AQA GCSE Combined Science - Trilogy | 8464

SPECIFICATION POINT 6.4.2.1

Radioactive decay and nuclear radiation

Past-paper questions

Tier	**Higher**
Question groups	**13**
Available paper years	**2018–2025**

Using this booklet

1. Answer the questions in order and show your working.
2. Original question numbers and marks are retained.
3. Print at actual size (100%) for measuring questions.
4. Use the companion answer booklet to check your work.

Name: _____ **Date:** _____

Whole questions are retained for context, so some parts assess other specification points. Current and legacy sources are labelled. Continue on extra paper if needed.

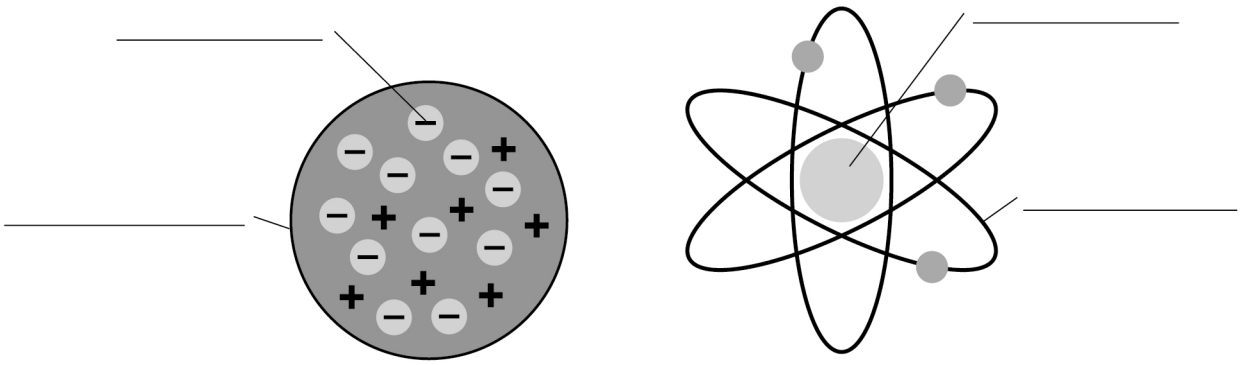
6.4.2.1 Radioactive decay and nuclear radiation

Question 01

June 2018 | 8464/P/1H | Original Q1

0 1 **Figure 1** shows two models of the atom.

Figure 1



Plum pudding model

Nuclear model

0 1 . 1 Write the labels on **Figure 1**

Choose the answers from the box.

[4 marks]

atom	**electron**	**nucleus**
neutron	**orbit**	**proton**

0 1 . 2 Explain why the total positive charge in every atom of an element is always the same.

[2 marks]

6.4.2.1 Radioactive decay and nuclear radiation

Question 01 · continued

0 1 . 3 The results from the alpha particle scattering experiment led to the nuclear model.

Alpha particles were fired at a thin film of gold at a speed of 7% of the speed of light.

Determine the speed of the alpha particles.

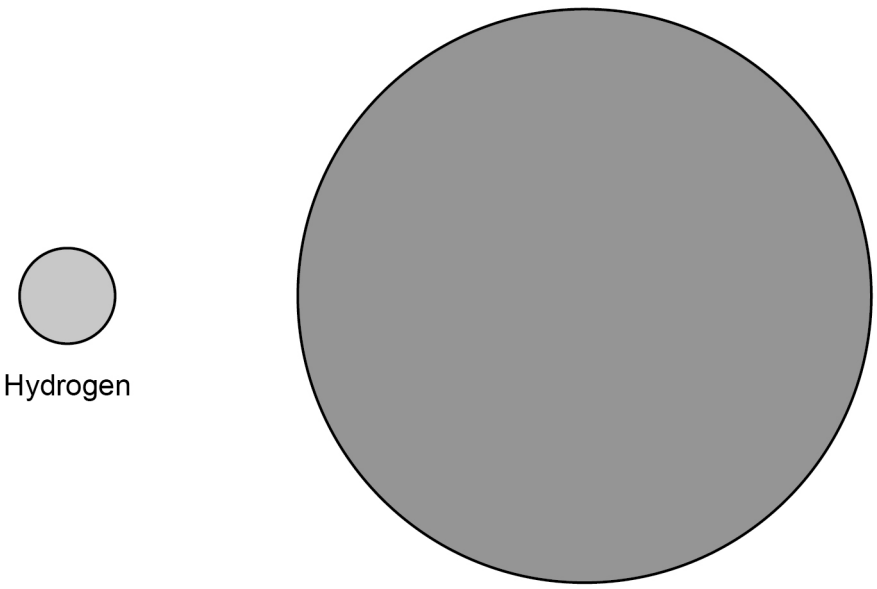
Speed of light = 300 000 000 m/s

[2 marks]

Speed = _____ m/s

0 1 . 4 **Figure 2** shows two atoms represented as solid spheres.

Figure 2



A hydrogen atom has a radius of 2.5×10^{-11} m

Determine the radius of a magnesium atom.

Use measurements from **Figure 2**

[2 marks]

Radius = _____ m

10

6.4.2.1 Radioactive decay and nuclear radiation

Question 02

0 4 The Chernobyl disaster was a nuclear accident that happened in 1986

Radioactive isotopes were released into the environment.

The radioactive isotopes emitted alpha, beta and gamma radiation.

0 4 . 1 What is an alpha particle?

[1 mark]

Tick **one** box.

- 2 charged particles and 2 neutral particles. ☐
- 2 charged particles and 4 neutral particles. ☐
- 4 charged particles and 2 neutral particles. ☐
- 4 charged particles and 4 neutral particles. ☐

0 4 . 2 Which statement about beta radiation is true?

[1 mark]

Tick **one** box.

- It is the fastest moving type of radiation. ☐
- It is the type of radiation with a negative charge. ☐
- It is the type of radiation with the greatest mass. ☐
- It is the type of radiation with the greatest range in air. ☐

6.4.2.1 Radioactive decay and nuclear radiation

Question 02 · continued

0 4 . 3 Which statement about gamma radiation is true?

[1 mark]

Tick **one** box.

- It is a low frequency electromagnetic wave. ☐
- It causes the charge of the nucleus to change. ☐
- It causes the mass of the nucleus to change. ☐
- It has a very long range in air. ☐

Question 4 continues on the next page

Question 02 · continued

Table 3 shows the half-lives of two of the radioactive isotopes that contaminated the environment.

Table 3

Isotope	Half-life
Caesium–137	30 years
Iodine–131	8 days

0 4 . 4 A soil sample was taken from the area around Chernobyl in 1986

The soil sample was contaminated with equal amounts of caesium–137 and iodine–131

Explain how the risk linked to each isotope has changed between 1986 and 2018

Both isotopes emit the same type of radiation.

[4 marks]

0 4 . 5 Determine the year when the activity of the caesium–137 in the soil sample will be 1/32 of its original value.

[3 marks]

Year = _____

10

6.4.2.1 Radioactive decay and nuclear radiation

Question 03

June 2019 | 8464/P/1H | Original Q6

0 6 Lanthanum-140 is a radioactive isotope.

0 6 . 1 A nucleus of lanthanum-140 emits gamma radiation.

What happens to the mass number and the charge of the nucleus when gamma radiation is emitted?

[1 mark]

Tick (✓) **one** box.

Mass number	Charge	
Decreases	Decreases	☐
Decreases	Stays the same	☐
Stays the same	Decreases	☐
Stays the same	Stays the same	☐

0 6 . 2 Why is it difficult to detect gamma radiation?

[1 mark]

Question 6 continues on the next page

Question 03 · continued

0 6 . 3 Activity is the rate at which a radioactive source decays.

A teacher measured the count-rate from a sample of lanthanum-140 using a Geiger-Muller (G-M) tube.

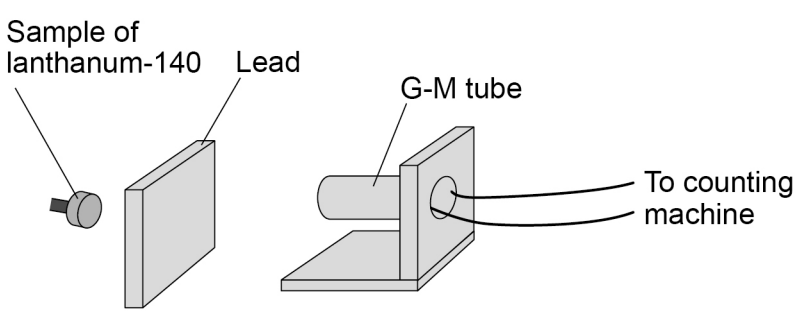
Explain why the count rate was less than the activity of the sample of lanthanum-140

[2 marks]

The teacher investigated how the thickness of lead affected the amount of gamma radiation that could pass through it.

Figure 6 shows the apparatus.

Figure 6



0 6 . 4 Explain why the teacher stood as far away from the apparatus as possible.

[2 marks]

Question 03 · continued

Table 1 shows the results.

Table 1

Thickness of lead in cm	Count rate in counts per second
0.5	110
1.0	60
1.5	33
2.0	18
2.5	10

0 6 . 5 The teacher concluded that the count rate was **not** inversely proportional to the thickness of lead.

Explain why the teacher was correct.

Use the data in **Table 1**.

[3 marks]

0 6 . 6 Lanthanum-140 can also emit beta radiation and change into cerium.

Complete the equation showing the decay of lanthanum (La) 140 into cerium (Ce).

[2 marks]

$$^{140}_{57}\mathrm{La} \longrightarrow {}^{\quad}_{\quad}\mathrm{e} + {}^{\quad}_{\quad}\mathrm{Ce}$$

Question 03 · continued

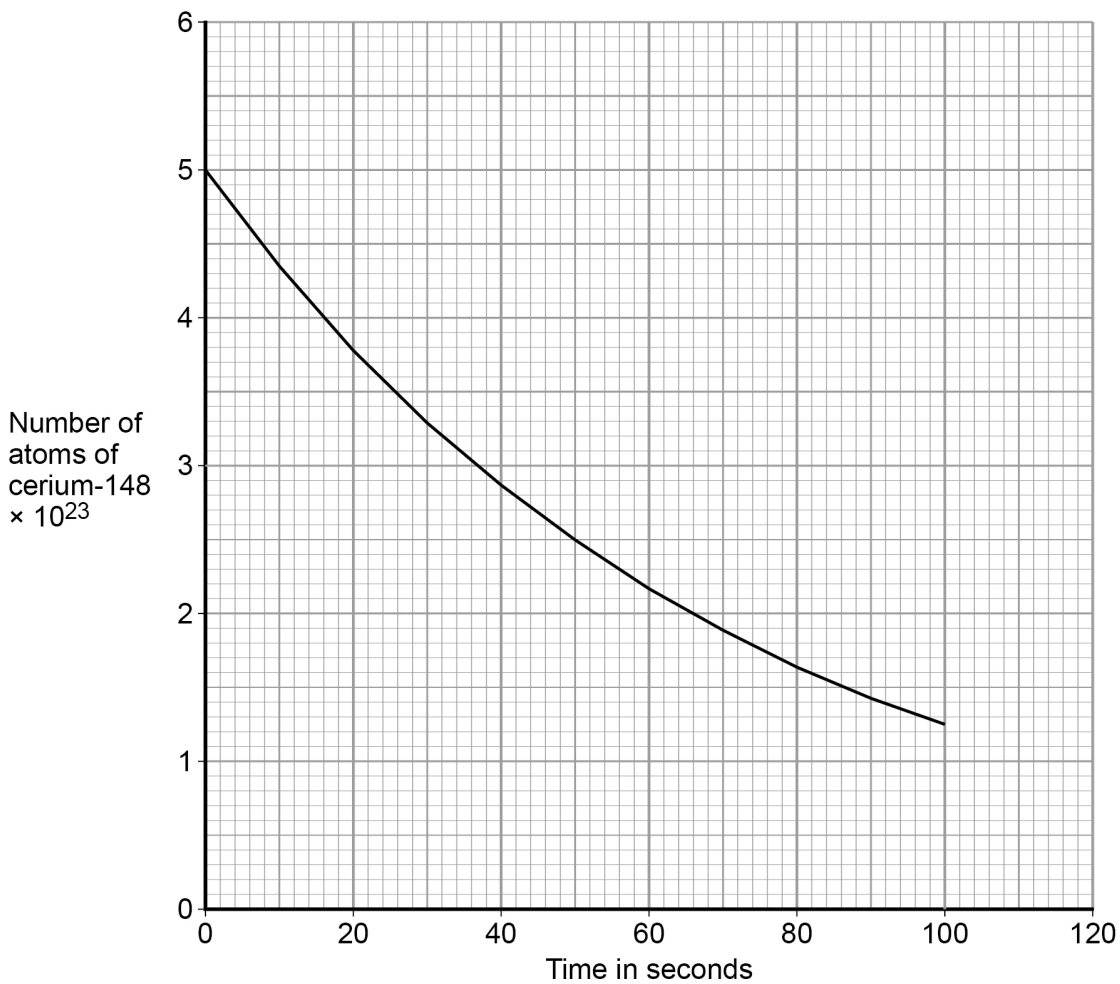
There are other isotopes of cerium which are radioactive.

Different isotopes of cerium have different half-lives.

The half-life of an isotope can be found by studying how the number of atoms changes over time.

Figure 7 shows how the number of atoms of cerium-148 in a 120 g sample changes over time.

Figure 7



6.4.2.1 Radioactive decay and nuclear radiation

Question 03 · continued

0 6 . 7 Determine the ratio of the number of cerium atoms in the sample when it was 100 seconds old compared with when the sample was 350 seconds old.

Use data from **Figure 7**.

[4 marks]

Ratio = _____

0 6 . 8 Determine the activity of the sample of cerium when the sample was 20 seconds old.

Use **Figure 7**.

[3 marks]

Activity = _____ Bq

18

6.4.2.1 Radioactive decay and nuclear radiation

Question 04

November 2020 | 8464/P/1H | Original Q2

0 2 Different radioactive isotopes emit different types of nuclear radiation.

A polonium-210 (Po) nucleus emits an alpha particle (α) and turns into a lead (Pb) nucleus.

This can be represented by the equation:

$$^{210}_{84}Po \longrightarrow {}^{A}_{Z}Pb + \alpha$$

0 2 . 1 What is the value of A in the equation?

[1 mark]

Tick (✓) **one** box.

A = 206 ☐ A = 208 ☐ A = 210 ☐ A = 211 ☐

0 2 . 2 What is the value of Z in the equation?

[1 mark]

Tick (✓) **one** box.

Z = 80 ☐ Z = 82 ☐ Z = 85 ☐ Z = 86 ☐

Question 2 continues on the next page

6.4.2.1 Radioactive decay and nuclear radiation

Question 04 · continued

0 2 . 3 A strontium-89 nucleus (Sr) emits a beta particle (β) and turns into an yttrium nucleus (Y).

This can be represented by the equation:

$$^{89}_{38}\text{Sr} \longrightarrow {}^{A}_{Z}\text{Y} + \beta$$

What are the values of A and Z in the equation?

[2 marks]

A = _____

Z = _____

0 2 . 4 Gamma radiation is another type of nuclear radiation.

What does gamma radiation consist of?

[1 mark]

Tick (✓) **one** box.

- [ ] High energy neutrons
- [ ] Electromagnetic waves
- [ ] Particles with no charge
- [ ] Positively charged ions

6.4.2.1 Radioactive decay and nuclear radiation

Question 04 · continued

0 2 . 5 Explain the differences between the properties of alpha, beta and gamma radiations.

[6 marks]

11

6.4.2.1 Radioactive decay and nuclear radiation

Question 05

November 2020 | 8464/P/1H | Original Q6

0 6 A student modelled radioactive decay by rolling some dice in a tray.

Dice that landed on the number six were removed from the tray.

The removed dice represent nuclei that have decayed.

0 6 . 1 Why is rolling dice a suitable model for radioactive decay?

[1 mark]

0 6 . 2 The student rolled 144 dice and removed all those that landed on the number six.

The student rolled the remaining dice and again removed all those that landed on the number six.

When the student had rolled the dice 20 times there were 9 dice left.

Calculate the most likely number of times that the student had rolled the dice before the number of dice had halved.

You should show how you work out your answer.

[3 marks]

Answer = _____ rolls of the dice

Question 05 · continued

0 6 . 3 The number of times the dice have to be rolled to halve the original number of dice in the tray represents the half-life.

Figure 7 shows an eight-sided dice and a six-sided dice.

Figure 7



The student now used eight-sided dice to model radioactive decay. Dice that landed on the number six were again removed from the tray.

The half-life represented by rolling eight-sided dice is likely to be different from the half-life represented by rolling six-sided dice.

Explain how.

[2 marks]

0 6 . 4 A teacher has two radioactive sources, **A** and **B**.

Source **A** has a longer half-life than source **B**.

What can be deduced about the nuclei in source **A** compared with the nuclei in source **B**?

Do **not** refer to isotopes in your answer.

[1 mark]

7

6.4.2.1 Radioactive decay and nuclear radiation

Question 06

November 2021 | 8464/P/1H | Original Q2

0 2 A radioactive source emits alpha, beta and gamma radiation.

0 2 . 1 An alpha particle is the same as a helium nucleus.

How many times bigger is the radius of a helium atom than the radius of an alpha particle?

[1 mark]

Tick (✓) **one** box.

- Less than 100 times bigger ☐
- Exactly 5000 times bigger ☐
- More than 10 000 times bigger ☐

0 2 . 2 Alpha particles can ionise atoms in the air.

What happens to an atom when it is ionised by an alpha particle?

[2 marks]

Tick (✓) **two** boxes.

- A neutron in the atom becomes a proton. ☐
- The atom becomes a positive ion. ☐
- The atom gains a neutron. ☐
- The atom gains a proton. ☐
- The atom loses an electron. ☐

Question 2 continues on the next page

6.4.2.1 Radioactive decay and nuclear radiation

Question 06 · continued

0 2 . 3 A spark detector is a device that can be used to detect alpha radiation.

A spark detector works by alpha particles ionising atoms in the air near a wire mesh.

A large potential difference creates a spark when the air near the wire mesh is ionised.

Suggest why a spark detector **cannot** detect beta radiation.

[1 mark]

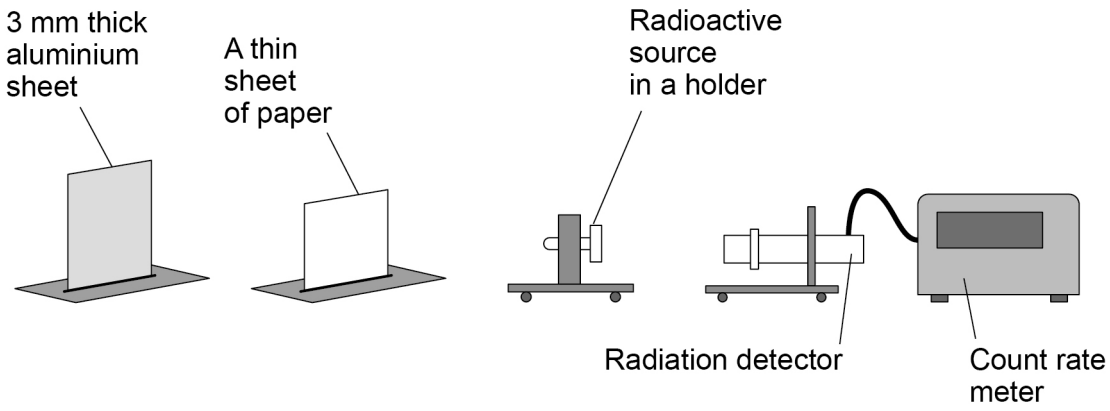
6.4.2.1 Radioactive decay and nuclear radiation

Question 06 · continued

0 2 . 4 A teacher wants to demonstrate that the radioactive source emits alpha, beta and gamma radiation.

Figure 3 shows the equipment the teacher has.

Figure 3



Describe a method the teacher could use.

[6 marks]

10

6.4.2.1 Radioactive decay and nuclear radiation

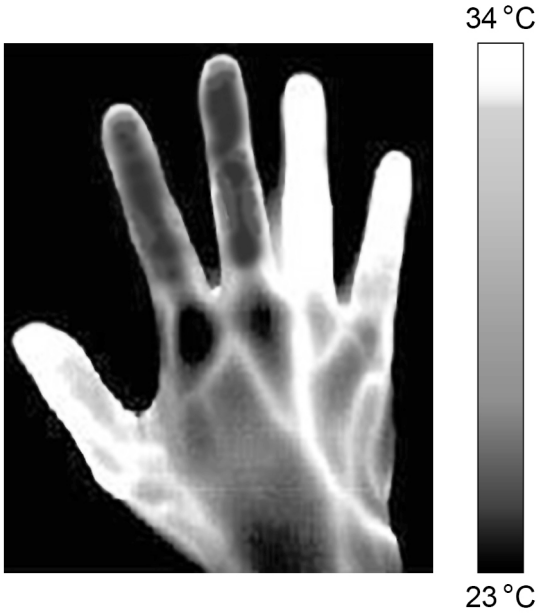
Question 07

November 2021 | 8464/P/2H | Original Q5

0 5 Different parts of the electromagnetic spectrum are used in medical imaging.

Figure 8 shows an image of a person's hand taken with an infrared camera.

Figure 8



0 5 . 1 Explain why the infrared camera is able to show that parts of the hand are at different temperatures.

[2 marks]

Question 5 continues on the next page

0 5 . 2 Infrared has a range of wavelengths from 700 nm to 1 mm.

Which part of the electromagnetic spectrum would have waves with a wavelength of 6.5×10^{-7} m?

[1 mark]

Tick (✓) **one** box.

- Infrared ☐
- Microwaves ☐
- Radio waves ☐
- Visible light ☐

6.4.2.1 Radioactive decay and nuclear radiation

Question 07 · continued

0 5 . 3 **Figure 9** shows X-rays and gamma rays being used for medical imaging.

Figure 9

X-rays **Gamma rays**



To use X-rays for medical imaging, a machine produces a very brief burst of X-rays.

To use gamma rays for medical imaging, a radioactive isotope is injected into the patient's blood. The isotope is circulated around the body in the blood. The isotope emits gamma rays.

Compare the potential risks to a patient of using X-rays and gamma rays for medical imaging.

[4 marks]

Question 5 continues on the next page

6.4.2.1 Radioactive decay and nuclear radiation

Question 07 · continued

X-rays are produced by colliding high-energy electrons into a metal target.

The electrons have high energy because they are accelerated to high speeds.

Only a small proportion of the kinetic energy of an electron is converted into an X-ray when it collides with the metal target.

0 5 . 4 An electron is accelerated through a distance of 15 mm.

The work done on the electron is 1.2×10^{-13} J.

Calculate the force on the electron.

[3 marks]

Force = _____ N

0 5 . 5 The metal target is made from tungsten.

Tungsten has the highest melting point of any metal.

Explain why using tungsten as the metal target enables the X-ray machine to be more powerful.

[3 marks]

13

6.4.2.1 Radioactive decay and nuclear radiation

Question 08

June 2022 | 8464/P/1H | Original Q6

0 6 A smoke detector contains a source of alpha radiation in a plastic case.

0 6 . 1 A source of beta radiation in a smoke detector would be more hazardous than a source of alpha radiation.

Explain why.

[2 marks]

0 6 . 2 Actinium (Ac) is one source of alpha radiation.

An actinium (Ac) nucleus emits an alpha particle (α) and turns into a francium (Fr) nucleus.

This can be represented as:

$$^{A}_{Z}Ac \longrightarrow {}^{223}_{87}Fr + \alpha$$

Determine the values of **A** and **Z**.

[2 marks]

A = _____

Z = _____

0 6 . 3 A teacher wanted to find out what nuclear radiation is emitted from a source.

The teacher placed different barriers between the source and a detector.

The teacher recorded the count for 30 seconds after each barrier was put in place.

Table 2 shows the results.

Table 2

Barrier	Thickness in millimetres	Count after 30 seconds
None		985
Paper	0.1	149
Aluminium	5.0	0
Lead	20.0	0

Explain what nuclear radiation was emitted by the source.

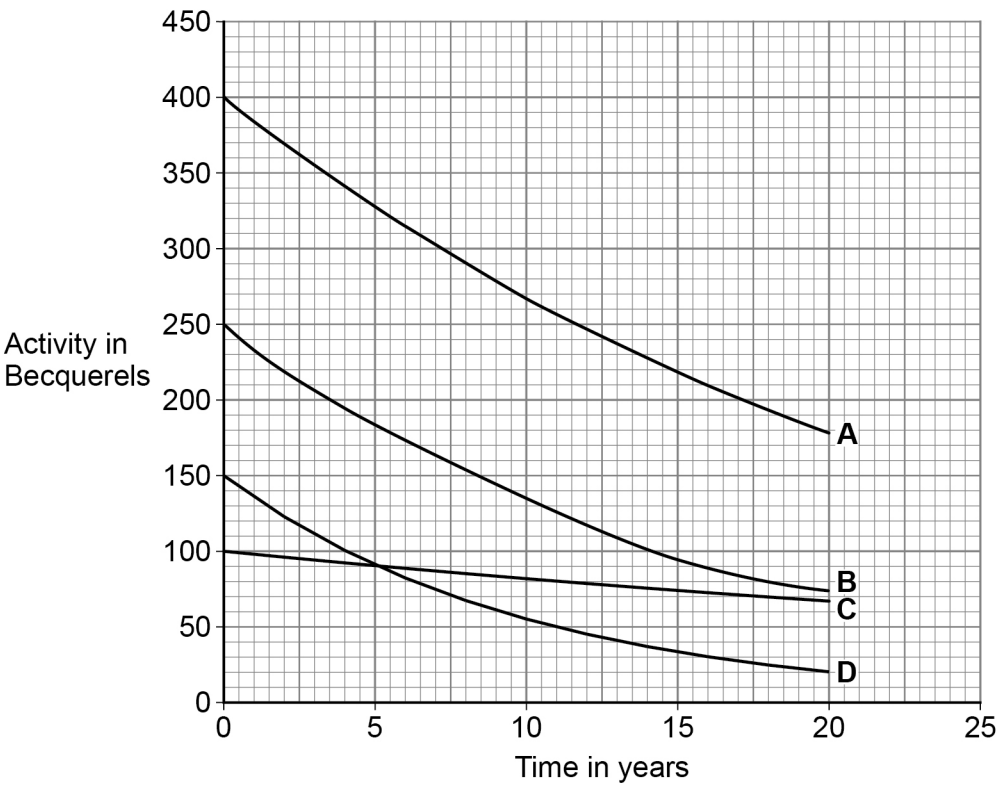
[4 marks]

Question 6 continues on the next page

Question 08 · continued

0 6 . 4 **Figure 11** shows how the activity of four different radioactive isotopes, **A**, **B**, **C** and **D**, changes over time.

Figure 11



6.4.2.1 Radioactive decay and nuclear radiation

Question 08 · continued

Write the isotopes **A**, **B**, **C** and **D** in order of increasing stability of their nuclei.

Explain your answer.

[3 marks]

Least stable **Most stable**

_____ _____ _____ _____

Explanation _____

_____

_____

_____

_____

_____

11

6.4.2.1 Radioactive decay and nuclear radiation

Question 09

June 2023 | 8464/P/1H | Original Q4

0 4 A scientist investigated a sample of a radioactive material to determine if it would be suitable for medical use.

0 4 . 1 The method, results and conclusions of the scientist will need to be checked by other scientists before the results of the investigation are published.

What name is given to this checking process?

[1 mark]

0 4 . 2 There is an increased risk of cancer if the scientist is irradiated by nuclear radiation.

What property of nuclear radiation causes the increased risk of cancer?

[1 mark]

0 4 . 3 The activity of a radioactive source is the rate at which the nuclei of the source decay.

What is the unit for the activity of a radioactive source?

[1 mark]

0 4 . 4 The scientist placed a radiation detector near the sample and measured the count-rate.

Explain why the count-rate is less than the activity of the sample.

[2 marks]

6.4.2.1 Radioactive decay and nuclear radiation

Question 09 · continued

0 4 . 5 The scientist recorded the count-rate from the sample with the radiation detector at different distances from the sample.

Table 2 shows the results.

Table 2

Distance between the sample and the detector in centimetres	Count-rate in counts/second
2.0	300
5.0	24
10.0	0

Explain which type of radiation was emitted by the sample.

[2 marks]

Question 4 continues on the next page

6.4.2.1 Radioactive decay and nuclear radiation

Question 09 · continued

0 4 . 6 The scientist moved the detector closer to the sample and started a stopwatch.

The scientist measured the count-rate from the sample at different times.

Table 3 shows some of the results.

Table 3

Time in minutes	Count-rate in counts/second
0	1568
30	**X**
60	98

The scientist realised that 30 minutes is a whole number of half-lives.

Calculate the value of **X** in **Table 3**.

[3 marks]

X = _____ counts/second

6.4.2.1 Radioactive decay and nuclear radiation

Question 09 · continued

0 4 . 7 The scientist had a second sample of the radioactive material.

The scientist made appropriate measurements, then calculated the half-life of each sample.

Why was the half-life calculated from the second sample slightly different from the half-life calculated from the first sample?

[1 mark]

Tick (✓) **one** box.

Radioactive decay is a random process. ☐

The count-rate from a radioactive sample is predictable. ☐

The samples were at different temperatures. ☐

The size of each sample was different. ☐

11

Turn over for the next question

6.4.2.1 Radioactive decay and nuclear radiation

Question 10

June 2023 | 8464/P/2H | Original Q1

0 1 The Sun emits a continuous spectrum of electromagnetic waves.

Figure 1 names some of the groups of waves in the electromagnetic spectrum.

Figure 1

A	**B**	Infrared	Visible light	Ultraviolet	**C**	Gamma rays

0 1 . 1 Name groups **A**, **B** and **C** in **Figure 1**.

[2 marks]

A _____

B _____

C _____

0 1 . 2 Give **one** similarity and **one** difference between the properties of ultraviolet waves and gamma rays.

[2 marks]

Similarity _____

_____

Difference _____

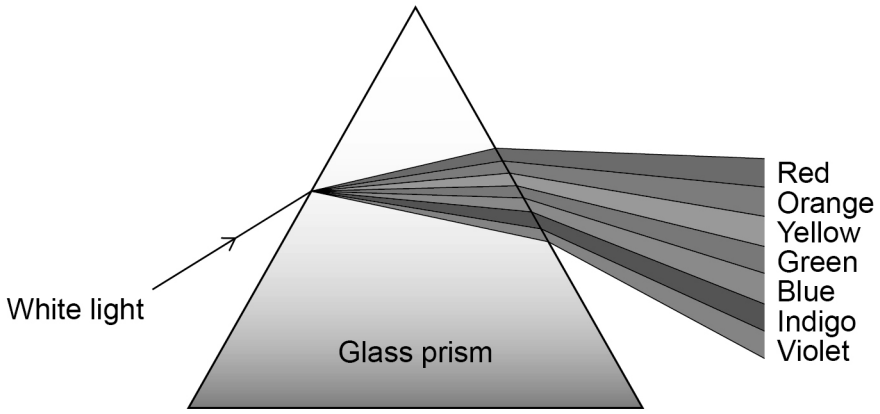
_____

6.4.2.1 Radioactive decay and nuclear radiation

Question 10 · continued

Figure 2 shows white light split into a spectrum of different colours by a glass prism.

Figure 2



0 1 . 3 Light changes direction when it enters the glass prism.

What name is given to this process?

[1 mark]

_____

Question 1 continues on the next page

6.4.2.1 Radioactive decay and nuclear radiation

Question 10 · continued

Use the Physics Equations Sheet to answer questions **01.4** and **01.5**.

0 1 . 4 Write down the equation that links frequency (f), wavelength (λ) and wave speed (v).

[1 mark]

0 1 . 5 The wave in the middle of the spectrum has a wavelength of 5.0×10^{-7} m.

wave speed of light = 3.0×10^{8} m/s

Calculate the frequency of the wave.

[3 marks]

Frequency = _____ Hz

9

6.4.2.1 Radioactive decay and nuclear radiation

Question 11

June 2024 | 8464/P/1H | Original Q2

0 2 Last century, scientists used evidence from the alpha particle scattering experiment to develop a new model of the atom.

In the experiment, alpha particles were directed towards a piece of gold foil.

0 2 . 1 What does an alpha particle consist of?

[1 mark]

0 2 . 2 A gold atom has the symbol $^{197}_{79}Au$.

How many neutrons are there in this gold atom?

[1 mark]

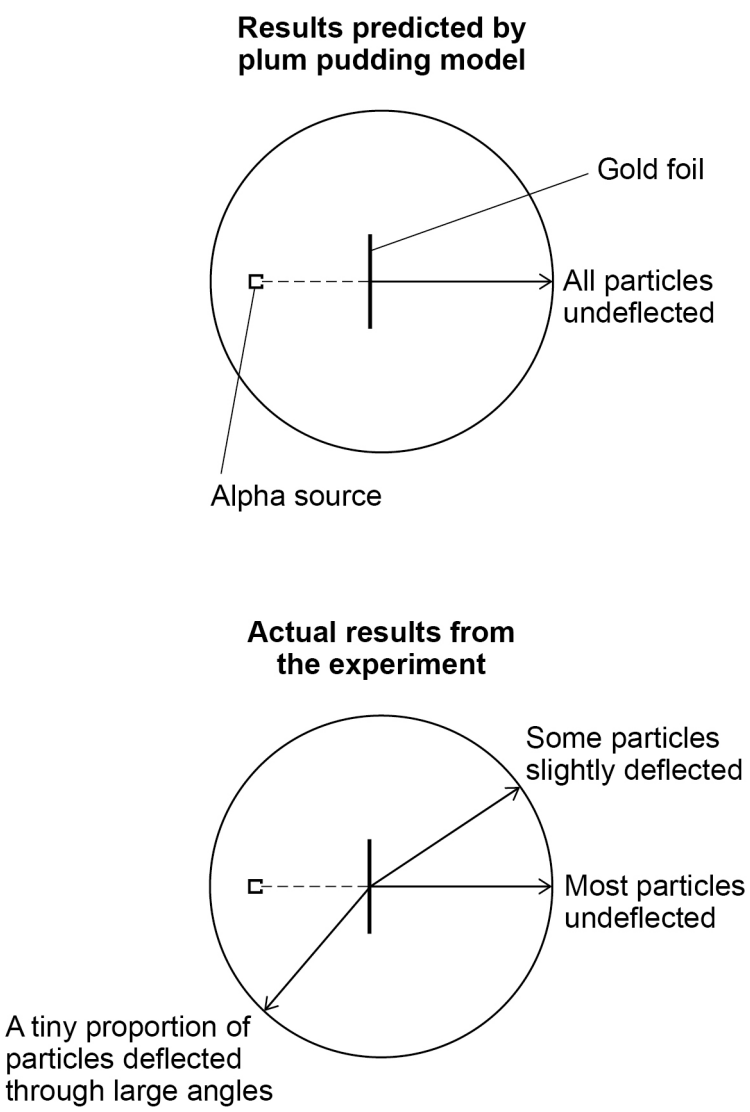
Number of neutrons = _____

Question 2 continues on the next page

0 2 . 3 The alpha particle scattering experiment led to the plum pudding model of the atom being replaced by the nuclear model.

Figure 2 shows the results predicted by the plum pudding model and the actual results from the alpha particle scattering experiment.

Figure 2



6.4.2.1 Radioactive decay and nuclear radiation

Question 11 · continued

Describe how the actual results led to the plum pudding model of the atom being replaced by the nuclear model.

You should include details of the plum pudding model and the nuclear model of the atom.

[6 marks]

0 2 . 4 Scientists did not know that neutrons existed when they first did alpha particle scattering experiments.

Which scientist did the experiments that provided evidence that neutrons exist?

[1 mark]

Tick (✓) **one** box.

Isaac Newton ☐

James Chadwick ☐

Niels Bohr ☐

9

6.4.2.1 Radioactive decay and nuclear radiation

Question 12

June 2024 | 8464/P/1H | Original Q5

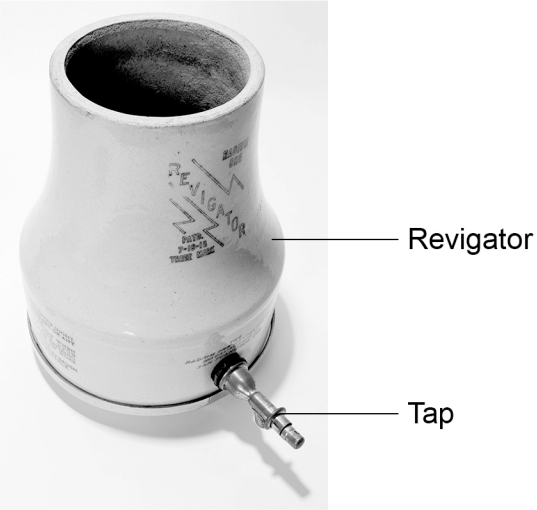
0 5 Some people used to think that radioactive substances had health benefits.

In the 1920s, a water container called a revigator was sold.

The walls of a revigator contain radioactive isotopes.

Figure 6 shows a revigator.

Figure 6



The revigator was filled with water and left overnight.

People then drank the water from the revigator.

6.4.2.1 Radioactive decay and nuclear radiation

Question 12 · continued

0 5 . 1 The water was irradiated and contaminated by the radioactive isotopes in the walls of the revigator.

Explain how irradiating and contaminating the water affected the hazard caused by drinking the water.

[4 marks]

Irradiating _____

_____

_____

_____

Contaminating _____

_____

_____

_____

Question 5 continues on the next page

6.4.2.1 Radioactive decay and nuclear radiation

Question 12 · continued

A scientist tested some water that had been left in a revigator.

The water contained radon-222 and vanadium-52.

0 5 . 2 Vanadium-52 (V) decays by emitting beta particles.

What is the correct nuclear equation for this process?

[1 mark]

Tick (✓) **one** box.

$^{52}_{23}V - {}^{0}_{-1}\beta \rightarrow {}^{52}_{22}Ti$ ☐

$^{52}_{23}V - {}^{0}_{-1}\beta \rightarrow {}^{52}_{24}Cr$ ☐

$^{52}_{23}V \rightarrow {}^{52}_{22}Ti + {}^{0}_{-1}\beta$ ☐

$^{52}_{23}V \rightarrow {}^{52}_{24}Cr + {}^{0}_{-1}\beta$ ☐

Question 12 · continued

0 5 . 3 **Table 2** shows the half-lives of radon-222 and vanadium-52.

Table 2

Isotope	Half-life
Radon-222	3.8 days
Vanadium-52	3.7 minutes

The scientist measured the radiation emitted by a sample of radon-222 and the radiation emitted by a sample of vanadium-52.

The scientist repeated the measurements 7.4 minutes later.

Explain how the activity of the radon-222 and vanadium-52 had changed after 7.4 minutes.

[4 marks]

Radon-222 _____

_____

_____

_____

Vanadium-52 _____

_____

_____

_____

0 5 . 4 Scientists monitored the effects of drinking the water from a revigator.

Their methods and results were checked by other scientists.

What name is given to the process of other scientists checking work before it is published?

[1 mark]

_____

10

6.4.2.1 Radioactive decay and nuclear radiation

Question 13

June 2025 | 8464/P/1H | Original Q4

0 4 Three types of radiation emitted by unstable nuclei are:

- alpha particle
- beta particle
- gamma ray.

0 4 . 1 Describe each type of radiation.

[3 marks]

Alpha particle _____

_____

Beta particle _____

_____

Gamma ray _____

_____

0 4 . 2 The radioactive isotope gold-198 (Au) decays to mercury (Hg) by emitting beta radiation.

Complete the nuclear equation for the decay of gold-198.

[2 marks]

$$^{198}_{79}\text{Au} \rightarrow \ ^{\quad}_{\quad}\text{Hg} + \ ^{\quad}_{\quad}\beta$$

Question 4 continues on the next page

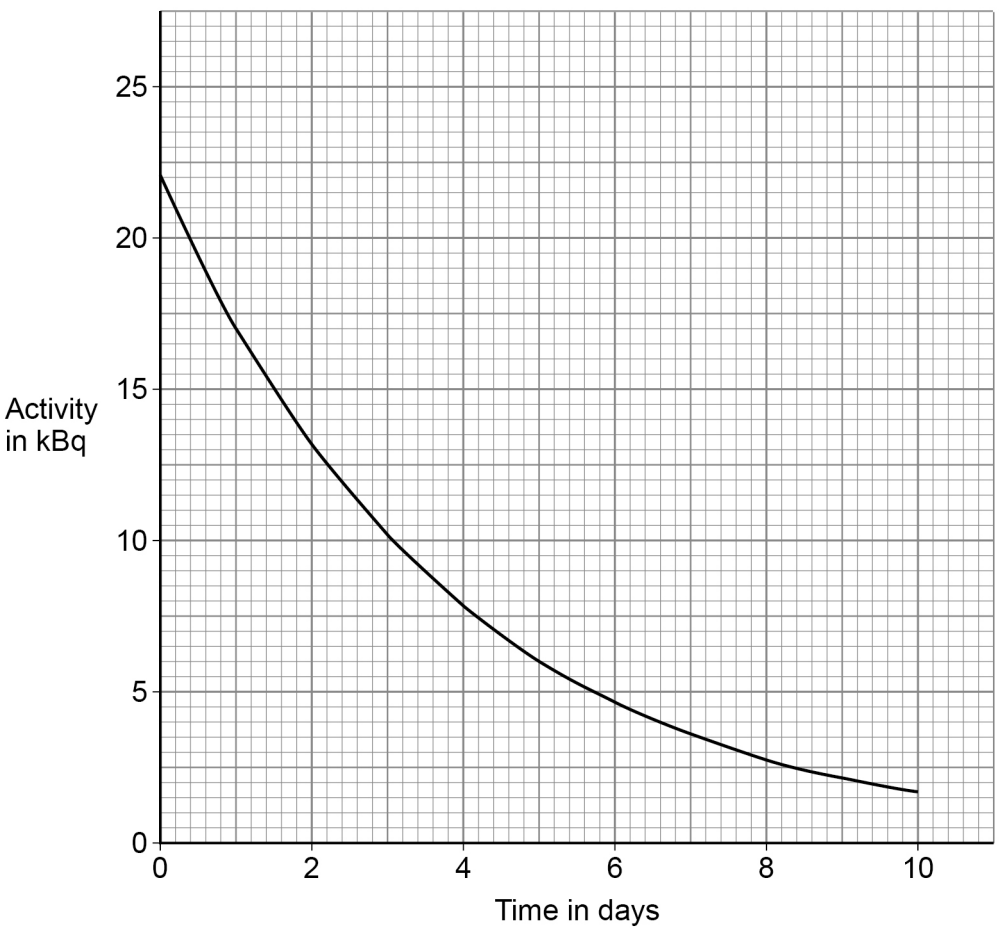
Question 13 · continued

Gold-198 is used in the treatment of cancer.

A small sample containing gold-198 is surgically implanted into a patient, very near to the cancer cells.

Figure 4 shows how the activity of the sample changes after it has been implanted.

Figure 4



0 4 . 3 Determine the half-life of gold-198.

[2 marks]

Half-life = _____ days

6.4.2.1 Radioactive decay and nuclear radiation

Question 13 · continued

0 4 . 4 Determine the percentage decrease in the activity at 5 days.

Give your answer to 2 significant figures.

[4 marks]

Percentage decrease (2 significant figures) = _____ %

0 4 . 5 The sample containing gold-198 is implanted very near to the cancer cells.

Give **two** reasons why.

[2 marks]

1 _____

2 _____

0 4 . 6 After treatment, the sample containing gold-198 is **not** removed from the patient.

Suggest why the sample is left in the patient and **not** removed.

[1 mark]

_____

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