detector, for a period of one minute
- increase the number of lead sheets between the source and detector and repeat this process

The table gives some of the variables from the technician's method.

Complete the table by placing a tick (Π) in each row to show whether each variable is an independent, a dependent or a control variable.

(3)

Variable	Independent variable	Dependent variable	Control variable
count measured using the detector			
distance between source and detector			
number of lead sheets			
time period for measuring the count			

(Total for question = 5 marks)

Q5.

(a) Which statement describes the term **atomic number** for a nucleus?

(1)

☒ **A** number of electrons in the nucleus

☒ **B** number of neutrons in the nucleus

☒ **C** number of protons in the nucleus

☒ **D** number of protons and neutrons in the nucleus

(b) Which statement describes the term **mass number** for a nucleus?

(1)

☒ **A** number of electrons in the nucleus

☒ **B** number of neutrons in the nucleus

☒ **C** number of protons in the nucleus

☒ **D** number of protons and neutrons in the nucleus

(c) Which statement describes the term **isotopes**?

(1)

☒ **A** atoms with the same number of electrons but a different number of protons

☒ **B** atoms with the same number of neutrons but a different number of electrons

☒ **C** atoms with the same number of neutrons but a different number of protons

☒ **D** atoms with the same number of protons but a different number of neutrons

(d) An atom contains 8 protons, 8 neutrons and 8 electrons.

Which of these would result in a negatively charged ion of the same element?

(1)

☒ **A** adding an electron

☒ **B** adding a proton

☒ **C** removing an electron

☒ **D** removing a proton

(e) It is not possible to predict exactly when a radioactive nucleus will decay.

Which feature of radioactive decay best explains this observation?

(1)

☒ **A** radioactive decay can change the structure of the nucleus

☒ **B** radioactive decay happens at random

☒ **C** radioactive decay is irreversible

☒ **D** radioactive decay makes a nucleus more stable

(f) Which of these is the correct unit for measuring the activity of a radioactive sample?

(1)

☒ **A** becquerel (Bq)

☒ **B** coulomb (C)

☒ **C** joule (J)

☒ **D** watt (W)

(Total for question = 6 marks)

Q6.

Gallium-67 is a radioactive isotope of gallium used as a medical tracer.

Medical tracers are placed in the body to diagnose illnesses.

The tracer emits radiation which can be used to find the position of the tracer in the body.

(a) Gallium-67 can be represented using the symbol

$$^{67}_{31}Ga$$

Give the number of protons and the number of neutrons in gallium-67.

(2)

number of protons = ...

number of neutrons = ...

(b) When gallium-67 decays it emits gamma radiation.

Explain why this makes it an effective medical tracer.

(2)

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(c) Gallium-68 is another radioactive isotope of gallium that can be used as a medical tracer.

Describe the difference between the nucleus of gallium-68 and the nucleus of gallium-67.

(2)

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(Total for question = 6 marks)

Q7.

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

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

(1)

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

$$^{226}_{88}Ra$$

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

(1)

- ☒ **A** 88
- ☒ **B** 138
- ☒ **C** 226
- ☒ **D** 314

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

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

(1)

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

State the type of radiation emitted by the radioactive source.

(1)

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

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

(2)

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

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

(1)

☒ **A** 0.67×10^{21}

☒ **B** 1.33×10^{21}

☒ **C** 1.88×10^{21}

☒ **D** 2.66×10^{21}

(Total for question = 7 marks)

Q8.

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

$$^{210}_{82}Pb$$

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

(2)

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

(1)

☒ **A** 82

☒ **B** 128

☒ **C** 210

☒ **D** 292

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

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

Calculate the half-life of lead-210.

(2)

half-life = ... years

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

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

This incomplete equation summarises these stages.

$$^{210}_{82}\text{Pb} \rightarrow {}^{206}_{82}\text{Pb} + \underline{\quad}\alpha + \underline{\quad}{}^{0}_{-1}\beta$$

Complete the equation by giving the missing numbers.

Write your answers in the spaces provided.

(2)

(Total for question = 7 marks)

Q9.

A teacher does an investigation to determine the half-life of a radioactive source.

(a) The radioactive source emits particles of radiation that are negatively charged.

Name the type of radiation emitted by this source.

(1)

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(b) This is the teacher's method.

- measure the count rate in the room
- bring the radioactive source into the room
- measure the count rate from the radioactive source every two hours
- to determine the corrected count rate, subtract the count rate in the room from each count rate measured from the radioactive source
- plot a graph of corrected count rate against time
- use the graph to determine the half-life of the radioactive source

(i) Give a reason why the teacher measures the count rate in the room before bringing the radioactive source into the room.

(1)

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(ii) State the dependent variable in the teacher's investigation.

(1)

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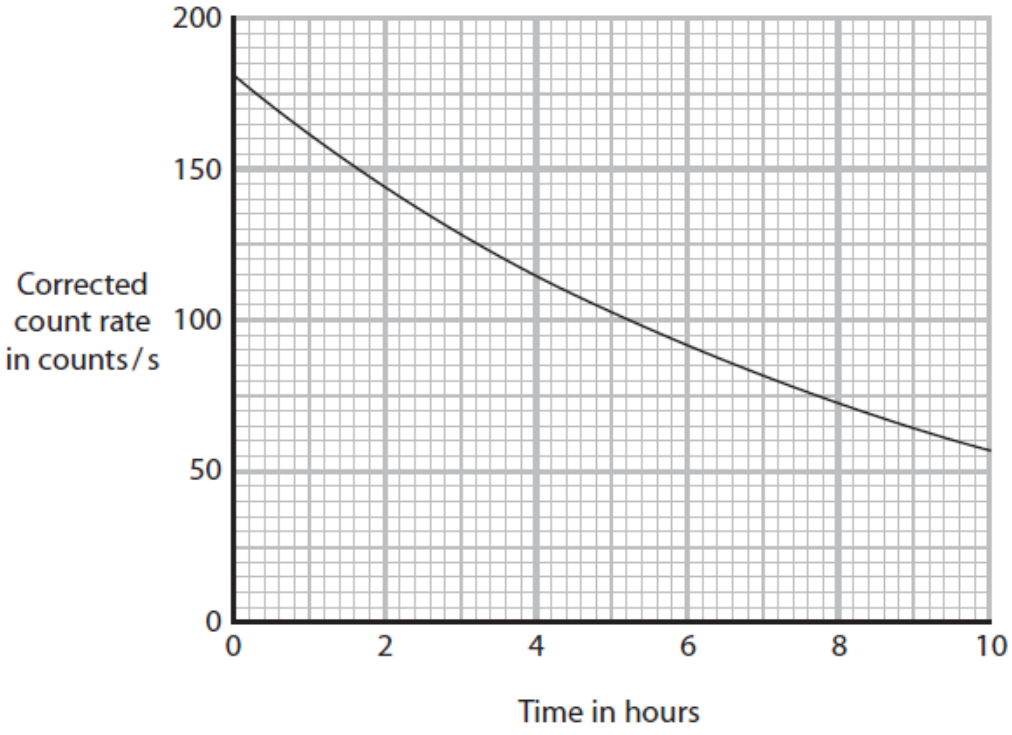
(c) The graph shows the teacher's results.



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

(2)

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(ii) A different radioactive source has the same initial corrected count rate but a shorter half-life.

Sketch another line on the graph to show how the corrected count rate of this different source changes with time.

(2)

(Total for question = 7 marks)

Q10.

An aircraft travels along a runway.

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

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

(3)

distance = ... m

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

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

(i) Explain what is meant by background radiation.

(2)

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

(3)

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(Total for question = 8 marks)

Q11.

The photograph shows a glass plate made from uranium glass.

© Laura Healey/Shutterstock

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

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

$$^{238}_{92}U$$

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

(2)

92.....

238.....

(ii) Uranium-238 decays by alpha emission.

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

(2)

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

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

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

(2)

number of atoms = ...

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

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

(3)

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(Total for question = 9 marks)

Q12.

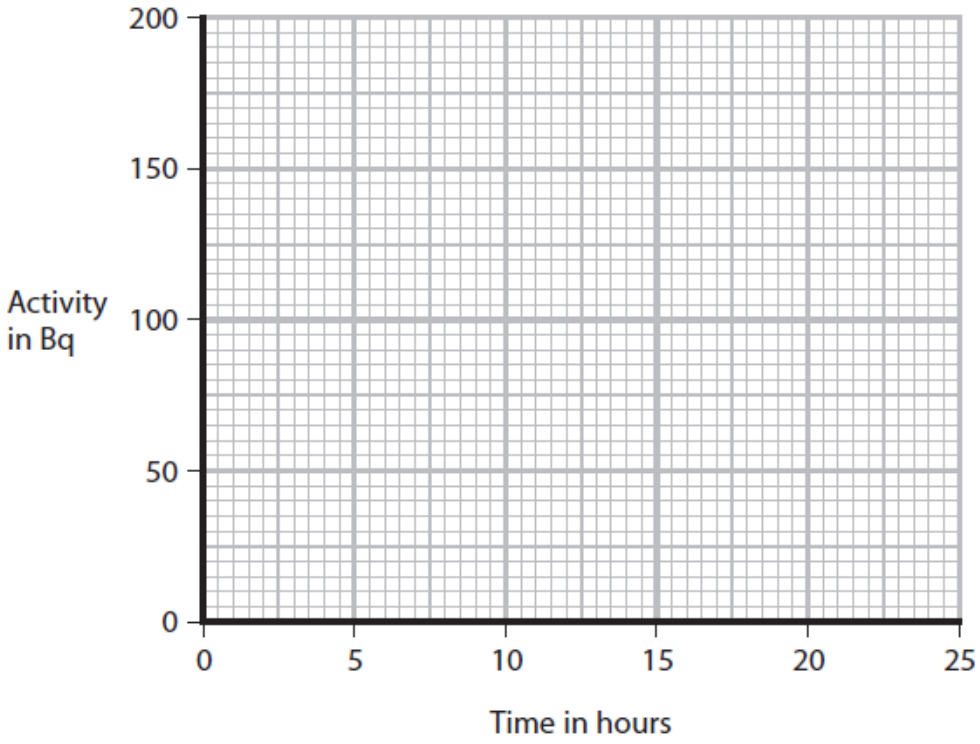
Technetium-99m is an isotope of the element technetium.

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

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

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

(3)



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

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

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

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

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

(1)

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

(2)

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

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

(3)

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(Total for question = 9 marks)

Q13.

A material called granite is used as a work surface in a kitchen.

(Source: Ksana_uk/Shutterstock)

(a) Granite is formed naturally and contains radioactive isotopes.

The granite work surface contributes to the background radiation in the kitchen.

Give another naturally occurring source of background radiation.

(1)

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(b) Granite contains the isotope thorium-232 $(^{232}_{90}\text{Th})$.

Thorium-232 decays by a sequence of alpha decays and beta decays to form radon-220 $(^{220}_{86}\text{Rn})$.

(i) State two differences between alpha radiation and beta radiation.

(2)

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2 .....

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(ii) The incomplete nuclear decay equation summarises the decay sequence of thorium-232 into radon-220.

$$^{232}_{90}\text{Th} \longrightarrow {}^{220}_{86}\text{Rn} + \square\, {}^{4}_{2}\alpha + \square\, {}^{0}_{-1}\beta$$

Calculate the number of alpha particles and the number of beta particles emitted in this decay sequence.

(3)

number of alpha particles = ...

number of beta particles = ...

(c) Thorium-232 is a solid and remains in the work surface.

Radon-220 is a gas and is emitted from the work surface.

Thorium-232 and radon-220 both emit alpha radiation.

Discuss the hazards due to the granite work surface when a person is working in the kitchen.

Refer to contamination and irradiation in your answer.

(3)

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(Total for question = 9 marks)

Q14.

Technetium-98 and technetium-99 are isotopes of the element technetium.

(a) (i) Describe the difference between the nuclei of technetium-98 and technetium-99

(2)

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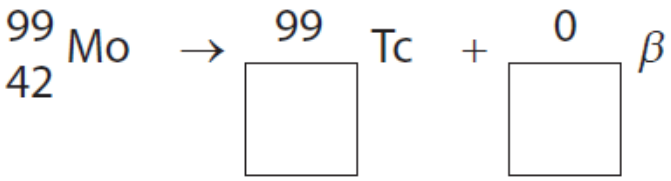
(ii) Technetium-99 is formed when the element molybdenum-99 decays.

Complete the nuclear equation for the decay of molybdenum into technetium-99

(2)



(b) Describe an experiment that a scientist could use to demonstrate that the emission from technetium-99 is gamma radiation.

Include details of a safety precaution in your answer.

(5)

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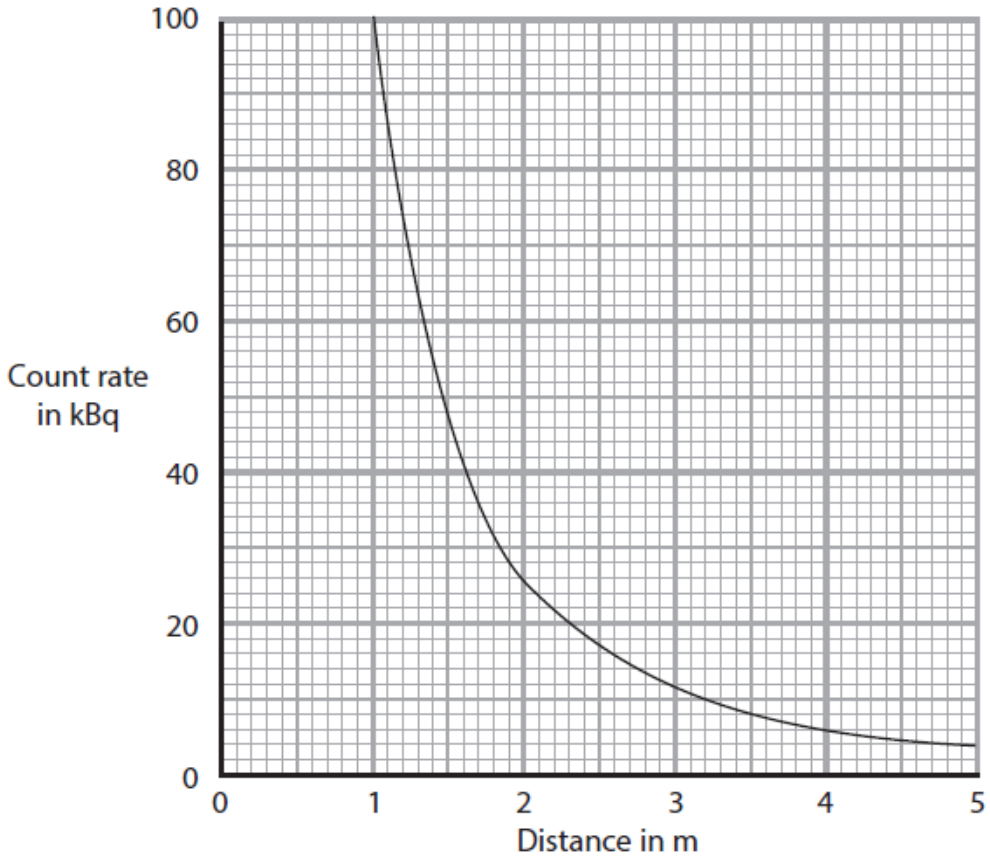
(c) A scientist measures the count rate at different distances from the technetium source.

The graph shows how the count rate changes with distance from the technetium source.



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

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

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

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(Total for question = 13 marks)

Q15.

A teacher demonstrates the penetrating ability of alpha, beta and gamma radiation from some radioactive sources.

(a) (i) State a precaution the teacher should take to make sure they are working safely with the radioactive sources.

(1)

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(ii) State the name of a detector the teacher could use to detect the radiation from each source.

(1)

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(b) Draw crosses (✕) in the table to show which type of radiation **cannot** penetrate each material in the table.

(3)

	Material		
Type of radiation	**10 cm of air**	**2 cm of aluminium**	**10 cm of lead**
alpha			
beta			
gamma			

(c) An alpha particle of mass 6.6×10^{-27} kg travelling at a speed of 2.1×10^{7} m/s hits a sheet of paper.

(i) Calculate the kinetic energy (KE) of the alpha particle.

(3)

KE = ... J

(ii) State the work done on the alpha particle when its speed is reduced to 0 m/s by the sheet of paper.

(1)

work done = ... J

(iii) State which energy store of the paper increases when the alpha particle is stopped.

(1)

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(Total for question = 10 marks)

Q16.

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

The deioniser contains a small block of polonium-210.

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

(2)

$$^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + \begin{array}{|c|}\hline\ \ \ \ \\ \hline\ \ \ \ \\ \hline\end{array}\ \alpha$$

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

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

(1)

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

(2)

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

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

(2)

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

Calculate the activity of the source after 420 days.

(3)

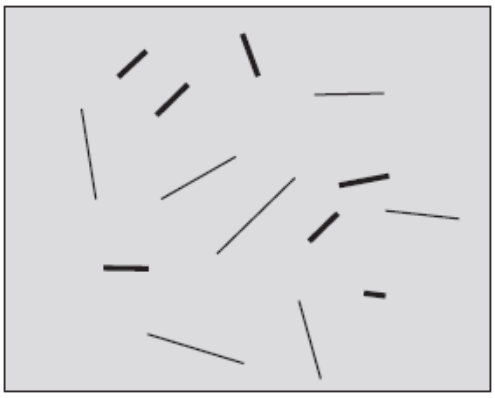
activity = ... kBq

(Total for question = 10 marks)

Q17.

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

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



Alpha particles produce the shorter, thicker tracks.

Beta particles produce the longer, thinner tracks.

Explain why alpha particles produce the shorter, thicker tracks.

(2)

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

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

(2)

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

(2)

$$^{235}_{92}U \rightarrow \square\,^{231}Th + \square\,^{}_{2}\alpha$$

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

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

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

(5)

(Total for question = 11 marks)

Q18.

Radon is a radioactive gas that contributes to background radiation.

(a) Describe what is meant by the term **background radiation**.

(2)

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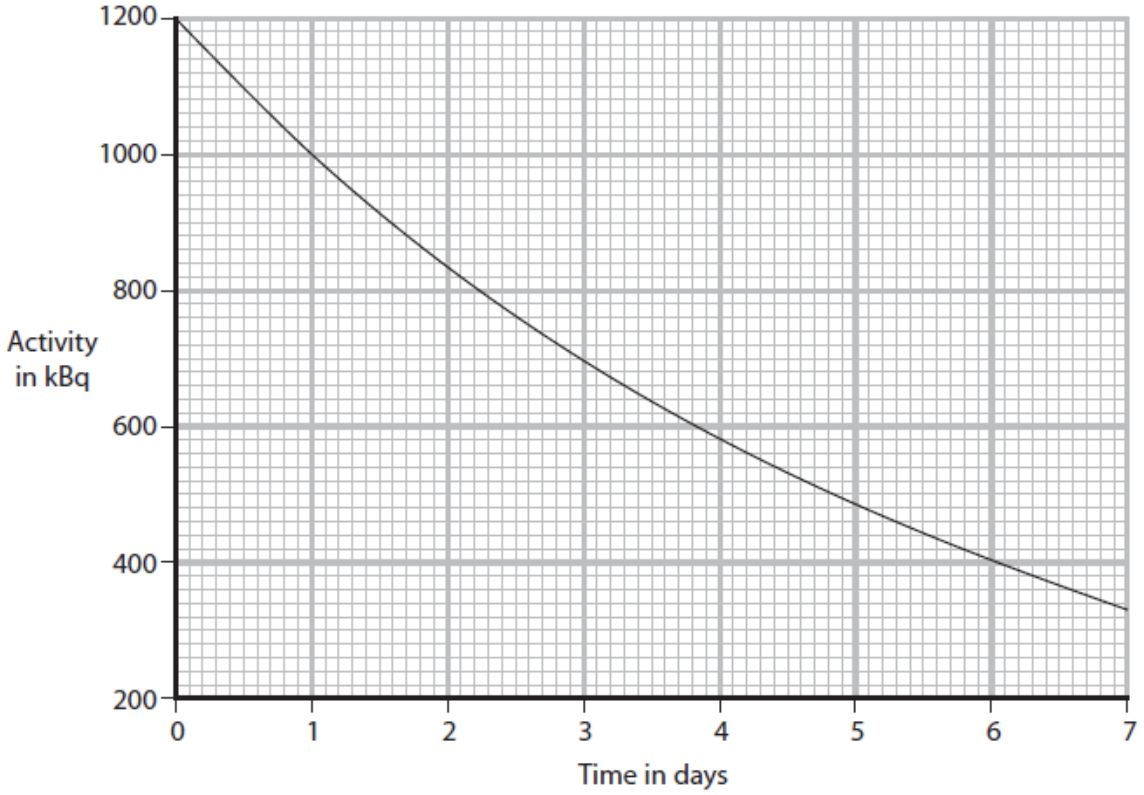
(b) The graph shows the activity of a sample of radon-222.



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

(2)

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(ii) Use the graph to determine the half-life of radon-222.

(2)

half-life = ... days

(c) Radon-222 is formed by multiple alpha decays of uranium-234.

Complete the nuclear equation by giving the missing information.

(3)

$$^{234}_{92}\mathrm{U} \rightarrow \ ^{222}_{\square}\mathrm{Rn} + 3\,^{\square}_{\square}\alpha$$

(d) Radon-222 also emits alpha radiation.

Explain the hazard to humans of breathing in air contaminated with radon-222.

(2)

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(Total for question = 11 marks)

Q19.

This is a question about alpha particles.

(a) Describe the nature of an alpha particle.

(1)

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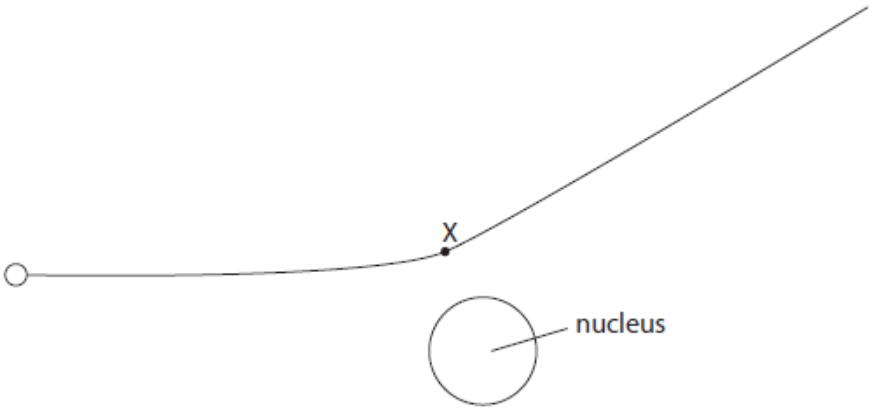
(b) The diagram shows the path of an alpha particle as it passes close to a nucleus.



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

Label this force Y.

(2)

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

Label this force Z.

(2)

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

(3)

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

Calculate the acceleration of the alpha particle.

(3)

acceleration = ... m/s^2

(Total for question = 11 marks)

Q20.

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

This is the teacher's method.

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

The teacher repeats this method for different absorbing materials.

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

(1)

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

(1)

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

(2)

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

(1)

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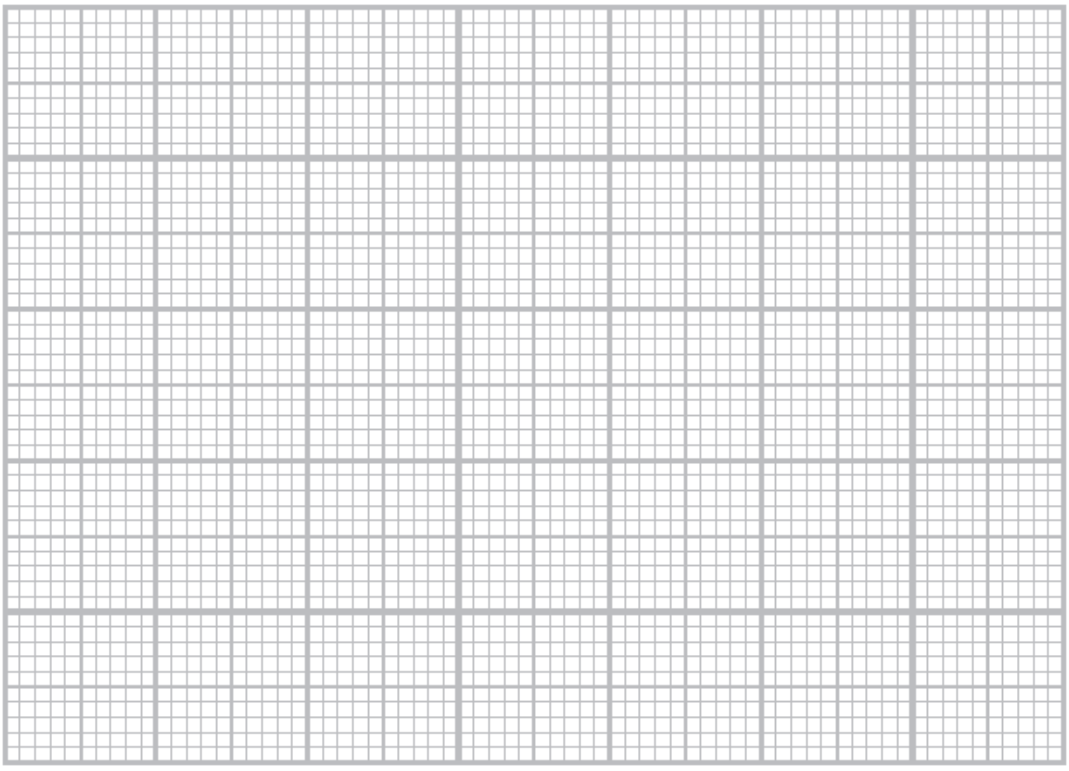
(e) The table shows the teacher's results for seven different absorbing materials.

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

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

(3)



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

(1)

☒ **A** absorbing material is a continuous variable

☒ **B** absorbing material is not a continuous variable

☒ **C** count rate is a continuous variable

☒ **D** count rate is not a continuous variable

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

Evaluate the student's conclusion.

(2)

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(Total for question = 11 marks)

Q21.

Cobalt-60 is a radioactive isotope of cobalt.

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

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

(a) Give a suitable unit for activity.

(1)

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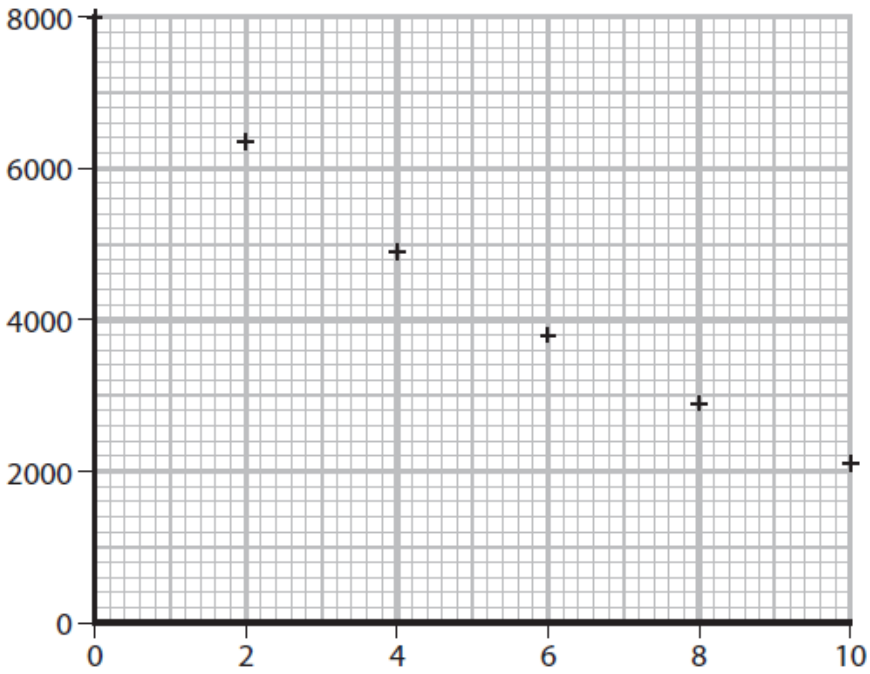
(b) The graph shows the data.



(i) Label both axes.

(1)

(ii) Draw the curve of best fit.

(1)

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

(2)

half-life = ... years

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

(2)

time = ... years

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

The nuclei of these two isotopes can be represented as

$^{60}_{27}Co$ $^{59}_{27}Co$

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

(2)

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(d) Cobalt-60 decays by beta emission.

Describe what happens to the nucleus of a cobalt-60 atom during beta decay.

(2)

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(e) Cobalt-60 also emits gamma radiation.

Cobalt-60 is produced in a nuclear reactor.

Discuss the hazards involved and the precautions taken when disposing of cobalt-60.

(4)

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(Total for question = 15 marks)

Q22.

A teacher investigates the count rate detected from a radioactive source.

(a) (i) State one source of background radiation.

(1)

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(ii) Describe how the teacher could measure the count rate from a radioactive source and correct the count rate for background radiation.

(4)

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(b) The teacher places a piece of lead sheet between the radioactive source and a radiation detector.

The teacher determines the corrected count rate from the radioactive source three times and calculates the mean.

They repeat this process using different thicknesses of lead sheet.

The table shows their results.

Thickness of lead in mm	Count rate in Bq			
	trial 1	trial 2	trial 3	mean
0.0	480	504	469	484
2.0	374	337	357	356
4.0	247	239	229	238
6.0	141	154	148	
8.0	110	104	131	115
10.0	88	91	85	88

(i) Calculate the mean count rate when the thickness of lead is 6.0 mm.

(2)

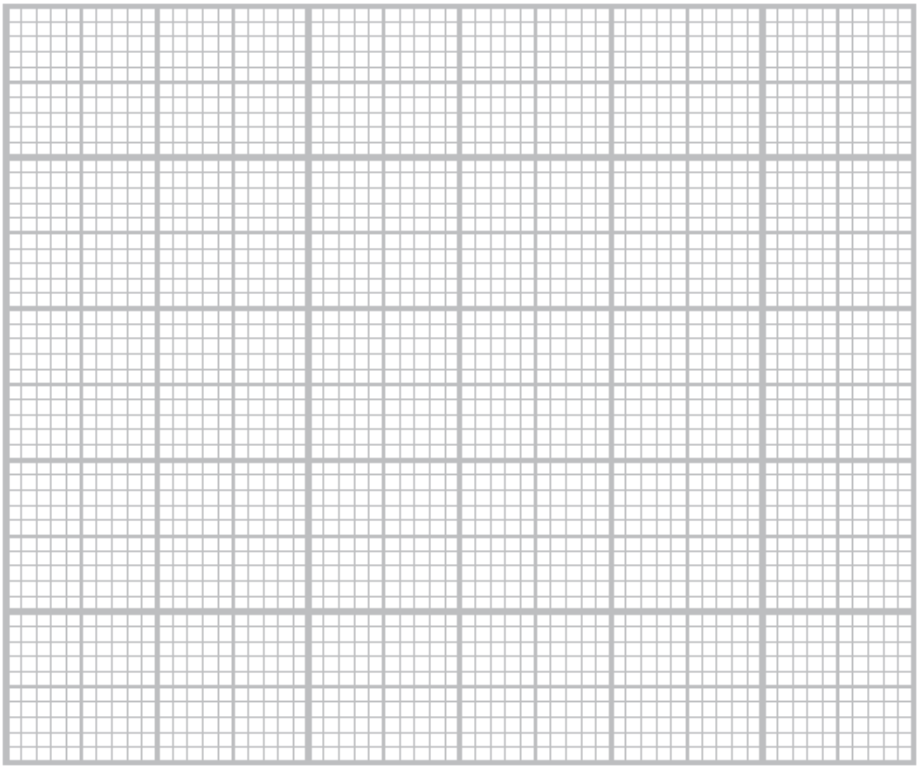
mean count rate = ... Bq

(ii) Plot a graph of mean count rate against thickness of lead.

(3)

(iii) Draw the curve of best fit.

(1)



(iv) When there is not a sheet of lead between the radioactive source and the radiation detector, the mean
count rate is 484 Bq.

Use the graph to determine the thickness of lead needed to reduce the mean count rate by 25%.

(2)

thickness = ... mm

(c) The radioactive source emits only one type of radiation.

Explain which type of radiation this radioactive source emits.

(2)

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(Total for question = 15 marks)