

PHYSICS



EXAM QUESTION PACK

P6.1 RADIOACTIVE EMISSIONS

SCORE

/167

PERCENTAGE

%

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Gateway Physics A (9-1)

Radioactive emissions

Please note that you may see slight differences between this paper and the original.

Candidates answer on the Question paper.

OCR supplied materials:

Additional resources may be supplied with this paper.

Other materials required:

- Pencil
- Ruler (cm/mm)

Duration: Not set

Candidate
forename

Candidate
surname

Centre number

Candidate number

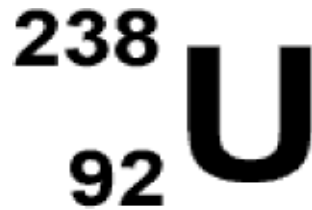
INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions, unless your teacher tells you otherwise.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Where space is provided below the question, please write your answer there.
- You may use additional paper, or a specific Answer sheet if one is provided, but you must clearly show your candidate number, centre number and question number(s).

INFORMATION FOR CANDIDATES

- The quality of written communication is assessed in questions marked with either a pencil or an asterisk. In History and Geography a *Quality of extended response* question is marked with an asterisk, while a pencil is used for questions in which *Spelling, punctuation and grammar and the use of specialist terminology* is assessed.
- The number of marks is given in brackets [] at the end of each question or part question.
- The total number of marks for this paper is **167**.
- The total number of marks may take into account some 'either/or' question choices.

1 What is the number of neutrons in this isotope of uranium?



- A 92
- B 119
- C 146
- D 238

Your answer

[1]

2 All radioactive sources have a half-life.

Which statement about the half-life of a source is correct?

- A It is half the time for the radioactive source to become safe.
- B It is half the time it takes for an atom to decay.
- C It is half the time it takes the activity of the source to decrease to zero.
- D It is the time it takes the activity of the source to decrease by half.

Your answer

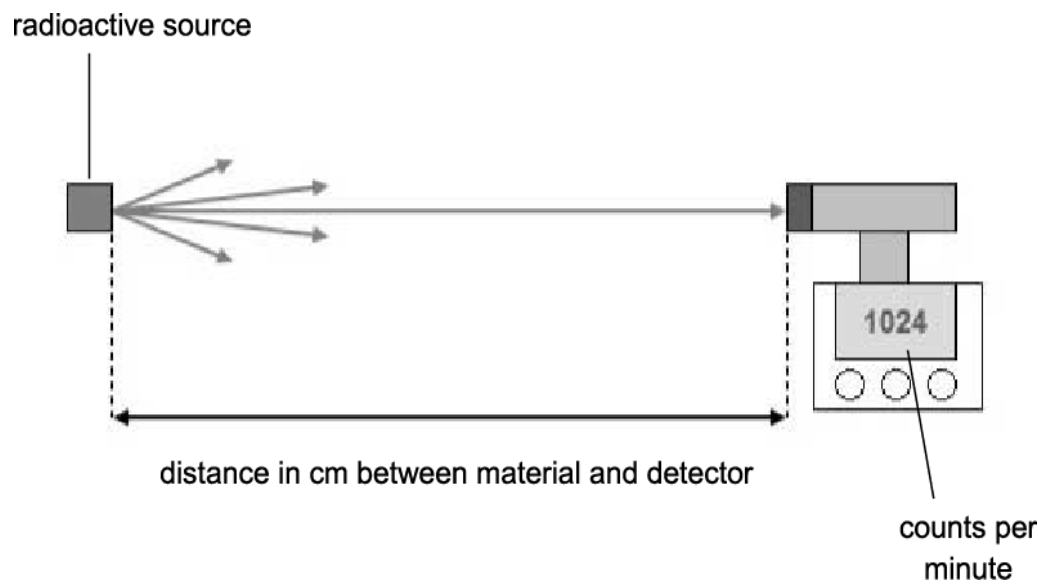
[1]

3(a) Matt experiments with radioactive materials.

He investigates how the activity of radiation changes with distance.

The radiation moves from the source to a detector.

He measures the counts per minute from a radioactive source.



The table shows the results from the experiment.

Distance between the source and the detector (cm)	Count rate (counts per minute)
10	1000
20	240
40	60
80	20

Matt could **not** take an accurate reading at 0 cm.

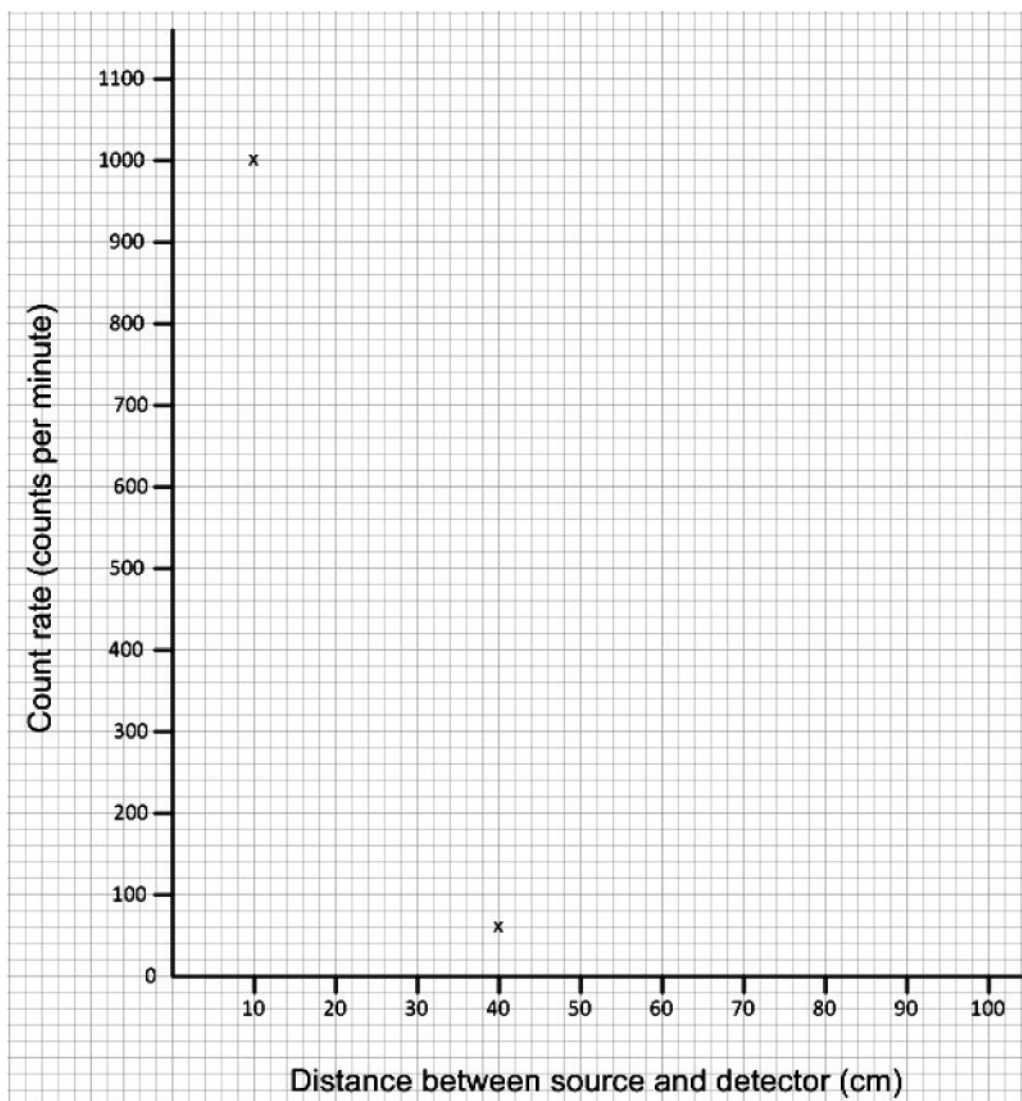
Suggest a reason why.

-----[1]

(b)

(i) Two points for 10 cm and 40 cm have been plotted on the graph below.

Plot the rest of Matt's results and join the points with a smooth curve.



[2]

(ii) Use the graph to estimate the reading at 30 cm.

answer: counts per minute

[1]

(c)

(i) What pattern is shown by the results as the distance is increased from 20 cm to 40 cm?

----- [2]

(ii) Matt wants to find the count rate at 5 cm.

Estimate the count rate at a distance of 5 cm.

answer: ----- counts per minute [1]

4 An element has more than one isotope.

Which correctly describes the atoms of all isotopes of this element?

	Numbers of electrons	Numbers of protons	Numbers of neutrons
A	different	different	different
B	same	different	different
C	same	same	different
D	same	different	same

Your answer

☐

[1]

5 The most abundant form of radium is radium-226.

Its nuclear mass is 226 and its nucleus contains 138 neutrons.

Which is an **isotope** of radium?

- A nuclear mass 226; 137 neutrons
- B nuclear mass 226; 139 neutrons
- C nuclear mass 227; 138 neutrons
- D nuclear mass 227; 139 neutrons

Your answer

☐

[1]

6 Radium-226, $^{226}_{88}\text{Ra}$, decays to become radon-222, $^{222}_{86}\text{Rn}$.

What is emitted when a nucleus of radium-226 decays?

- A a beta particle
- B an alpha particle
- C four neutrons
- D four protons

Your answer

[1]

7 A radioactive source has a half-life of 80 s.

How long will it take for $\frac{7}{8}$ of the source to decay?

- A 10 s
- B 70 s
- C 240 s
- D 640 s

Your answer

[1]

8(a) The information below shows information on radioactive isotopes.

Radioactive isotope	Type of radiation	Half-life	Penetration through human flesh
A	alpha	300 years	2mm
B	beta	7 hours	60mm
C	gamma	7 hours	> 10m
D	alpha	9 seconds	2mm
E	gamma	3 years	> 10m

A doctor injects a patient with isotope C to track blood flow through the body.

Use the data to suggest why the doctor uses isotope C.

-----[1]

(b) A doctor implants radioactive isotope A into a patient to treat a localised cancer which is a few mm in size.

She intends to remove the isotope in a few weeks.

Use the data to suggest **two** reasons why the doctor uses isotope A.

-----[2]

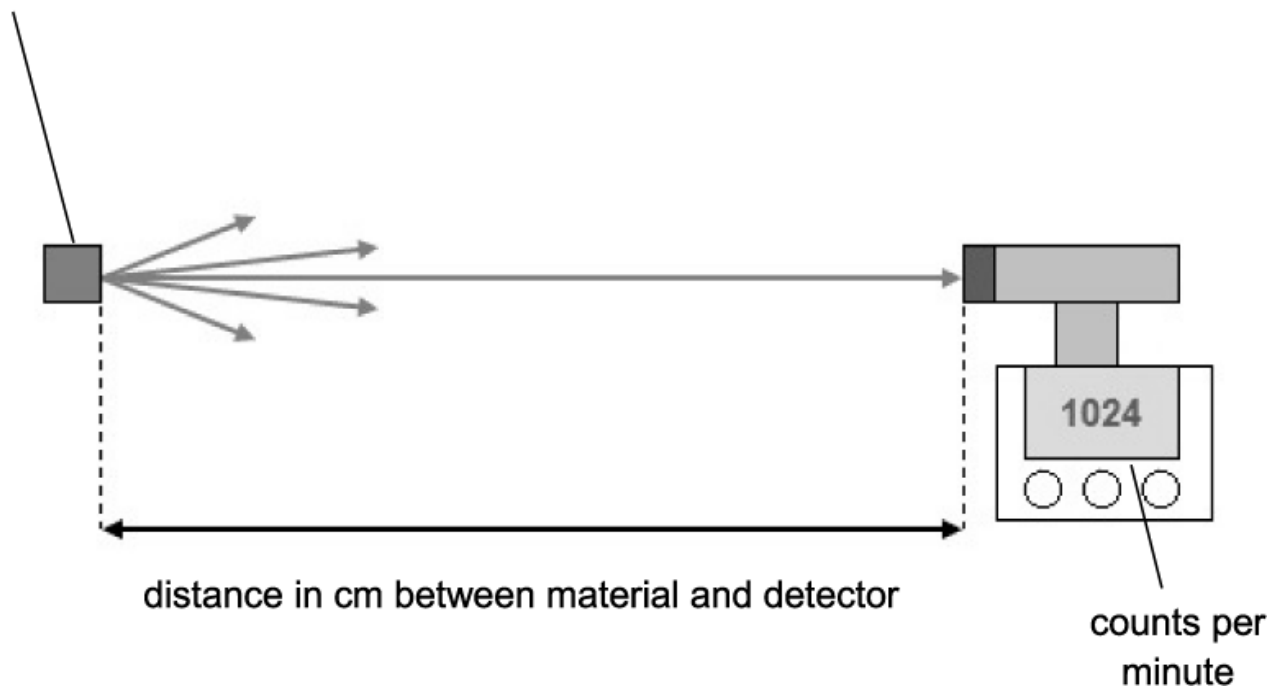
9(a) Matt experiments with radioactive materials.

He investigates how the activity of radiation changes with distance.

The radiation moves from the source to the detector.

He measures the counts per minute from a radioactive source.

radioactive source



The table shows the results from the experiment.

Distance between the source and the detector (cm)	Count rate (counts per minute)
10	1024
20	256
40	64
80	16

Describe using the data in the table how the count rate changes as the detector is moved away from the source.

----- [2]

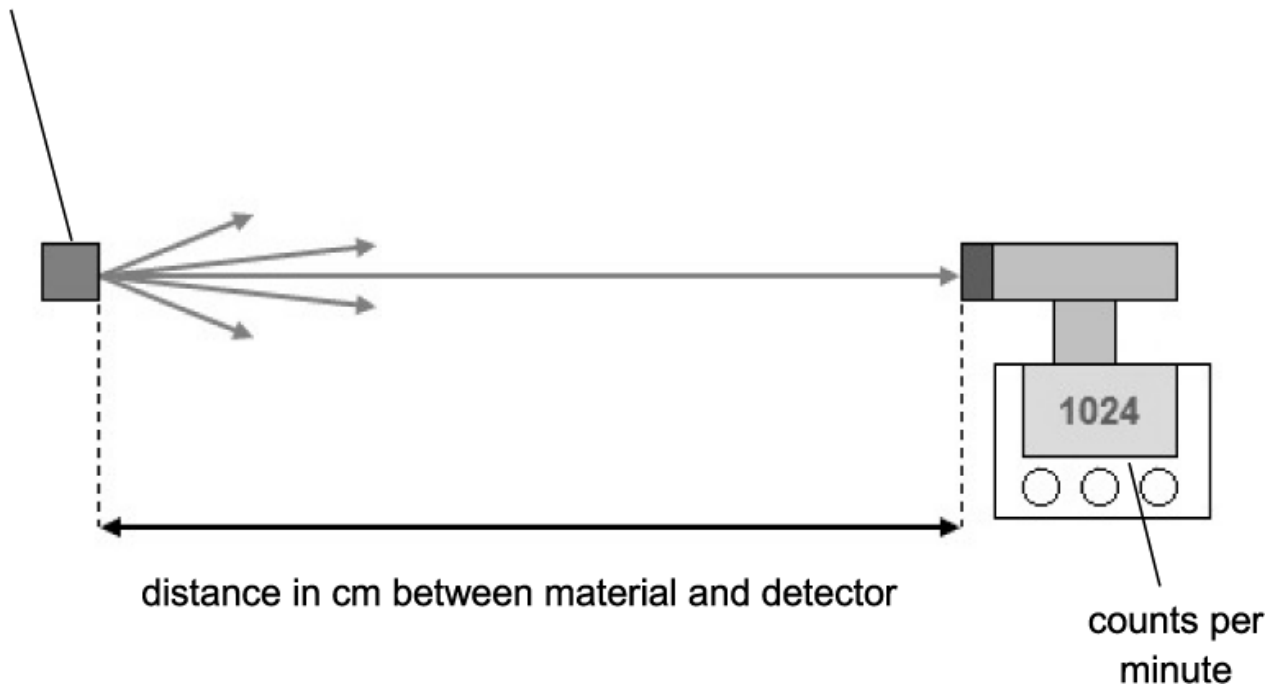
(b) Matt experiments with radioactive materials.

He investigates how the activity of radiation changes with distance.

The radiation moves from the source to the detector.

He measures the counts per minute from a radioactive source.

radioactive source



Distance between the source and the detector (cm)	Count rate (counts per minute)
10	1024
20	256
40	64
80	16
160	6
320	0

As the distance is increased to 160 cm and 320 cm the results do not follow the same pattern as the other results.

What do you think these results should have been?

Explain the anomalies in the last two results.

[3]

10 Mrs Khan explains to her class how to identify the three types of nuclear radiation that can be emitted.

She investigates four different radioactive sources: A, B, C and D.

Mrs Khan has paper, aluminium and lead to use as absorbers.

She measures the radioactive count rate with and without the absorbers.

Look at her results.

	Radioactive count rate in counts per minute			
Radioactive source	No absorber	Paper	Aluminium	Lead
A	200	202	199	22
B	300	22	20	21
C	100	78	22	23
D	250	140	142	20

Use the data above to identify which radiations are emitted by each source. Justify your answers.



The quality of written communication will be assessed in your answer to this question.

[6]

11 Nuclear radiation is used in hospitals.

Nuclear radiation from radioactive sources is used as a medical tracer.

Alpha emitters **cannot** be used as medical tracers.

Explain why.

----- [1]

12(a) Nuclear radiation is used in hospitals.

Medical tracers must **not** remain active in the body for long periods of time.

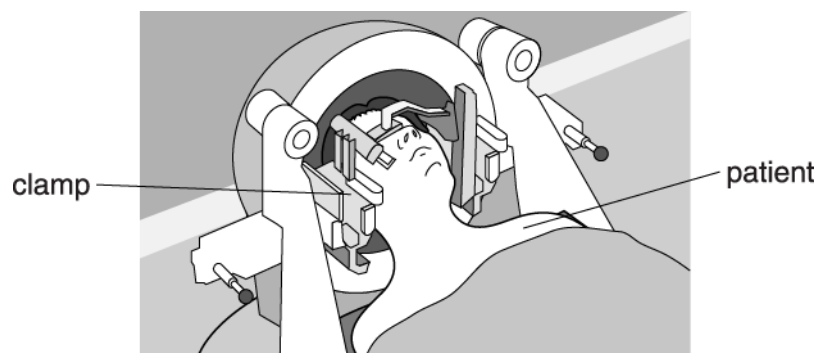
(i) Why is it dangerous for a tracer to remain active in the body for long periods of time?

----- [1]

(ii) What property of the tracer affects the time it remains active in the body?

----- [1]

- (b) Gamma knife treatment is used to treat brain cancer.
A gamma knife uses many gamma beams that can be accurately focused on one place.



The patient's head is clamped to keep their head fixed in one position.
Explain why this is important.

----- [2]

- 13 The radiation from tracers needs to be detected outside the body.

Only two types of **nuclear** radiation can pass through the skin.

Which **two** types?

Choose your answers from:

alpha

beta

gamma

ultrasound

ultraviolet

answer ----- and -----

[2]

14 Mrs Khan is doing some experiments using **radioactive** sources.

She wants to demonstrate the **three** different types of nuclear radiation to her class.

She asks the class about some of the **safety** precautions she should follow when using the radioactive sources.

Explain the safety precautions Mrs Khan should take and name the three different types of nuclear radiation.



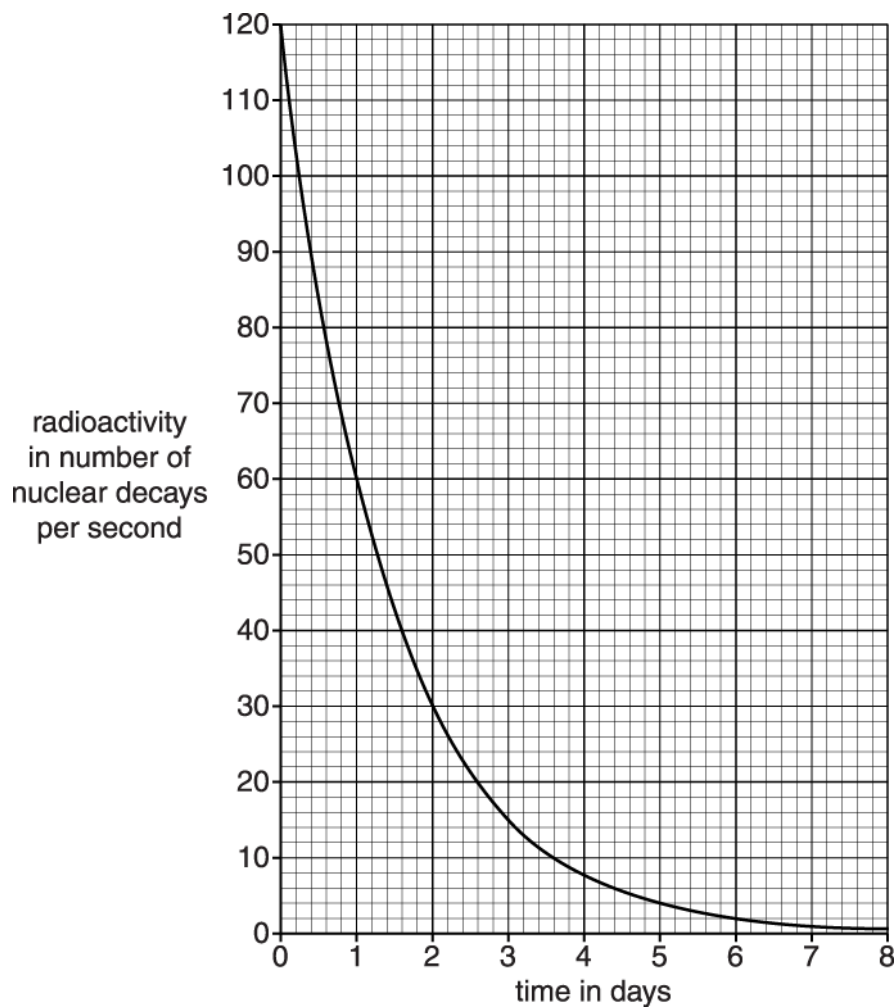
The quality of written communication will be assessed in your answer to this question.

[6]

15(a) Medical radioisotopes use radioactive elements.

Radioactivity is measured by the number of nuclear decays per second.

Look at the graph showing the radioactive decay of element A.



- (i) What happens to the radioactivity of element **A** between day 1 and day 2?

 ----- [2]

- (ii) Doctor Hanif compares radioactive element **A** with radioactive element **B**.

Both elements start with the same radioactivity of 120 nuclear decays per second.

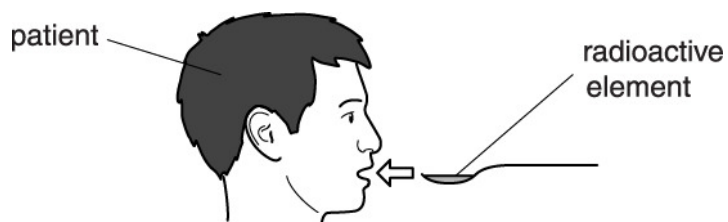
Element **B** has a **longer** half-life.

Draw a line on the graph to show the decay of element **B**.

[1]

(b) Doctor Hanif uses element in the hospital where he works.

(i) The patient swallows a liquid containing a small amount of radioactive element.

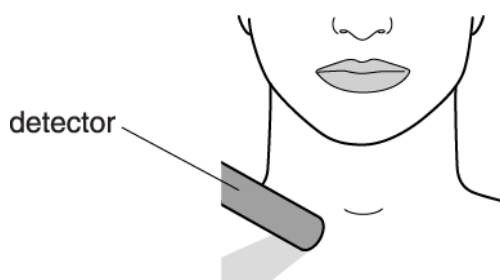


It is important to use a small amount of a radioactive element that decays quickly.

What is the risk of using a radioactive element with a **longer** half-life?

-----[1]

(ii) The amount of radioactivity near the patient's throat is measured.



What type(s) of radiation can pass through the skin to the detector?

Choose from

alpha only

alpha and beta

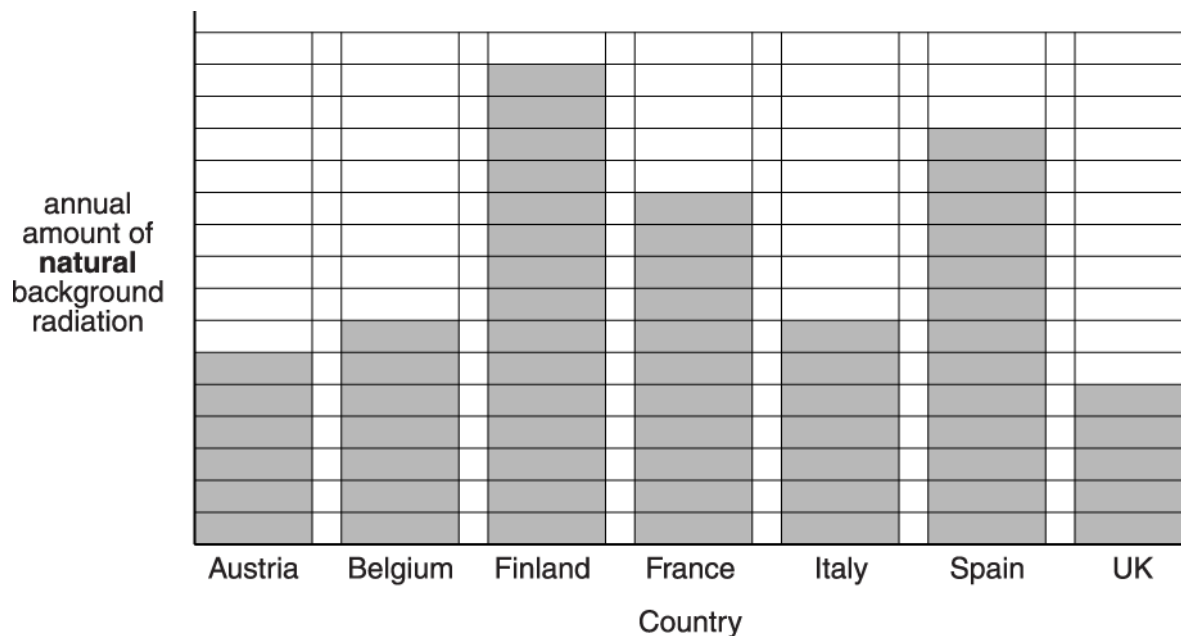
beta only

beta and gamma

answer [1]

- 16 This question is about natural and artificial background radiation.

Ben finds information on the internet about **natural** background radiation in different countries.



- (i) What does the data show about the **natural** background radiation in different countries?

..... [1]

- (ii) Suggest why Finland has a high annual amount of **natural** background radiation.

..... [1]

17(a) Radiation comes from the nucleus of an atom that is unstable.

An alpha particle is a helium nucleus.

What is a beta particle?

Choose the **best** answer from

an electron

a fast moving electron

a proton

a fast moving proton

-----[1]

(b) What happens to a nucleus when a beta particle is emitted?

Put ticks (?) next to the **two** correct statements.

mass number is unchanged

☐

nucleus has one more neutron

☐

nucleus has one more proton

☐

atomic number decreases by one

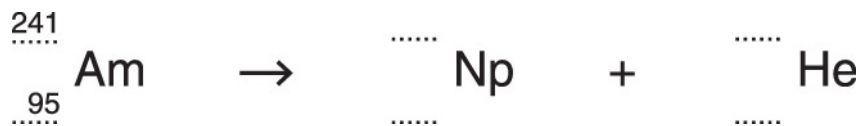
☐

[1]

(c) Radioactive americium (Am) is used in smoke alarms.

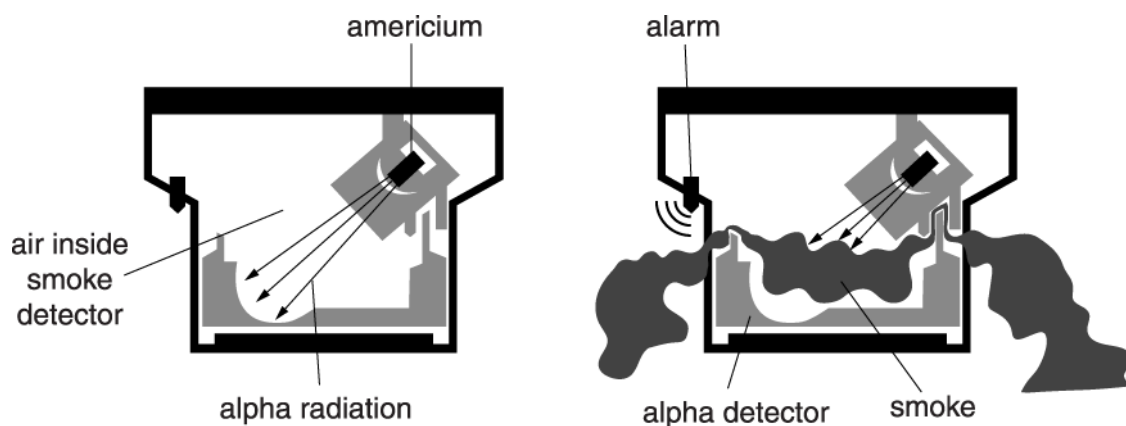
(i) Complete the equation for alpha decay.

An alpha particle is a helium nucleus.



[2]

(ii) Here are two diagrams showing how a smoke detector works.



Use the diagrams to describe how a smoke detector works.

[2]

18 Scientists use several methods to find out when old plants lived.

Here is information about two methods.

	Relative Dating	Absolute Dating
Method	Find out where plant fossils are in layers of rocks. Newer rocks are on top of older rocks. The method can be used in very old rocks.	This uses carbon dating. The amount of radioactive Carbon-14 can be measured in dead plants. This can be compared with the amount of Carbon-14 in living plants to find the age.
Problems	Cannot find the exact age of the plant fossils.	Cannot be used for very old dead plants as the amount of Carbon-14 is too low.

Describe why scientists might use both methods to find out when old plants lived.

[2]

19(a) Radioactivity is measured by the number of decays per second.

Here are measurements from three radioactive sources A, B and C.

	Number of decays per second		
Time in minutes	Source A	Source B	Source C
0	2020	998	1034
100	998	251	862
200	496	63	674
300	252	16	566
400	174	4	472

Describe what happens to the measurements for **all** the sources.

----- [2]

(b) Source **B** has the shortest half-life.

Explain how the measurements in the table show this.

----- [1]

(c) Where does this radiation come from?

Choose the **best** answer from

all atoms

all elements

electrons orbiting the nucleus

nucleus

answer -----

[1]

20 Scientists use several methods to find out when old plants lived.

Here is information about two methods.

	Relative Dating	Absolute Dating
Method	Find out where plant fossils are in layers of rocks. Newer rocks are on top of older rocks. The method can be used in very old rocks.	This uses carbon dating. The amount of radioactive Carbon-14 can be measured in dead plants. This can be compared with the amount of Carbon-14 in living plants to find the age.
Problems	Cannot find the exact age of the plant fossils.	Cannot be used for very old dead plants as the amount of Carbon-14 is too low.

Describe why scientists might use both methods to find out when old plants lived.

[2]

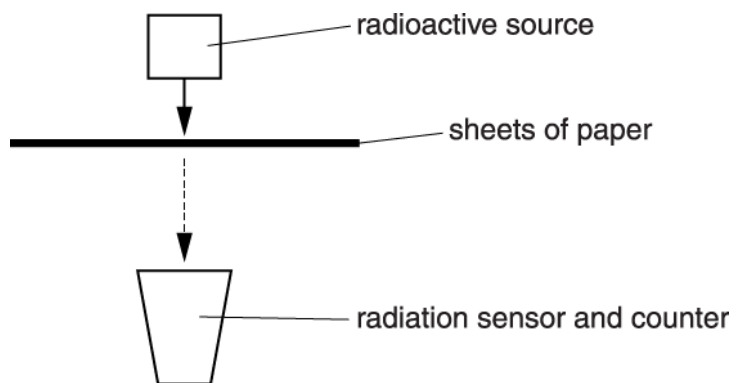
21 Dr Williams shows her class an experiment with radioactivity.

She uses three different radioactive sources

- an alpha emitter
- a beta emitter
- a gamma emitter.

She uses different thicknesses of sheets of paper between the source and the sensor.

Look at the diagram.



Dr Williams measures the nuclear radiation from each source using the sensor.

Each radioactive source emits only one type of radiation.

This can be alpha, beta or gamma.

Look at her results for each source.

Thickness of sheets of paper in mm	Average count rate in counts per second		
	Radioactive source X	Radioactive source Y	Radioactive source Z
0	30	68	65
0.2	32	36	60
0.4	31	21	57
0.6	33	5	52
0.8	34	1	48
1.0	29	0	45
1.2	31	1	41
1.4	30	0	39
1.6	31	0	38
1.8	30	2	35
2.0	31	1	33

Use the data to identify and explain which radiation comes from sources X, Y and Z. Comment on how useful each source is for detecting the thickness of sheets of paper up to 2 mm.



The quality of written communication will be assessed in your answer to the question.

[6]

22 Radioactive substances decay naturally.
Look at the information about two different radioactive substances.

Time in hours	Activity of substance X in counts per second	Activity of substance Y in counts per second
0	8 070	12 810
1	6 801	6 385
2	5 697	3 221
3	4 808	1 594
4	4 027	807
5	3 390	392
6	2 861	197
7	2 410	102
8	2 008	51

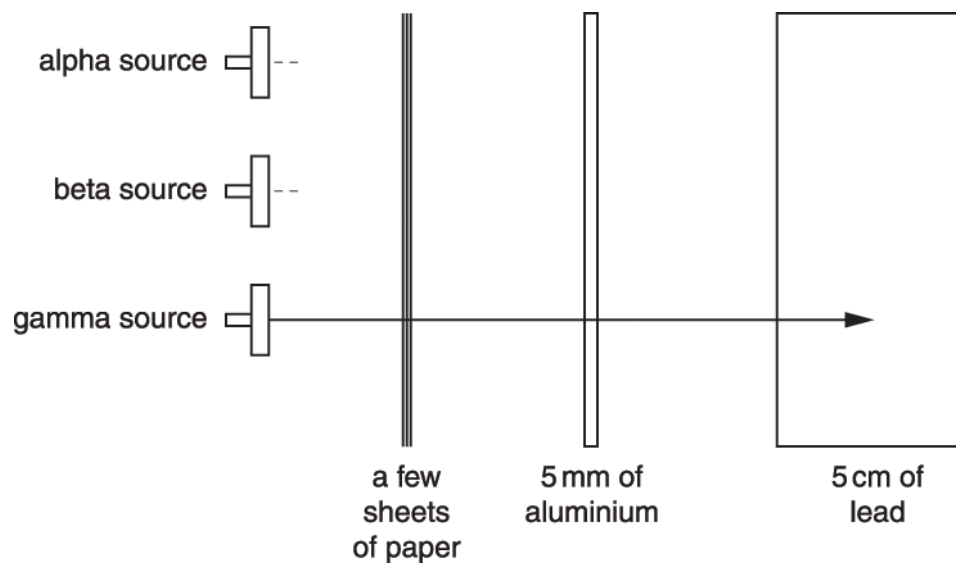
Use the data in the table to compare the half-life of substance X and the half-life of substance Y.

[2]

23 This question is about nuclear radiation.

Complete the diagram to show the penetrating power of alpha **and** beta radiation.

Gamma radiation has been completed for you.

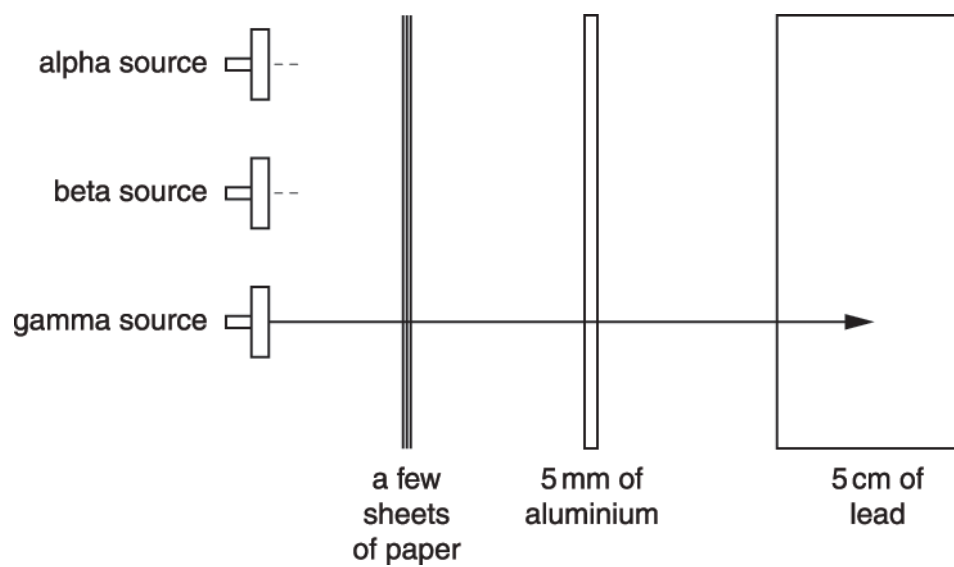


[1]

24 This question is about nuclear radiation.

Complete the diagram to show the penetrating power of alpha **and** beta radiation.

Gamma radiation has been completed for you.



[1]

25 There are three types of nuclear radiation: alpha, beta and gamma.

The three types of radiation have different penetrating powers. They are stopped by different materials.

Mrs Brown shows a gamma source to her class. Her class are not convinced it is a gamma source. She needs to prove it emits gamma radiation only.

Explain how she can **safely** demonstrate to the class that it emits **gamma** radiation but not alpha or beta radiation.

You may draw a diagram to show your answer.



The quality of written communication will be assessed in your answer to this question.

[6]

The amount of carbon in dead plants is used to find their age.

When they were alive they took in Carbon-14 (C-14) and Carbon-12 (C-12).

Scientists measure the amount of these two types of carbon.

Percentage of C-14 remaining	Percentage of C-12 remaining	Number of years dead (Age)
100	100	0
50	100	5 730
25	100	11 460
12.5	100	17 190

(i) Use the information in the table to explain what happens to the two types of carbon when the plant dies.

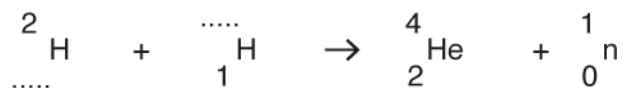
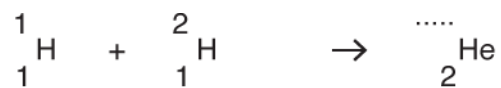
[2]

(ii) Calculate the age of a dead plant with 6.25 percentage of C-14 remaining.

[1]

Different hydrogen isotopes can undergo fusion.

Complete the **three** gaps in the nuclear equations.



[3]

Substance	Passes through skin	Used to treat cancer	Harmful to healthy cells
A	yes	yes	very harmful
B	yes	no	not harmful
C	yes	yes	harmful
D	no	yes	harmful
E	no	no	not harmful

(i) Which **two** substances emit gamma radiation?

Explain your answer.

[3]

(ii) A radiographer uses substances that emit gamma radiation.

Write down **one** safety precaution the radiographer must take.

[1]

29 Ralph investigates radioactive sources.

He puts different barriers between the sources and the radiation detector.

He measures the count rate from each source with the different barriers.

Look at the table.

Source	Amount of radiation (counts per minute)			
	No barrier	Paper barrier	Thin aluminium barrier	Thick lead barrier
A	542	541	10	10
B	257	255	255	9

Write down the type of radiation emitted by source A and source B.

Source A emits -----radiation.

Source B emits-----radiation.

[2]

30 Beta radiation is used to check the thickness of thin aluminium foil at a factory.

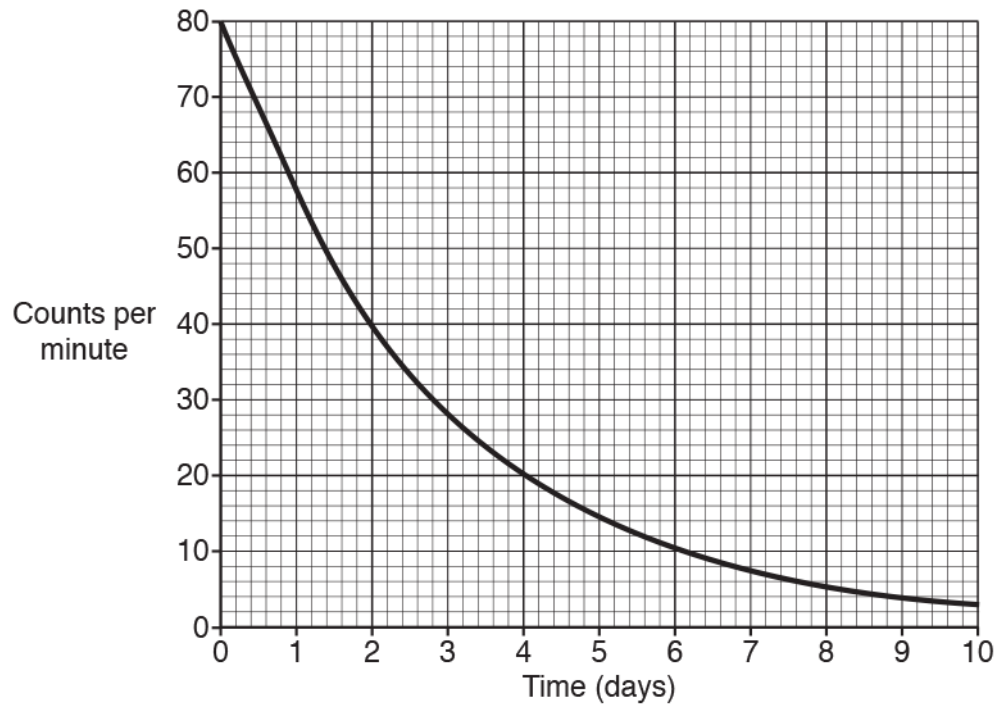
Why is beta radiation used?

- A All electromagnetic radiation is reflected by aluminium foil.
- B Beta radiation will **not** pass through aluminium foil.
- C Beta radiation will partially pass through aluminium foil.
- D Beta radiation is reflected by aluminium foil.

Your answer

[1]

31 A teacher measures the radiation from a radioactive source for 10 days.



What is the half-life of this radioactive source?

- A 1 day
- B 2 days
- C 4 days
- D 5 days

Your answer

[1]

32 An alpha particle collides with an atom to produce a positive ion.

What happens to the atom for it to become a positive ion?

- A It loses an electron from inside the nucleus.
- B It loses an electron from outside the nucleus.
- C It loses a neutron from inside the nucleus.
- D It loses a proton from outside the nucleus.

Your answer

[1]

33(a) Carbon is a common element. Carbon has two different isotopes called carbon-12 and carbon-14. Both of these isotopes have six protons in the nucleus.

- (i) Carbon-14 is radioactive and carbon-12 is **not** radioactive.

Explain why some isotopes are radioactive.

----- [1]

- (ii) Describe how the nucleus of carbon-12 is different to the nucleus of carbon-14.

----- [1]

(b) Decay equations are used to show the type of emission from different radioactive elements.

(i) Complete the decay equation for **alpha** emission.



(ii) Complete the decay equation for **beta** emission.



(iii) Complete the decay equation for **gamma** emission.



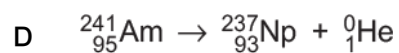
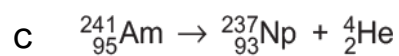
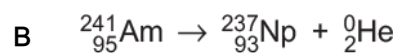
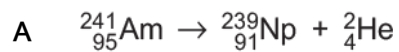
34 Which statement is true about the **nucleus** of an atom?

- A It contains neutrons and ions and has a negative charge.
- B It contains neutrons and ions and has a neutral charge.
- C It contains neutrons and protons and has a neutral charge.
- D It contains neutrons and protons and has a positive charge.

Your answer

[1]

35 Which equation shows a correct alpha decay?

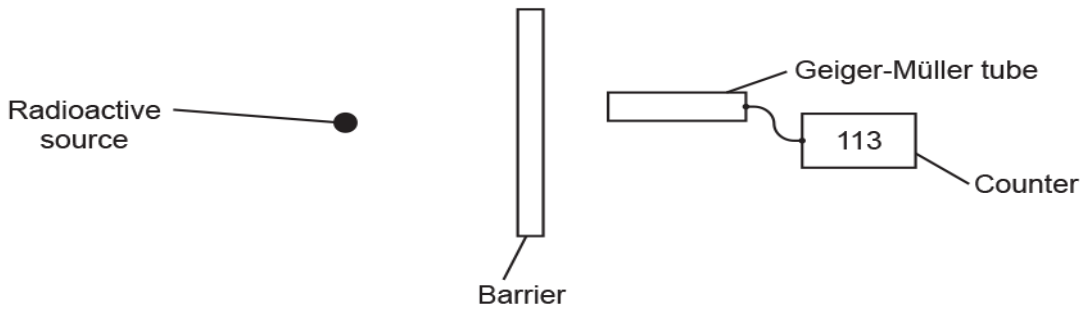


Your answer

[1]

36(a) A teacher demonstrates an experiment about radioactivity. He demonstrates how different types of radiation can be absorbed.

He puts different barriers between the source and the Geiger-Müller tube. He uses four different radioactive sources A, B, C and D.



Suggest two safety precautions that the teacher should use when demonstrating this experiment.

1.
-
2.
-

[2]

(b) The teacher chooses source A and uses the Geiger-Müller tube to measure the count rate (counts per minute) for different barriers. He repeats the experiment with source B, source C and then source D.

Look at his results.

Source	Count rate using different barriers			
	Paper	Aluminium	Lead	No barrier
A	113	112	22	112
B	20	21	20	182
C	162	23	21	164
D	282	78	24	280

He also finds that the average count rate with no sources and no barriers is 20.

(i) Which source A, B, C or D emits gamma radiation only?

Explain your answer.

Source ----- because -----

----- [2]

(ii) Which source A, B, C or D emits **alpha** radiation only?

Explain your answer.

Source ----- because -----

----- [2]

(iii) Which source A, B, C or D could emit both **beta** and **gamma** radiation?

Explain your answer.

Source ----- because -----

----- [2]

(c) The teacher notices that the count rate behind the lead barrier ranges from 20 to 24.

Give **two** reasons why there are a wide range of results around 22 counts per minute.

1. -----

2. -----

[2]

(d) The teacher decides to repeat the experiment.

This time he records the number of counts for a much longer time interval for each source.

Explain why this is an improvement to the experiment.

----- [2]

37 Fig. 20.1 shows thinking, braking and stopping distances for the same car travelling at different speeds.

Speed (m/s)	Thinking distance (m)	Braking distance (m)	Stopping distance (m)
8	6	6	12
16	12	24	36
32	24	96	120

Fig. 20.1

* Explain why the stopping distances are different for each speed in Fig. 20.1.

[6]

38 The table gives some information about four radioactive isotopes.

Which isotope is the best to use as a medical tracer?

	Half life	Radiation emitted
A	6 hours	alpha
B	6 hours	gamma
C	6 minutes	gamma
D	6 years	beta

Your answer

[1]

39 Which statement is **true** for isotopes of the same element?

N_p = number of protons and N_n = number of neutrons.

- A $N_p = N_n$
- B N_p is the same but N_n is different
- C N_p is always greater than N_n
- D The total ($N_p + N_n$) is always the same

Your answer

[1]

40(a) A teacher measures the activity of different radioactive isotopes.

Fig. 23.1 is a graph of her results for isotope A.

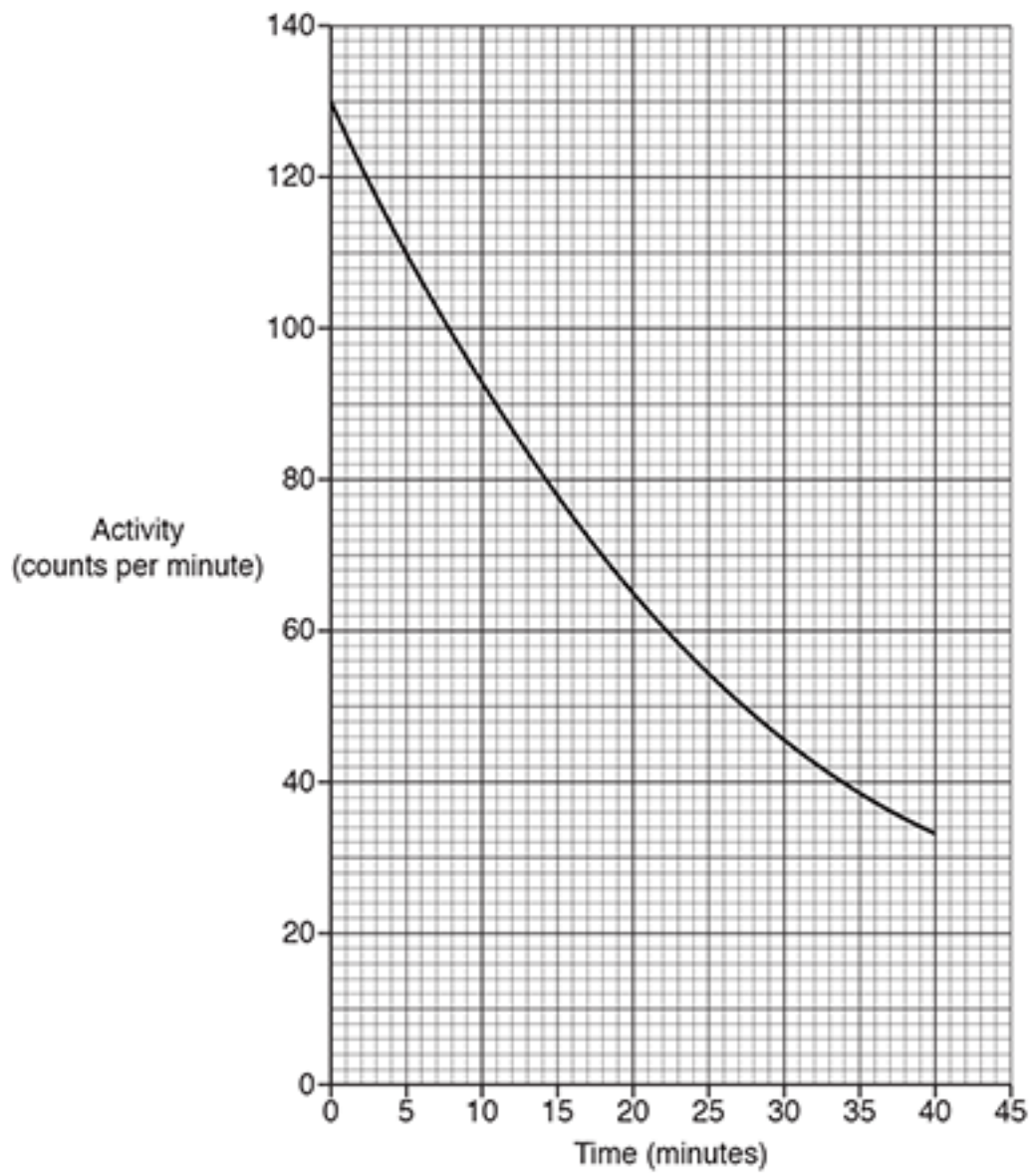


Fig. 23.1

Use Fig. 23.1 to calculate the half-life of isotope A.

Show your working on the graph in Fig. 23.1.

Half-life = ... minutes [2]

(b) The teacher measures the activity of isotope **B**.

She starts taking activity measurements after 20 minutes.

Table 23.1 shows her results for isotope **B**.

Time (minutes)	Activity (counts per minute)
0	
10	
20	84
30	64
40	52
50	40
60	32
70	25
80	20
90	16

Table 23.1

Predict the activity of isotope **B** at 0 minutes.

Use the information in **Table 23.1** to help you.

Activity = ... counts per minute [2]

(c) The teacher measures the activity of isotope C.

Fig. 23.2 is a graph which shows how activity varies with time for isotope C.

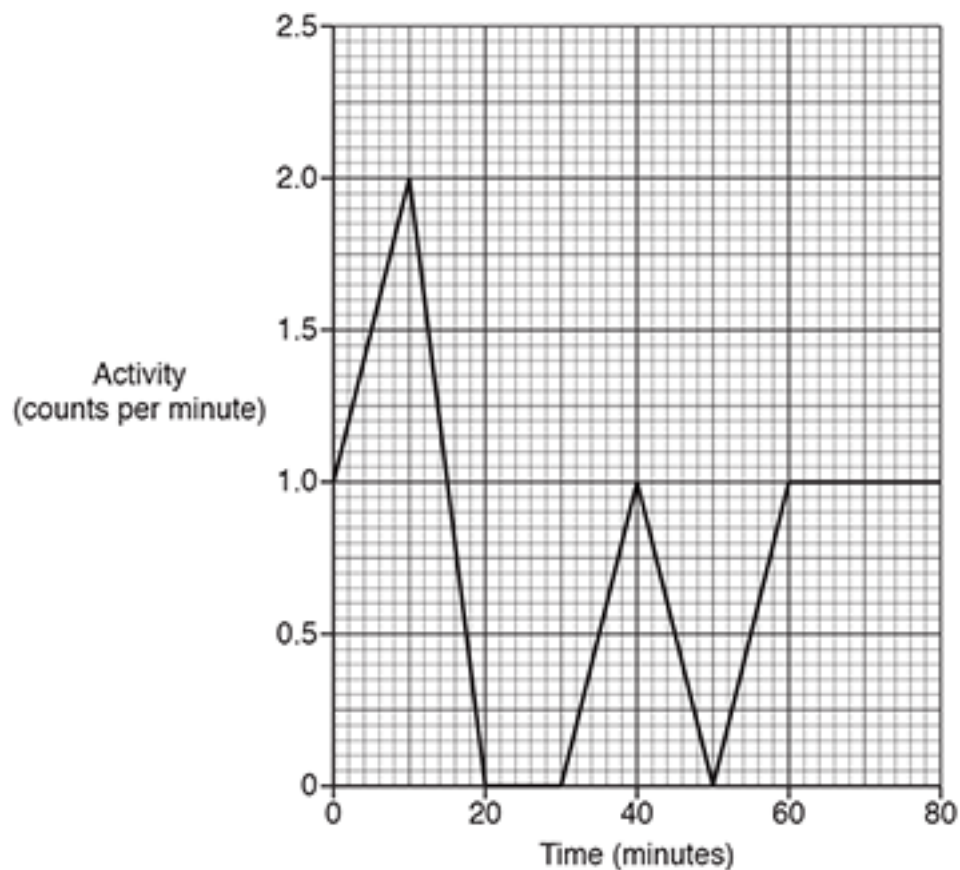


Fig. 23.2

A student makes two conclusions from the graph in Fig. 23.2:

- Conclusion 1:** I think the results are very inaccurate.
The isotope stops being radioactive and then gets more radioactive again.
- Conclusion 2:** I do **not** think the isotope has a half-life.

Is the student correct?

Evaluate **each** conclusion and explain your answer.

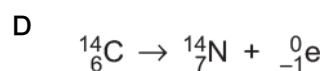
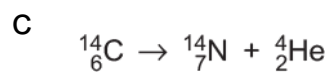
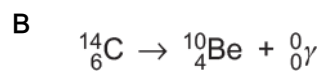
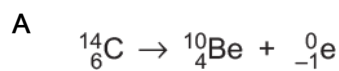
Conclusion 1

.....

.....

----- [2]

41 Which radioactive decay equation is correct?



Your answer

[1]

42(a) Atoms can absorb and emit electromagnetic radiation.

Describe **two** possible effects on an electron in an atom when it absorbs electromagnetic radiation.

1 -----

2 -----

[2]

(b) Alpha radiation is **not** emitted in the processes in part (a).

Explain why.

----- [2]

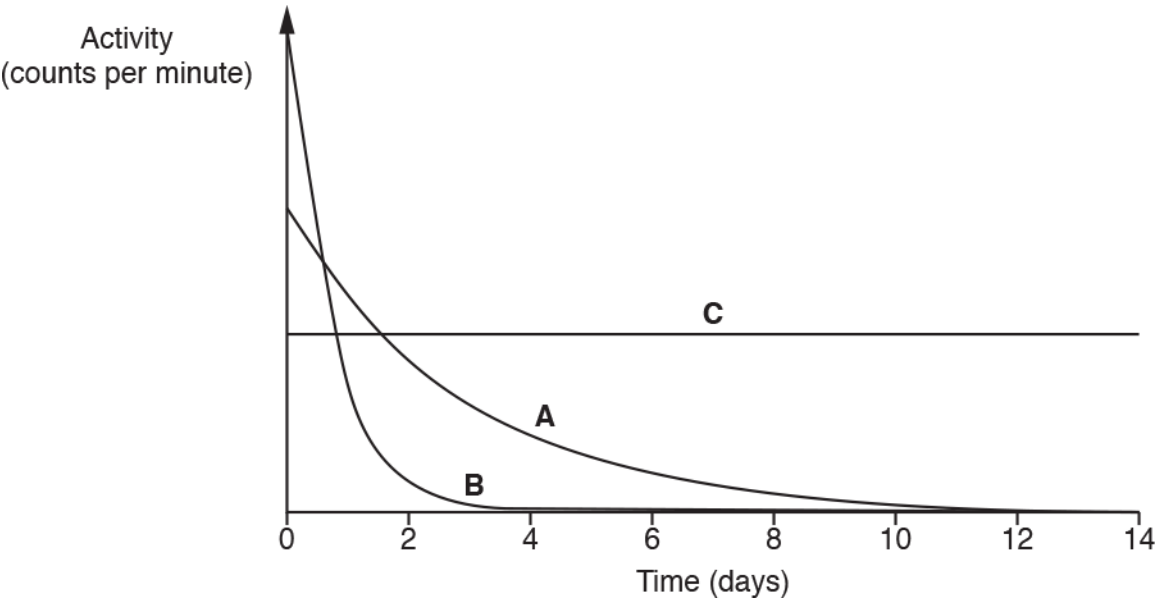
43(a) A radioactive isotope has a half-life of 6 hours.

50 g of the isotope are put in a container.

What mass of the isotope is left after 6 hours?

Mass = ... g [1]

(b) This is a graph showing the radiation emitted from samples of three different isotopes A, B and C.



(i) Which isotope, A, B or C, takes the longest time to decay?

Tick (✓) one box.

A ☐

B ☐

C ☐

[1]

Do you agree with the views of scientist 1 and scientist 2?

Use the graph and ideas about radioactivity and half-life to explain your answer.

Scientist 1

Scientist 2

[4]

(iii) **Scientist 1** wants to identify the type of radiation emitted by isotope **A**.

This is a list of equipment **Scientist 1** has in his laboratory:

- radiation detector
- piece of thick lead
- (ii) Two scientists discuss the isotopes in the graph.
- piece of cardboard
- piece of aluminium.

Scientist 1

Scientist 2

'I think isotope **A** is more hazardous than **B**.

'I think isotope **B** is more hazardous than **A**.

Describe how **Scientist 1** does the experiment and explain how they can work out the type of radiation emitted.

A has a higher activity than **B**.'

B has a longer half-life than **A**.'

You may include a diagram in your answer.

[4]

44 Which statement about alpha particles is correct?

- A They are fast moving electrons.
- B They are less penetrating than beta particles.
- C They can pass through lead.
- D They have less mass than beta particles.

Your answer ☐ [1]

45(a) Some isotopes of cobalt are radioactive.

The isotope cobalt-60 (Co-60) has the symbol:



The isotope cobalt-57 (Co-57) has the symbol:



(i) State the number of protons in a nucleus of Co-60.

Number of protons = ... [2]

(ii) Give **one** similarity and **one** difference between the nucleus of Co-57 and the nucleus of Co-60.

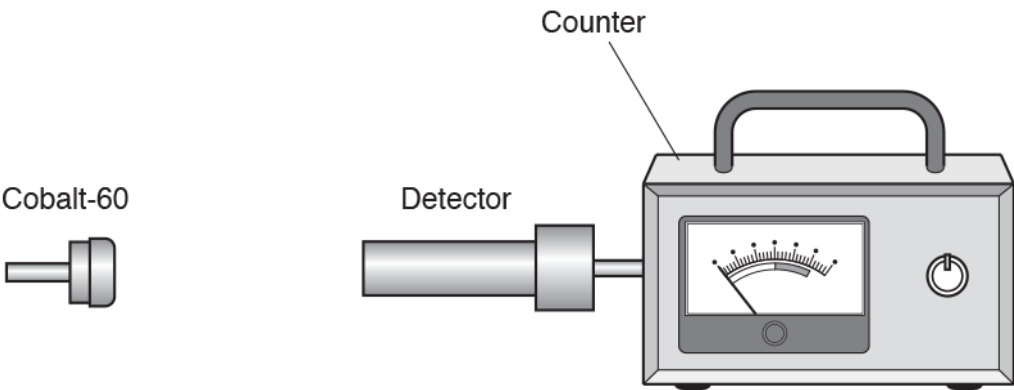
Similarity

Difference

[2]

(b) A teacher measures the radiation emitted by Co-60.

She uses this equipment:



The teacher's results are shown in Table 18.1.

	Count-rate (counts per minute)
Measurement 1	191

Measurement 2	224
Measurement 3	212

Table 18.1

- (i) Explain why the teacher's three measurements are **not** the same.

----- [1]

- (ii) Use the teacher's results in **Table 18.1** to calculate the mean count-rate for Co-60.

Count-rate = ... counts per minute [2]

- (iii) Co-60 emits gamma radiation.

The teacher puts thin aluminium foil between Co-60 and the detector.

State what happens to the count-rate.

----- [1]

(c)

(i) Explain what is meant by the half-life of a radioactive isotope.

-----[1]

(ii) The half-life of Co-60 is 5 years.

The count-rate of a sample of Co-60 is 160 counts per minute.

Calculate the count-rate of the Co-60 after 10 years.

Count-rate = ... counts per minute [3]

46 When an electron in an atom changes energy level, it emits electromagnetic radiation.

Which row in the table is correct?

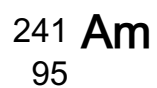
	Energy level of the electron	Type of radiation emitted
A	Decreases	Almost any electromagnetic radiation.
B	Decreases	Visible light only.
C	Increases	Almost any electromagnetic radiation.
D	Increases	Visible light only.

Your answer

[1]

47(a) Americium-241 is a radioactive source that is used in smoke detectors.

This is the symbol for americium-241:

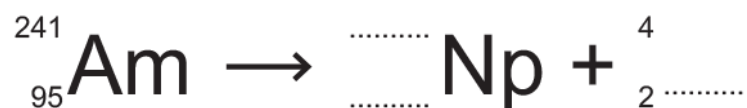


Describe the structure of an americium-241 **nucleus**.

----- [2]

(b) Americium-241 decays by emitting alpha radiation to form neptunium (Np).

Complete the balanced symbol equation for the decay.



[3]

(c) The half-life of americium-241 is 432 years.

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

----- [1]

(ii) Explain why the half-life of americium-241 is suitable for a smoke detector.

----- [1]

(iii) The table shows some data for two radioactive sources.

Source	Half-life (years)	Radiation emitted
Americium-241 (Am-241)	432	Alpha
Thorium-228 (Th-228)	2	Alpha

Both sources start with the same number of radioactive nuclei.

Which source is a greater health risk? Explain your answer.

----- [2]

(d) Read the information below about smoke detectors.

In smoke detectors, fine particles of americium-241 are rolled into a metallic foil. The americium-241 cannot be inhaled or move around.

The amount of radiation emitted is very small compared with the natural radioactivity in 1 m³ of soil.

Americium-241 also emits a small amount of gamma rays.

A scientist says, 'There is no risk from the disposal of smoke detectors in household waste.'

Do you agree with this statement? Give **two** reasons for your answer.

Yes

☐

No

☐

1 _____

2 _____

[2]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	1	
2			D	1	
			Total	1	
3	a		Reading would be very high (1)	1	
	b	i	All points correctly plotted (within + / – half a square) (1) Smooth single curve (1)	2	
		ii	140 (1)	1	ALLOW a tolerance of + / – 25
	c	i	Activity decreases (1) by a factor of 4 (1)	2	
		ii	4000 scores (1)	1	
			Total	7	
4			C	1	
			Total	1	
5			D	1	
			Total	1	
6			B	1	
			Total	1	
7			C	1	
			Total	1	
8	a		Any one from: Gamma can get out of body / least amount of time to do damage to the body / reasonable half-life (1)	1	
	b		Any two from: Alpha has short range (1) Highest ionising power (1) Longer half-life than D (1)	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	3	
9	a		Distance doubles count rate is $4 \times$ less / count rate is inversely proportional to the square of the distance / as distance triples activity is $9 \times$ less / AW (2)	2	ALLOW distance doubles count rate per minute is reduced by more than half (1)
	b		If the pattern was followed, 160 cm (ideally) should be 4 / 320 cm (ideally) should be 1 (1) Radiation / activity is random (1) Randomness is amplified at low readings / AW (1)	3	
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10			Level 3: (5 – 6 marks) The three types of radiation (alpha, beta and gamma) are correctly identified from at least three of the sources with valid explanations. Quality of written communication does not impede communication of the science at this level. Level 2: (3 – 4 marks) Two types of radiation (from alpha, beta or gamma) are correctly identified with reasons given. Quality of written communication partly impedes communication of the science at this level. Level 1: (1 – 2 marks) One type of radiation (from alpha or beta or gamma) with a simple reason is correctly identified OR two types of radiation are correctly identified. Quality of written communication impedes communication of the science at this level. Level 0: (0 marks) Insufficient or irrelevant science. Answer not worthy of credit.	6	Indicative scientific points may include: Sources • A is gamma – affected only by lead • B is alpha – stopped by paper / stopped by all barriers • C is alpha and beta – alpha as reduction with paper and beta as reduction with aluminium • D is alpha and gamma – alpha as reduction with paper, no reduction with aluminium, but gamma as reduction with lead. Ignore any source if all 3 types given (ie. simple guessing) Use the L1, L2, L3 annotations when useful. Do not use ticks. Examiner's Comments This was a level of response 6-mark data handling question on absorbing radiation. It was generally well understood and gave a range of marks from 0 to 6. Just over half of candidates scored 5 or 6 marks here. Candidates could generally identify the nature of the sources. Usually they could justify them too. Beta was the one most likely to be incorrect. Also some candidates failed to recognise that some sources had two types of radiation but this was still not essential to gain full marks.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11			alpha cannot get through the body (to reach the detector) [1] alpha is absorbed by the body / skin / tissue / flesh [1]	1	allow only beta and gamma can penetrate the skin / get through the body (to the reach the detector) [1] allow alpha does not penetrate (tissue / body / skin) [1] ignore references to alpha and paper ignore references to damage Examiner's Comments This question asked why alpha was not used as a tracer. Some answers referred to high ionising power but failed to develop that and say they the alpha was absorbed by the body. Others stated that alpha is stopped by paper but failed to develop that further. Weaker answers did not refer to penetration but to the damage caused by alpha.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12	a	i	(can cause) cancer / mutations [1] can damage or ionise cells / DNA / tissues / (named) organs [1]	1	allow can kill for idea of damage eg kills cells [1] not merely 'damage' Examiner's Comments This was quite well answered with more candidates mentioning damage or ionisation of cells than in previous years. Damage to tissues or organs was often seen and worthy of the mark.
		ii	half-life [1]	1	allow correct descriptions of half-life allow rate of (radioactive) decay ignore speed of decay / mass or amount of sample ignore because it decays quickly Examiner's Comments Over 60% of candidates answered correctly with 'half-life.' 'Rate of decay' was occasionally seen too [1]. Weaker answers included 'its radioactivity' or 'how old it is'.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		any two from so (all) gamma is (only) concentrated / focussed on the tumour / cancer cells AW [1] so that healthy / normal / other / non-cancerous cells receive less gamma / AW [1] otherwise (if patient moves) gamma may damage / affect (more) healthy / normal cells or tissue / ora [1]	2	Eg. idea that tumour has maximum exposure / cancer cells get a lethal dose [1] cancer cells rather than healthy cells get a lethal dose [2] allow (clamp is needed to hold the patients head still) to avoid damage to other tissue [1] Examiner's Comments Many referred rather vaguely to gamma hitting the 'right place' or the 'wrong place'. Better answers explained that gamma is meant to be focussed on the tumour [1] but (if the head moved) it may damage (surrounding) healthy cells [1].
			Total	4	
13			beta [1] gamma [1]	2	either order Examiner's Comments This question was focussed on the use of radiation in hospitals. Around half knew that beta and gamma could penetrate skin. It was surprising that many identified ultrasound as a form of radiation.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14			Level 3: (5 – 6 marks) Reference to the three types of radiation AND two safety precautions. Quality of written communication does not impede communication of the science at this level. Level 2: (3 – 4 marks) Reference to two types of radiation AND a simple safety precaution. Quality of written communication partly impedes communication of the science at this level. Level 1: (1 – 2 marks) Simple reference to two types of radiation OR a simple safety precaution. Quality of written communication impedes communication of the science at this level. Level 0: (0 marks) Insufficient or irrelevant science. Answer not worthy of credit.	6	This question is targeted up to grade E Indicative scientific points may include: radiations • alpha • beta • gamma safety precautions • use tongs • keep a safe distance • do not point at people or body part • protective clothing • short exposure time • shielded storage • labelled storage Use the L1, L2, L3 annotations in Scoris; do not use ticks. Examiner's Comments About 10% of candidates did not attempt the question. There were some excellent responses to this question. The majority of candidates correctly identified the three types of radiation. In terms of safety precautions the most common was protective clothing. Candidates wrote at length about gloves, goggles, aprons etc., but this was only one point. Other precautions were safe handling and safe storage.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a	i	decreases [1] but decreases by half / by 30 (decays per second) [2]	2	allow from 60 to 30 [2] eg 60 and 30 indicated on graph scores [2] if NO marks awarded allow by one half life [1] Examiner's Comments Most knew the activity had reduced [1] and many went on to say or describe in numbers that it had halved [2].
		ii	line starting at 120 and always to the right and above right element A [1]	1	any line curving upwards (at any part) scores [0] graphs must not cross each other Examiner's Comments Many gained [1] for sketching the graph with a longer half life. The most common error was the graphs crossing usually around 6 to 8 days. It was encouraging to rarely see graphs with a shorter half life [0].
	b	i	(idea that nuclear radiation) can increase risk of cancer or cell damage [1]	1	allow (idea that) the radioactivity is not in the body for a long time (to cause damage) [1] Examiner's Comments This discriminated very well. Better candidates understood the dangers of using medical tracers with a longer half life and often made a good link to cell damage.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	beta and gamma [1]	1	more than one scores 0 marks if answer line blank allow correct answer indicated in list Examiner's Comments In general most knew that beta and gamma radiation can penetrate skin. The most common error was to identify that gamma only can penetrate skin.
			Total	5	
16		i	(idea that it) varies [1]	1	allow named examples ie it is higher in Finland / Spain [1] allow named examples ie it is lower in UK / Austria [1] Examiner's Comments Most candidates interpreted the information in the bar chart very well
		ii	any one from (more) radioactive rocks / uranium in rocks [1] (more) granite [1] (more) radon gas [1]	1	allow (more) cosmic rays [1] allow higher level answers in terms of northern lights / near the northern lights [1] but not just Finland is further north / near the north pole Examiner's Comments There were very few correct responses in suggesting why a country has a higher natural background count rate. Most answers referred to artificial contributions to background radiation.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
17	a		a fast moving electron (1)	1	if answer line blank allow correct answer circled or underlined more than one answer = 0 marks Examiner's Comments This objective question produced a range of answers with 'electron' or 'fast moving protons' being commonly seen wrong answers.
	b		mass number is unchanged ☒ nucleus has one more neutron ☐ nucleus has one more proton ☒ atomic number decreases by one ☐	1	both ticks required more than two ticks = 0 marks Examiner's Comments Despite being instructed to tick two boxes, a large number only indicated one choice. About a quarter of candidates, however, got this correct.
	c	i	$\begin{array}{c} 237 \\ \dots\dots \end{array} \text{Np} + \begin{array}{c} \dots\dots 4 \\ 2 \end{array} \text{He}$ (2)	2	any two or three numbers correct = 1 mark Examiner's Comments This was about alpha decay and was better answered than in previous years with just over half of candidates gaining full marks.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	any two from alpha particles cause the air inside the smoke detector to ionise (1) idea that smoke particles absorb / stop (some alpha) radiation (1) less ionisation (of air) with smoke [1] current is reduced (causing alarm to sound) (1)	2	Ignore references to alpha detector Ignore merely particles 'hit' But alpha particles absorbed or stopped by smoke particles so less ionisation of air particles (2) <u>Examiner's Comments</u> The question on the smoke detector separated the grades clearly. Most candidates scored the 'smoke blocking alpha' mark but only the better answers referred to the ionisation of the air. References to current were usually not clear enough to be creditworthy.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18			any two from (idea that for absolute dating) absolute dating gives a more exact date / ora (1) (Idea about absolute dating) not enough Carbon-14 in old rocks (for absolute dating) or absolute dating only works when there is enough carbon in the sample (1) (idea that relative dating) can get the age of (very) old plants / wider age range of plants / ORA [1] (idea that for relative dating) need comparative data eg. requires knowledge of the ages of surrounding rocks (1) Idea that using both methods together gives a more reliable / valid / complete answer or both results support each other [1]	2	Allow carbon dating for absolute dating Eg. more accurate / precise Ignore 'better result' allow relative dating can get the age of (very) old rocks [1] Eg. both methods give more certain answer [1] Eg. both methods give more confidence in the result [1] Allow both methods give a more accurate answer [1] Accuracy mark can only be given once. <u>Examiner's Comments</u> Candidates usually gained one of the two marks available for the use of relative and absolute dating.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19	a		decrease (1) as time increases (1)	2	allow decrease with time (2) allow decrease faster initially / AW (2) allow higher level answers e.g. decrease exponentially (2) <u>Examiner's Comments</u> Nearly all could describe the trend in the data table correctly.
	b		the numbers half the fastest or the numbers half in less time / AW (1)	1	allow higher level answers e.g. the half-life is 50 ± 5 minutes or in each 100 minutes the numbers quartered (1) <u>Examiner's Comments</u> This question on comparing the half life of samples from the decay over time was one of the most challenging on the paper. Very few could correctly use the data to explain which sample had the shortest half life- most candidates simply focussing on the lowest activity at the end of the time interval. This discriminated very well. Better candidates understood the dangers of using medical tracers with a longer half-life and often made a good link to cell damage.
	c		nucleus (1)	1	if answer line blank allow correct answer circled or underlined more than one answer = 0 marks <u>Examiner's Comments</u> Around a third of candidates selected that radiation came from the nucleus. The most common wrong answer was selecting that it came from 'electrons orbiting the nucleus'.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20			any two from (idea that for absolute dating) absolute dating gives a more exact date / ora (1) (Idea about absolute dating) not enough Carbon-14 in old rocks (for absolute dating) or absolute dating only works when there is enough carbon in the sample (1) (idea that relative dating) can get the age of (very) old plants / wider age range of plants / ORA [1] (idea that for relative dating) need comparative data eg. requires knowledge of the ages of surrounding rocks (1) Idea that using both methods together gives a more reliable / valid / complete answer or both results support each other / [1]	2	allow Carbon dating for absolute dating Eg more accurate / precise / Ignore 'better result' allow relative dating can get the age of (very) old rocks [1] Eg both methods give more certain answer [1] Eg, both methods give more confidence in the result [1] Allow both methods give a more accurate answer [1] Accuracy mark can only be given once. <u>Examiner's Comments</u> Only higher ability candidates coped well with interpreting and applying the information provided to explain why both absolute and relative methods are used together.
			Total	2	

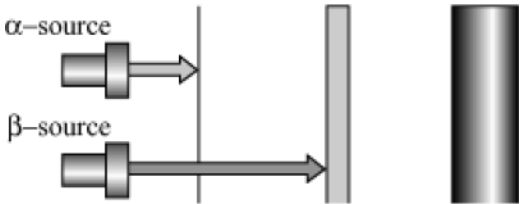
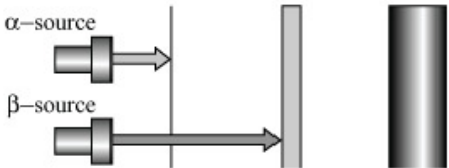
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
21	Level 3: (5–6 marks) Correctly identifies three sources with an explanation AND explains the usefulness of all three sources in terms of penetration. Quality of written communication does not impede communication of the science at this level. Level 2: (3–4 marks) Correctly identifies three sources OR explains the usefulness of all three sources in terms of penetration. Quality of written communication partly impedes communication of the science at this level. Level 1: (1–2 marks) Describes two basic trends in the data OR identifies one source correctly. Quality of written communication impedes communication of the science at this level. Level 0: (0 marks) Insufficient or irrelevant science. Answer not worthy of credit.	6	This question is targeted up to grade A Indicative scientific points may include: Level 3: • X is gamma, Y is alpha, Z is beta • gamma – no differential, alpha stopped too easily, beta shows differential with paper (thickness) Level 2: • X is gamma, Y is alpha, Z is beta • gamma – no differential, alpha stopped too easily, beta shows differential with paper (thickness) Level 1: • X / gamma unaffected • Y / alpha stopped by paper • Z / beta reduced with thickness • one source identified Answers which incorrectly identify X, Y or Z are limited to level 2 (4 marks) Use the L1, L2, L3 annotations in Scoris; do not use ticks. <u>Examiner's Comments</u> This six-mark level of response question on a radioactivity experiment was well answered and accessed by the great majority. Most answers were lengthy and often detailed. About a third of answers did not identify the sources correctly often getting gamma (X) and beta (Z) the wrong way round. Some became confused over the raw numbers – 'highest counts per minute means gamma', for example. The answers however discriminated well and gave a wide range of marks. About a third of candidates gave good answers and used the data logically to clearly explain their choice and get full marks.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	6	
22			half-life of Y is (approximately) 1 hour / h / hr (1) half-life of substance X is (approximately) 4 hour / h / hr (1) if no marks scored above: the idea that substance Y has a shorter half-life (than substance X) / ora for X scores (1)	2	allow range 0.75 - 1 hour correct units required for this marking point allow range 3.5 - 4 hours correct units required for this marking point ignore 'between 3 to 4 hours' but half-life of X is 4 x that of Y (2) Ignore incorrect units if stated for this marking point ignore substance X remains radioactive longer as targeting A* for 1 of the marks Examiner's Comments Most candidates had at least an appreciation of half life and identified X as having the longer of the two [1]. Better answers quantified this with X being 4 years and Y being 1 year [2]. There was a certain amount of confusion between half life and activity.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23			arrow or line from alpha to front / rear face of paper and arrow or line from beta to front / rear of aluminium (1)	1	allow alpha line slightly penetrating paper and beta line slightly penetrating aluminium but not passing all the way through  Do not allow mark if radiation emerges from barrier Examiner's Comments This question was well attempted with many candidates gaining full marks. Occasionally alpha and beta were the wrong way round. Occasionally also some candidates failed to attempt the question at all indicating that they had not read the paper with sufficient care. There were some careless diagrams with the arrows just stopping short of the barriers or just going beyond the barriers.
			Total	1	
24			arrow or line from alpha to front / rear face of paper and arrow or line from beta to front / rear of aluminium (1)	1	allow alpha line slightly penetrating paper and beta line slightly penetrating aluminium but not passing all the way through  Do not allow if radiation emerges from the barrier Examiner's Comments Most candidates were able to complete the diagram showing the penetrating power of alpha and beta radiation.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
25	Level 3 (5–6 marks) Answers must refer clearly to the use of lead to absorb gamma and that paper and aluminium will not stop gamma. The count only being reduced with a lead absorber or stopped by lead must be included. Safety should be addressed. If only one safety point addressed or there is one error with absorption award 5 marks. Quality of written communication does not impede communication of science at this level. Level 2 (3–4 marks) Answers refer to the idea of using absorbers and relative penetrating power. If absorption of alpha, beta and gamma are not all included award 3 marks. Quality of written communication partly impedes communication of science at this level. Level 1 (1–2 marks) Answers are limited to stopping one type of radiation or one safety features or the set-up. Errors in what absorbs a radiation will result in 1 mark being awarded. Quality of written communication impedes communication of science at this level. Level 0 (0 marks) Insufficient or irrelevant science. Answer not worthy of credit.	6	This question is targeted at grades up to C Relevant points about absorption include: • alpha stopped by paper or aluminium / (thin) metal • beta stopped by aluminium / (thin) metal • count does not reduce with paper and / or aluminium • gamma passes through paper / (thin) metal • gamma stopped by lead or concrete. Relevant safety points include: • protective clothing • tongs / keep a safe distance • short exposure time • keep class a safe distance • direction of source points away from teacher. Relevant points about set-up include: • GM tube detects radiation • source, absorber then GM tube. Some answers may be wholly or partly expressed in diagrams so mark them accordingly e.g: • experimental set up • relative absorptions • identification of source as gamma emitter Use the L1, L2, L3 annotations in scoris. Do not use ticks. Examiner's Comments This question was targeted at grades up to C and candidates often struggled to include sufficient detail about the absorption and penetrating power of alpha particles, beta particles and, in particular, gamma radiation. Often the penetrating powers were muddled, the appropriate

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					absorber often being for another nuclear radiation. Most candidates totally neglected safety , despite the emboldening of the word in the question. When diagrams were offered as part of the answer, they were often unclear as to what penetrated or was stopped by what.
			Total	6	
26		i	ONE from: - Either (percentage of ^{14}C decreases because) it is radioactive / decays - Or - no ^{14}C taken in after death (1) ONE from: (percentage of ^{12}C stays the same because) ^{12}C is not radioactive / does not decay / is stable (1)	2	Allow references to half-life Eg. undergoes half-lives Eg. 'it halves every 5730 years' (1) Allow unstable (isotope) (1)
		ii	22 920 (years)	1	
			Total	3	
27			3 (1) 3 (1) 1 (1)	3	each correct number scores 1 mark $\begin{array}{ccccc} 1 & & 2 & & \text{..3..} \\ \text{H} & + & \text{H} & \rightarrow & \text{He} \\ 1 & & 1 & & 2 \end{array} \quad (1)$ $\begin{array}{ccccc} 2 & & \text{..3..} & & 4 & & 1 \\ \text{H} & + & \text{H} & \rightarrow & \text{He} & + & \text{n} \end{array} \quad (1)$ $\text{..1..} \quad \quad 1 \quad \quad 2 \quad \quad 0 \quad \quad (1)$
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28		i	A and C (1) and any two from because gamma radiation passes through skin (1) because it is harmful to healthy cells (1) because it is used to treat cancer (1)	3	
		ii	any one from limit exposure time (1) use a screen (1) keep a safe distance (1) wear protective clothing (1) use appropriate handling technique (1)	1	allow any named example of a limit to exposure time e.g. wear radiation badges (1) allow any named example of a screen e.g. stand behind a glass wall (1) allow any named example of a safe distance e.g. keep away from the patient when treating them (1) allow named appropriate protective clothing e.g. lead apron (1) allow use tongs (1)
			Total	4	
29			source A: Beta (1) source B: Gamma (1)	2	allow β allow γ
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
30			C ✓	1 (AO2.1)	<u>Examiner's Comments</u>  Many candidates chose distractor B as they had the misconception that beta radiation will not pass through aluminium foil. While an aluminium plate will stop beta radiation, thin aluminium foil will not be an effective screen for all the beta radiation.
			Total	1	
31			B ✓	1 (AO1.2)	<u>Examiner's Comments</u> This question required candidates to use their knowledge of half-life to interpret the graph. The majority of candidates were able to work out the half-life of the source using the graph.
			Total	1	
32			B ✓	1 (AO1.1)	<u>Examiner's Comments</u> Most candidates successfully applied their knowledge of ionisation to identify what happens to the atom for it to become a positive ion.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a	i	(Radioactive nuclei) are unstable ✓	1 (AO1.1)	ALLOW (nuclei have) too many neutrons <u>Examiner's Comments</u> Just over half of the candidates correctly explained that some isotopes are radioactive because the nuclei are unstable or have too many neutrons. Common incorrect responses referred to 'more neutrons' or ideas about numbers of electrons or protons.
		ii	Different numbers of neutrons ✓	1 (AO1.1)	<u>Examiner's Comments</u> The majority of candidates successfully stated that there are a different number of neutrons in carbon-12 and carbon-14.
	b	i	${}^{226}_{90}\text{Th}$ ✓	2 (AO2.2) (AO2.2)	
		ii	${}^0_{-1}\beta$ ✓	2 (AO2.2) (AO2.2)	
		iii	${}^{235}_{92}\text{U} \rightarrow \gamma + {}^{235}_{92}\text{U}$ ✓	2 (AO2.2) (AO2.2)	<u>Examiner's Comments</u> Almost all candidates were able to complete all three decay equations. Of the small number who could not complete the equation the most common error was stating the atomic number of beta as +1 rather than -1.
			Total	8	
34			D ✓	1 (AO 1.1)	<u>Examiner's Comments</u> Most candidates answered this question although a common misconception was that the nucleus was uncharged (option D).
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35			C ✓	1 (AO 2.2)	<u>Examiner's Comments</u> Almost half of the candidates correctly recalled that an alpha particle had 2 protons and 2 neutrons and were able to show that they understood standard nuclear notation (conventional representation for nuclei).
			Total	1	

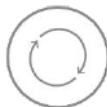
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
36	a		Any two from: Keeping a safe distance (from source) ✓ Use tongs ✓ Point sources away from people ✓ Keep sources in sealed containers ✓ Keep exposure time as short as possible ✓	2 (AO 2 x 1.2)	ALLOW behind (lead) screen IGNORE gloves/goggles ALLOW lead box Examiner's Comments Many candidates answered this question in general terms suggesting general laboratory rules rather than specific safety precautions relevant to the experiment. A large number of candidates suggested keeping a safe distance from the source. Some candidates were confused about whether the barrier was part of the experiment or a safety device. Higher ability candidates gave relevant precautions including the use of tongs to hold the source (in effect adding some distance), using the sources for a short period of time (to minimise exposure) and storing the sources in lead lined boxes.
	b	i	(Source) A ✓ (Source) A because (idea that) count rate unaffected by paper and aluminium OR only lead reduces / stops gamma ✓	2 (AO 3.2) (AO 2.1)	ALLOW cannot travel through lead Examiner's Comments Candidates were expected to interpret information from the table. The first mark was credited for identifying the correct source. Candidates then needed to apply their understanding to explain why source A could be the only correct answer for part i (because there was no change in the count rate through paper and aluminium, but the radiation was absorbed by the lead). The most common misconception was to choose source D because it had the largest count rate. For part (ii), half of the candidates correctly identified source B but fewer explained their choice in terms of paper absorbing the radiation.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(Source) B ✓ (Source) B because count rate is reduced by paper ✓	2 (AO 3.2a) (AO 2.1)	Examiner's Comments Candidates were expected to interpret information from the table. The first mark was credited for identifying the correct source. Candidates then needed to apply their understanding to explain why source A could be the only correct answer for part I (because there was no change in the count rate through paper and aluminium, but the radiation was absorbed by the lead). The most common misconception was to choose source D because it had the largest count rate. For part (ii), half of the candidates correctly identified source B but fewer explained their choice in terms of paper absorbing the radiation.
		iii	(Source) D ✓ (Source) D because (idea that) count rate decreases after aluminium (beta) <u>and</u> after lead (gamma) ✓	2 (AO 3.2a) (AO 2.1)	ALLOW not absorbed by paper Examiner's Comments One in four candidates identified the source correctly as D, but few justified their choice in terms of the count rate decreasing through the aluminium and then further decreasing after the lead.
	c		Any two from: Radioactive decay is random ✓ Variations are more pronounced at low count rates ✓ Background radiation ✓	2 (AO 2 x 3.1a)	Examiner's Comments Candidates found this question very challenging and fewer than 5% were credited with any marks. Many candidates responded in terms of the thickness of the lead barrier. It was expected that candidates would state that there was a range of results because of the random nature of radioactivity and that what was being measured was the background radiation.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		Any two from: Larger number of counts ✓ Less variation in count rate ✓ Gives an average count rate ✓ Gives more repeatable results ✓ Makes it easier to decide what the source is ✓	2 (AO 2 x 3.2b)	ALLOW more radiation detected ALLOW idea of smoothing out variations ALLOW more reliable IGNORE accurate Examiner's Comments A large number of candidates responded by repeated the stem of the question in their own words, many just stated that the time should be increased. A number of candidates stated that the experiment would be "more accurate" without any explanation and so did not gain any. This was a practical skills question, which also assessed candidates' understanding of Working Scientifically (Appendix 5e). Candidates were expected to understand that the longer recording time would give a larger number of counts and thus there would be less variation in count rate, or it would enable an average count rate to be determined. There were also marks available for stating that the teacher's observations would give more repeatable results.  AfL Candidates should be encouraged to interpret the question paper as to the expected length of their answers. In this question there were three answer lines and two marks available, which indicated that at least two improvements needed to be explained and that a short three-word answer was unlikely to gain both marks.
			Total	12	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
37	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) Explains quantitatively why the stopping distances are different for each speed in the table in terms of braking distance and thinking distance. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Explains qualitatively why the stopping distances are different for each speed in the table in terms of braking distance or thinking distance increasing with speed from the table <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) States basic ideas about thinking distance / braking distance / stopping distance OR identifies variation of thinking distance / braking distance / stopping distance with speed <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks - No response or no response worthy of credit.	6 (AO 2 x 1.1) (AO 2 x 2.1) (AO 2 x 3.2b)	AO1.1a Demonstrates knowledge and understanding of thinking, braking and stopping distance - Thinking distance is the distance the car travels while the driver reacts - Braking distance is the distance travelled while the brakes are applied - Stopping distance is thinking distance + braking distance AO2.1 Applies knowledge and understanding of thinking, braking and stopping distance in relation to the details in the table - Increasing the speed, increases the thinking distance - Increasing the speed, increases the braking distance - Increasing the speed, increases the stopping distance AO3.2b Analyses information to make judgements and draw detailed conclusions from table - Thinking distance is directly proportional to the speed - When speed doubles, thinking distance doubles - Braking distance is proportional to speed² - When speed doubles, braking distance quadruples Examiner's Comments This question gave candidates the opportunity to apply their knowledge and understanding of stopping distances. The question is deliberately set to be open ended so that candidates had the opportunity of structuring their answers logically. Higher ability candidates explained that the stopping distance was equal to the sum of

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			the thinking distance and braking distance before stating that the stopping distances increased with speed. Often candidates demonstrated the change in stopping distance using the data from the table. For the highest marks, candidates were expected to analyse the data quantitatively from the table. A few candidates used part (a) and stated that thinking distance doubled with speed and carried out a similar analysis for braking distance, stating that as speed doubled, braking distance quadrupled. Common misconceptions included thinking time increasing with speed, drivers being under greater pressure at high speed, braking forces increasing with speed. Other candidates discussed factors that affected thinking distance and braking distance rather than using the data in the table. Exemplar 2 (c)* Explain why the stopping distances are different for each speed in Fig. 20.1. When driving at 8 m/s the ~~stopping~~ thinking and braking distance are equal, 6 m. ~~therefore~~ the stopping is $6 \times 2 = 12$ m. When driving at 16 m/s the thinking distance double but it takes longer to break as your going at a faster speed. Some applies to 32 m/s as it takes 90 m longer than 8 m/s to stop. Meaning the stopping distance totals 120 m. This is a four mark, Level 2 response. The candidate has calculated the stopping distance for each speed and provided a limited analysis. They have made good use of mathematical expressions to show that stopping distance is equal to the product of thinking and breaking distance. The information presented is relevant, however there are limited links made between the bullet points. To progress to a Level 3 response the candidate could have added a short introduction and a final bullet point linking the analysis at each speed together

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					in a summary sentence. Exemplar 3 (e)* Explain why the stopping distances are different for each speed in Fig. 20.1. At higher speeds the thinking and braking distance increases. If the speed doubles the thinking distance doubles and the braking distance quadruples. This means the stopping distances get larger. The thinking distances increase because the car is travelling at a higher speed meaning it will travel further in that thinking time which stays the same. The braking distance increases massively with faster speed. This is because there is a higher velocity and a larger moment therefore it takes a lot more force and time to decelerate the car. What is shown in the graph is that this equates to a much longer a difference in stopping time because of these two factors, which caused by the different speeds. This is a six mark Level 3 response. This is very clear analysis of the data in the table that is linked together in a clear logical structured way. Although the candidate has not annotated their script (except in their response to (a) it is clear that they have processed the data in the table. They have described the complex mathematical relationships (for example 'if the speed doubles the thinking distance doubles and the breaking distance quadruples') although it would have been easier to present this conclusion numerically.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38			B ✓	1 (AO 1.1)	<u>Examiner's Comments</u> This question required candidates to apply their scientific knowledge and analyse the information in the table about nuclear radiation in order to choose the best isotope to use as medical tracer.  Misconception Many candidates could identify that gamma was the best radiation to use but had the misconception that a half-life of 6 minutes was long enough. Therefore, they incorrectly chose option C. Teaching often emphasises the need for a short half-life to reduce patient exposure to radiation, but this time cannot be shorter than the time required to carry out the procedure.
			Total	1	
39			B ✓	1 (AO 1.1)	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
40	a		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 20 (minutes) then award 2 marks Evidence on graph or elsewhere of half of activity indicated ✓ (Half life =) 20 (minutes) ✓	1 (AO 2×2.2)	ALLOW 19-21 (minutes) ✓✓ <u>Examiner's Comments</u> Most candidates were able to successfully work out the half-life of isotope A from the graph, although there was evidence that some candidates had not read the initial activity from the scale on the y axis correctly.
	b		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 128 (counts per minute) award 2 marks Evidence of halving /doubling using data ✓ (Activity =) 128 (counts per minute) ✓✓	1 (AO 2×2.2)	e.g. time to go from 64 to 32 (cpm) is 30 (mins) / initial activity = 64×2 If answer is 105 to 127 or 129 to 136 then award a maximum of 1 mark ✓ <u>Examiner's Comments</u> Candidates found this question challenging. Most candidates' answers were in the range allowed for 1 or 2 marks but many made the common error of trying to find the differences between values in the table rather than spotting where the activity had halved.
	c		Conclusion 1 (incorrect) Any one from: Idea that activity is a random/unpredictable occurrence / AW ✓ Idea that low numbers of counts amplify relative variations / AW ✓ Conclusion 2 (incorrect) Any one from: (All radioactive isotopes) have a half-life / AW ✓ changes in activity will be small if half-life is long ✓	1 (AO 2×3.1b)	ALLOW correct answers referring to background radiation/readings <u>Examiner's Comments</u> This Assessment Objective 3 question tested candidates' ability to analyse the information from the graph and draw conclusions about the activity and the half-life. Many candidates agreed with both conclusions and tried to justify their answers. Candidates were most likely to evaluate conclusion 2 correctly and state that all (radioactive) isotopes have a half-life. It was rare to see conclusion 1 evaluated correctly as candidates did not link the graph to the random nature of radioactive decay.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
41			D ✓	1 (AO1.2)	<u>Examiner's Comments</u> The majority of the candidates realised that the masses and charges needed to balance.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
42	a		Any two from: Electron absorbs or gains energy / AW ✓ Electron becomes 'excited' / moves to a higher energy level / moves to outer path / AW ✓ Electron escapes / leaves the atom / AW ✓	2 (AO 2×1.1)	ALLOW atom becomes ionised / charged <u>Examiner's Comments</u> This question tested candidates understanding of the effect on an electron that has absorbed electromagnetic radiation. Some candidates stated that the electron could gain energy and also the electron could lose energy. It was expected that candidates would understand that the electron gains energy and may become excited and move to a higher energy level or escape from the atom. Credit was given for candidates who stated that the atom became ionised. For this type of questions, candidates need to be precise in the use of terms. There was some confusion between atom and electron. Many candidates suggested that the electron lost charge. Candidates also need to take care over the use of "it". In this question, it was not always clear whether candidates were referring to the electron or the atom.
	b		Any two from: Electromagnetic radiation is being absorbed by electrons not nucleus ✓ Alpha emitted from the nucleus / electrons not present in the nucleus / AW ✓ Alpha emitted from unstable radioactive nuclei ✓ Alpha does not have electrons / has protons and neutrons only / AW ✓	2 (AO 2×1.1)	<u>Examiner's Comments</u> The mark bracket for this question indicates [2], which means that candidates need to answer by giving two points. Few candidates understood that alpha particles are emitted from the nucleus and that alpha particles do not have electrons.
			Total	4	

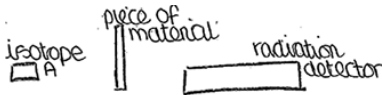
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
43	a		25(g) ✓	1 (AO 1.2)	<u>Examiner's Comments</u> About half the candidates correctly understood the term half-life and answered 25 g. There was evidence that other candidates either multiplied the numbers together (300) or divided the numbers (8.3).
	b	i	C ✓	1 (AO 2.2)	ALLOW answer from diagram if clear <u>Examiner's Comments</u> A large majority of the candidates correctly identified C as taking the longest time to decay. The common error was A.
		ii	Any four from: A is more hazardous / B is safer (for most of the time on the graph) ✓ A has a higher activity (for most of the time) ✓ B is more hazardous at the beginning ORA ✓ B has a higher activity at the beginning ORA ✓ A has a longer half-life / B has a shorter half-life ✓	4 (AO 4×3.1b)	<u>Examiner's Comments</u> This type of question gives candidates opportunities to demonstrate their knowledge of radioactivity as well as their skills in interpreting graphical information. In answering this type of question, candidates should look at the information from the graph and discuss what happens initially while B had the higher activity and then discuss what happened after the two graphs crossed. There should also be a link between activity and hazardousness. For the highest marks, there needed to be a comparison between the relative activity / hazardousness of the isotopes initially during the first day compared to activity / hazardousness of the isotopes after two days. Candidates could not gain the same mark twice, i.e. A had a longer half-life and B had a shorter half-life would only gain one mark. Again, the physics term "half-life" was expected to be seen. Exemplar 4

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Scientist 1 The fact that A has a higher activity than B is correct as it also has a longer half life. A is more hazardous due to its high activity rate Scientist 2 A has got a longer half life than B as it takes more days for the activity to decrease. B has a shorter activity than A causing it to have a shorter half - life than A. This candidate makes the link clearly between hazardous and activity and also clearly states on two occasions that A has the longer half-life. The candidate says that A has a higher activity which is assumed as overall. The writing at the end has been ignored and it would seem that the candidate did not fully understand the term half-life. To improve on this answer, some comment should have been made with regard to the graph initially during the first day. This answer was given 3 marks.
		iii	Maximum two from: One absorber placed between detector and isotope A ✓ (Idea of) change absorber and repeat experiment ✓ Measures (background) count with no source ✓ Maximum two from: Drop in count rate with cardboard indicates alpha ✓ Drop in count rate with aluminium indicates beta ✓ Drop in count rate with lead OR cardboard and aluminium / all materials are penetrated indicates gamma ✓	4 (AO 2×2.2) (AO 2×1.2)	May be described or drawn in a diagram ALLOW stopped / absorbed for drop in count rate Examiner's Comments Good candidates drew a diagram to indicate the experimental set-up. Many candidates were able to describe how they would place the absorbers in front of the detector. It would be better if they had stated in turn. A few candidates under the procedure section stated that they would take a reading with no absorber present. A few candidates also stated that would take a reading without a source, i.e. taking a background count. Several candidates were confused as to

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					which absorber would stop which type of radiation. Exemplar 5  The scientist should detect how much radiation the isotope has on its own and then place each material (one at a time) between the isotope and the detector. Gamma radiation is the strongest, therefore should pass through everything except aluminium. Alpha is the weakest, so it should be stopped by cardboard. Beta should be stopped by lead. This candidate has a clear diagram, indicating the piece of material placed between the isotope and the detector. In the text, the candidate clearly states that each of the materials should be placed between the detector and isotope in turn ("one at a time"). The candidate's understanding of the likely results is muddled and not always correct (gamma radiation stopped by thin aluminium), but the candidate does correctly state that alpha should be stopped by cardboard. This answer was given 3 marks.  Candidates should be able to explain experimental procedures using a labelled diagram.
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
44			B ✓	1 (AO1.1)	
			Total	1	
45	a	i	27 ✓	2 (AO1.1)	
		ii	The same number of protons / atomic number / they both have 27 protons ✓ Co-60 has 3 more neutrons ORA / Co-60 has 33 neutrons and Co-57 has 30 neutrons / mass number is different ✓	2 (AO2 × 1.1)	ALLOW Co-57 has 27 neutrons 0
	b	i	Radioactivity is a random process ✓	1 (AO1.1)	ALLOW background radiation fluctuates
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 209 (counts per minute) award 2 marks (191 + 224 + 212) ÷ 3 ✓ = 209 (counts per minute) ✓	2 (AO2 × 1.2)	
		iii	The count-rate stays the same ✓	1 (AO2.1)	ALLOW the count-rate goes down slightly DO NOT ALLOW the count-rate goes down
	c	i	The time it takes the number of undecayed/radioactive nuclei to halve ✓	1 (AO1.1)	ALLOW count-rate or activity for number of undecayed nuclei
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 40 (counts per minute) award 3 marks 10y = 2 half lives ✓ 160 / 2 = 80 (counts per minute) ✓ 80 / 2 = 40 (counts per minute) ✓	3 (AO2 × 2.1)	
			Total	11	
46			A ✓	1 (AO1.1)	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
47	a		(The nucleus contains) 95 protons ✓ (and) 146 neutrons ✓	2 (AO2 × 1.1)	IGNORE references to electrons ALLOW the nucleus has a charge of (+) 95
	b		237 ✓ 93 ✓ He / α ✓	3 (AO2 × 2.2) (AO1 × 1.1)	
	c	i	The time it takes the number of (undecayed/radioactive) nuclei to halve ✓	2 (AO1.1)	ALLOW count-rate or activity for number of undecayed nuclei ALLOW the time it takes for half of the (radioactive) nuclei to decay ALLOW atoms for nuclei
		ii	It is long enough so the activity does not change significantly / source will not need to be replaced ✓	1 (AO2.1)	ALLOW it will last a long time
		iii	Thorium (is greatest risk to begin with) / ORA ✓ As thorium will have a higher activity/count-rate (at the beginning) / ORA ✓	2 (AO2 × 3.2a)	ALLOW thorium decays faster / ORA

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		Any two from: (Agree) Smoke alarms use small amounts of americium-241 ✓ Mainly emits alpha particles which are stopped by skin/soil ✓ Americium-241 is contained within the foil / AW ✓ Americium-241 cannot move out of materials in detector / be inhaled ✓ Soil emits more radiation ✓ Or Any two from: (Disagree) Smoke alarm contains an isotope with a long half-life ✓ The smoke alarm/foil could be damaged ✓ Americium-241 may contaminate objects (in the waste) ✓ Americium-241 also emits gamma rays (which are more penetrating than alpha particles) ✓ Soil may not absorb all radiation ✓	2 (AO2 × 3.2a)	IGNORE vague answers such as 'bad for the environment' ALLOW gamma is not stopped by the foil
			Total	11	