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OCR GCSE PHYSICS A (J249): QUESTIONS BY TOPIC

Topic P6: Radioactivity (F)

GCSE Physics A Foundation Tier (J249) · Topic P6

37 questions · 166 marks · Mark schemes included

OCR GCSE (9–1) Physics A (Gateway Science) J249, June 2018 – June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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2. Q13	J249/02 Paper 2 June 2018	1	6
3. Q12	J249/02 Paper 2 June 2019	1	7
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QUESTIONS

37 questions · 166 marks · grouped by sub-topic, lowest tariff first



SUB-TOPIC P6.1

RADIOACTIVE EMISSIONS

32 questions in this sub-topic · 141 marks · lowest tariff first



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

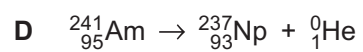
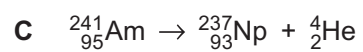
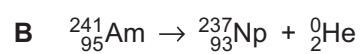
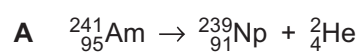
- A It contains neutrons and ions and has a negative charge.
- B It contains neutrons and ions and has a neutral charge.
- C It contains neutrons and protons and has a neutral charge.
- D It contains neutrons and protons and has a positive charge.

Your answer

[1]



13 Which equation shows a correct alpha decay?

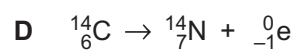
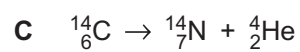
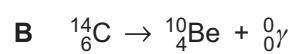
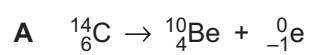


Your answer

[1]



12 Which radioactive decay equation is correct?



Your answer

[1]



1 What is the typical size for a small molecule?

A 0.1 cm

B 0.1 km

C 0.1 m

D 0.1 nm

Your answer

[1]



2 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]



1 Which of the following would you find in the nucleus of an atom?

- A Neutrons and electrons
- B Neutrons, electrons and protons
- C Protons and electrons
- D Protons and neutrons

Your answer

[1]



7 Which statement explains why the atomic model has changed over time?

- A** Models can explain different situations.
- B** Models can only be used for a limited time period.
- C** New information is discovered.
- D** Scientists are paid to keep changing models.

Your answer

[1]



4 A radioactive source has a count rate of 200 counts per minute (cpm).

The half-life of the radioactive source is 3 minutes.

What is the count rate of the radioactive source after 3 minutes?

- A** 0 cpm
- B** 100 cpm
- C** 200 cpm
- D** 400 cpm

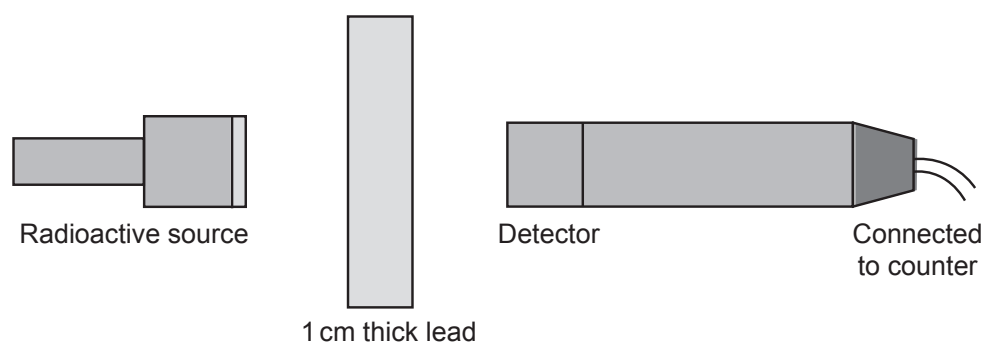
Your answer

[1]



- 7 A radioactive source produces gamma rays.

The diagram shows a detector and a piece of lead placed near the radioactive source.



The count rate is 1840 counts per minute (cpm) **without** the lead in place.

What could the count rate be **with** the lead in place?

- A 0 cpm
- B 160 cpm
- C 1840 cpm
- D 2530 cpm

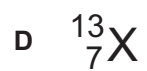
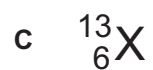
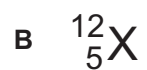
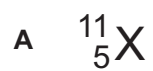
Your answer

[1]

14 Carbon-12 is an isotope of carbon.

Carbon-12 contains 6 protons and 6 neutrons.

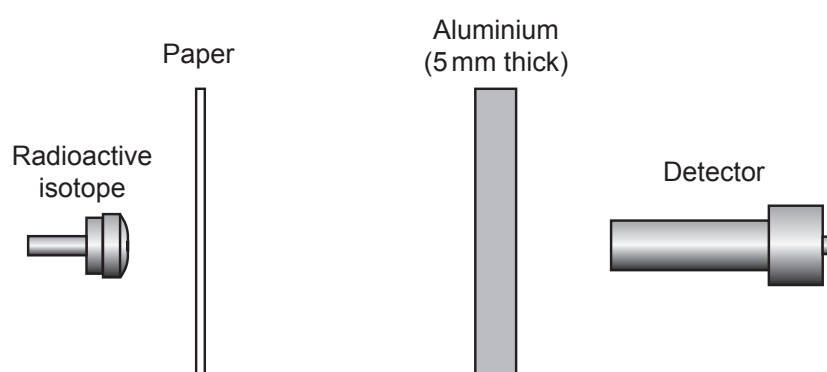
Which atom **X** is also an isotope of carbon?



Your answer

[1]

- 5 The diagram shows a radioactive isotope emitting alpha particles **and** beta particles.



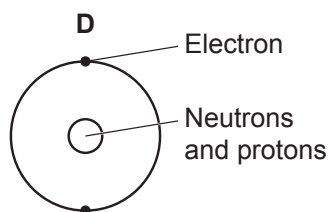
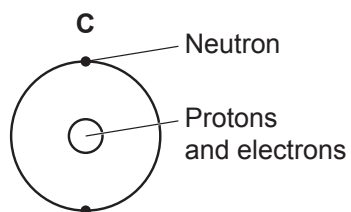
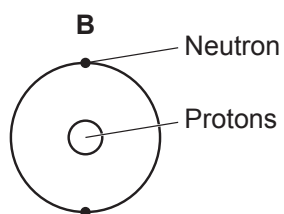
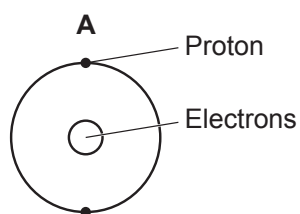
Which particles are detected by the detector?

- A Alpha particles and beta particles
- B Alpha particles only
- C Beta particles only
- D No particles

Your answer

[1]

2 Which diagram shows the correct model of an atom?



Your answer

[1]

12 The symbol for an isotope of hydrogen is ${}^3_1\text{H}$.

What is the correct diagram of the nucleus of this isotope of hydrogen?

Key

 = Neutron

 = Proton

A



B



C



D



Your answer

[1]

1 Which word describes the charge on the **nucleus** of an atom?

- A Negative
- B Neutral
- C Positive
- D Zero

Your answer

[1]



12 What is the correct order, from oldest to newest model, for the development of the atomic theory?

- A** Bohr → Thomson → Rutherford
- B** Rutherford → Bohr → Thomson
- C** Thomson → Bohr → Rutherford
- D** Thomson → Rutherford → Bohr

Your answer

[1]



1 Which statement describes the nucleus of an atom?

- A It contains electrons and protons only.
- B It contains neutrons only.
- C It contains protons and neutrons only.
- D It contains protons, neutrons and electrons.

Your answer

[1]



3 One atom of carbon contains 6 protons, 6 electrons and 6 neutrons.

Another atom of carbon contains 6 protons, 6 electrons and 7 neutrons.

Which answer describes these different atoms of carbon?

A Alpha particles

B Ions

C Isotopes

D Nuclei

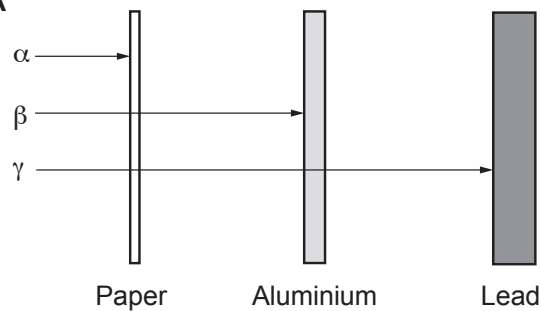
Your answer

[1]

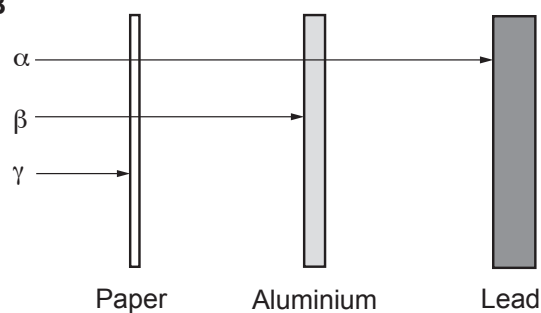


- 7 Which diagram shows how alpha particles (α), beta particles (β) and gamma rays (γ) penetrate different materials?

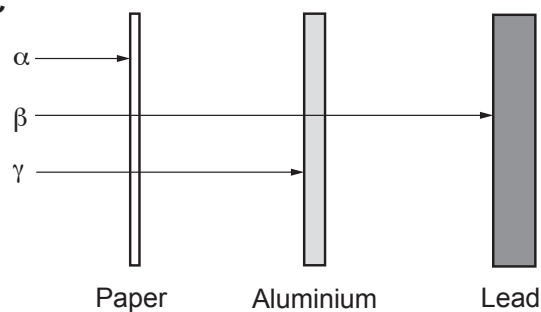
A



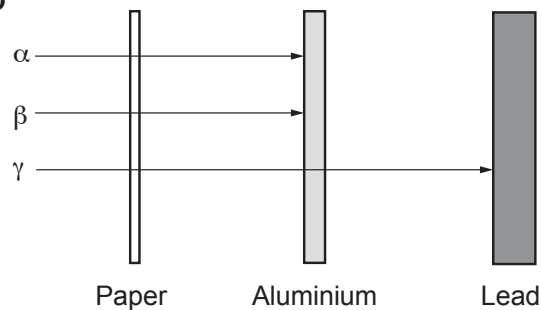
B



C



D



Your answer

[1]

6 The isotope aluminium-27 has the symbol ${}_{13}^{27}\text{Al}$.

How many **neutrons** are in a nucleus of aluminium-27?

A 13

B 14

C 27

D 40

Your answer

[1]



8 Which material will gamma radiation **not** easily penetrate?

- A A sheet of paper
- B A thick block of lead
- C A thin sheet of aluminium
- D Human skin

Your answer

[1]



22 Atoms can absorb and emit electromagnetic radiation.

(a) 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.

.....

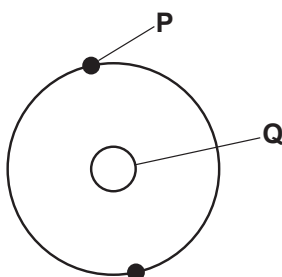
.....

.....

[2]



16 (a) The diagram shows a simple model of an atom.



Answer the questions using words from the list.

electron	negative	neutral	neutron	nucleus	proton
----------	----------	---------	---------	---------	--------

(i) What is the name of the part of the atom labelled **Q**?

..... [1]

(ii) Which **two** particles are found within part **Q**?

..... and [2]

(iii) What is the name of the particle labelled **P**?

..... [1]

(iv) What is the overall charge on an atom?

..... [1]

(b) Suggest why the model of the atom has changed over time.

.....

.....

.....

..... [2]

17 Atomic models have changed over time.

Old atomic model – Atoms are a positive mass with negative electrons fixed in it.

Current atomic model – Atoms are made from protons, neutrons and electrons. Protons and neutrons are in a central nucleus surrounded by a cloud of electrons.

(a) (i) Write down **two** differences between these models.

1

.....

2

..... [2]

(ii) Why did the atomic model change?

.....

.....

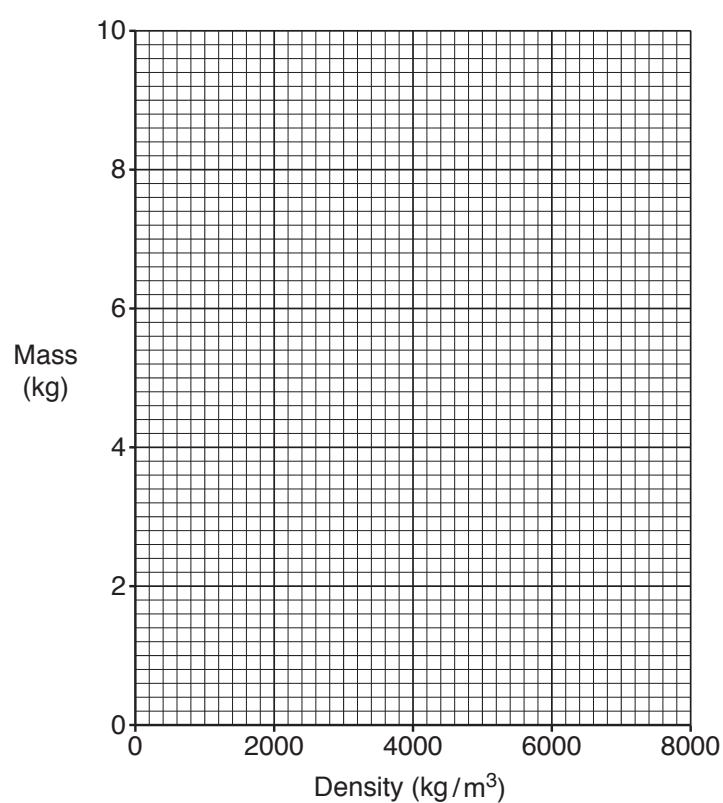
..... [2]

(b) A student has data on four blocks of different materials.

Each block has the **same** volume.

Block	Mass (kg)	Density (kg/m^3)
A	2	2000
B	4	4000
C	6	6000
D	8	8000

(i) Plot this data onto the graph and draw a line of best fit.



[2]

(ii) Describe the pattern shown on the graph.

.....

 [2]

16 (a) Complete the sentences about an atom.

Use words from the list.

You may use each word once, more than once, or not at all.

Atom	Electrons	Negatively	Neutrons
Nucleus	Orbits	Positively	Protons

An atom has a charged nucleus surrounded by charged electrons.

The nucleus contains protons and

Almost all of the mass of an atom is in the

[4]

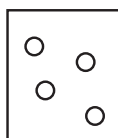
(b) (i) A swimming pool contains 9970 kg of water in 10 m^3 .

Calculate the density of water.

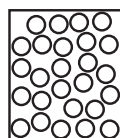
Use the equation: density = mass $\div$ volume

Density = ... kg/m^3 [2]

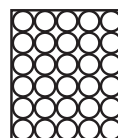
(ii) The diagrams, **A**, **B** and **C**, show the particles in three states of matter.



A



B



C

Write the letters in the boxes to give the correct order of density, from **most** to **least** dense.

Most dense —————→ **Least dense**



[1]

(iii) Explain why you chose the order in (b)(ii).

.....

[1]

22 This question is about radioactivity.

- (a) The nucleus of an isotope of phosphorous (P) has a relative charge of +15.
The relative mass of the nucleus is 32.

- (i) Complete the symbol for this isotope.

.....
..... P

[1]

- (ii) A nucleus of this isotope emits beta radiation.

State values for the relative charge and relative mass of the nucleus after beta radiation is emitted.

Relative charge

Relative mass

[2]

- (b) The table shows some information for two different isotopes of phosphorous.
The isotopes are labelled **A** and **B**.

	Relative charge	Relative mass
Isotope A	+15	29
Isotope B	+15	32

Complete the sentences below to describe the nucleus of isotope **A** and the nucleus of isotope **B**.

Use phrases from the list.

less than B

more than B

the same as B

The number of protons in the nucleus of **A** is

The number of neutrons in the nucleus of **A** is

[2]



(c) A doctor needs to explore a patient's internal organs. The doctor follows these steps:

- Injects a radioactive isotope into the patient.
- Sets up a special camera outside the patient's body.
- Uses the camera to detect radiation emitted from the isotope.

(i) Which radiation should be emitted by the isotope?

Tick (✓) **one** box.

Alpha

☐

Beta

☐

Gamma

☐

State a reason for your answer.

.....
..... [2]

(ii) There are three different isotopes with the following half-lives:

4 minutes

6 hours

18 days

The doctor chooses the isotope with a half-life of **6 hours**.

Suggest **two** reasons why **6 hours** is the most suitable half-life.

1
.....
2
.....

[2]



18 The model of the atom has changed over time.

(a) Three scientists worked on models of the atom.

Draw lines to connect each **scientist** with the correct description of the **scientist's work**.

Scientist

Bohr

Rutherford

Thomson

Scientist's work

developed the
plum pudding
model of the
atom

discovered
electrons can
only move in
fixed orbits
called shells

fired alpha
particles at
gold foil

[2]

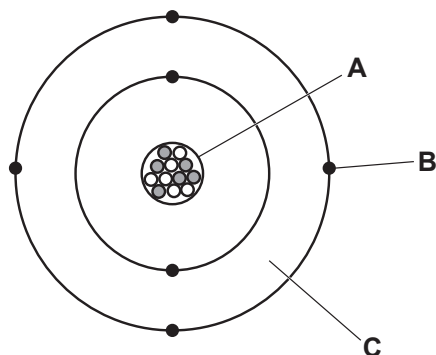
(b) Suggest **one** reason why models change over time.

.....

..... [1]



(c) The diagram shows a model of an atom.



Write down which letter, **A**, **B** or **C**, represents the following in the diagram.

The nucleus:

An electron:

[2]

(d) Complete the sentences.

Put a ring around the correct statement in each box.

The nucleus is

negatively charged
neutral
positively charged

Electrons are

negatively charged
neutral
positively charged

[2]

(e) One atom has a diameter of 1×10^{-10} m.

A molecule has 50 atoms in a line.

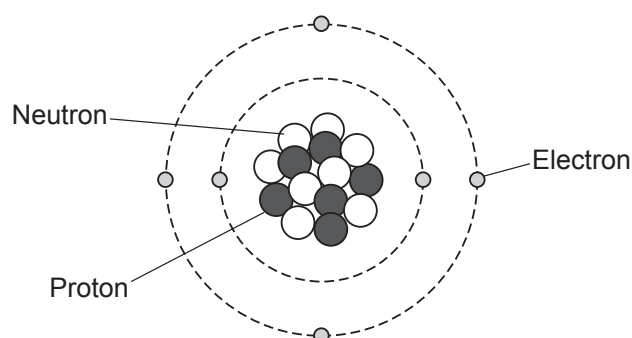
Calculate the length of this molecule.

Write your answer in **standard form**.

Length = ... m [2]

Turn over

18 The diagram shows a radioactive atom of carbon-14.



(a) The carbon-14 atom has 6 protons and 8 neutrons in its nucleus.

Carbon-12 is a different isotope of carbon.

State **one** similarity and **one** difference between an atom of carbon-14 and an atom of carbon-12.

Similarity

.....

Difference

.....

[2]

(b) An atom of carbon-14 decays by emitting a negatively charged beta particle from the nucleus.

Describe the effect this has on the mass number and on the charge of the nucleus.

Mass number

Charge

[2]

(c) Technicians store carbon-14 as a gas in sealed metal containers.

(i) Explain how the sealed metal containers prevent the technicians from being **irradiated** by beta particles emitted from carbon-14.

.....

.....

.....

[2]

- (ii) Explain how the sealed metal containers prevent the technicians from being **contaminated** by carbon-14.

.....
..... [1]

- (iii) The technicians check the safety of the containers by measuring the count rate next to the container. The count rate is the number of counts of radiation per minute.

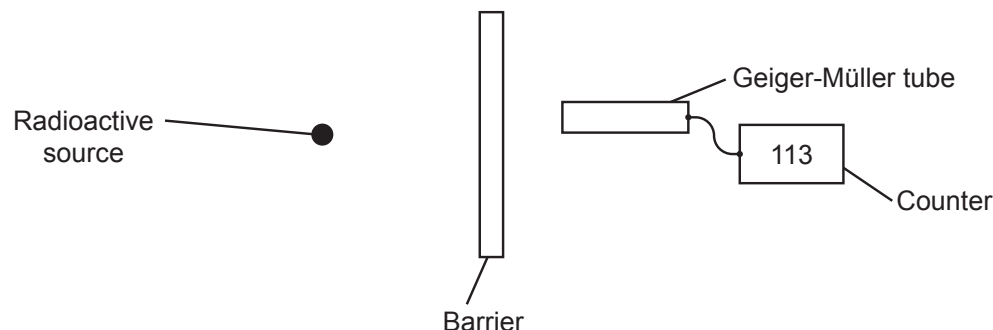
State the name of **two** pieces of equipment the technicians use to measure the count rate.

1
2 [2]



- 17 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**.



- (a) 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.

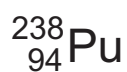
Explain why this is an improvement to the experiment.

.....
.....
..... [2]



19 Plutonium-238 (Pu-238) is a radioactive element.

(a) This is the symbol for Pu-238:



Draw lines to connect each box with the correct answer.

Mass number

94

Number of protons

144

Number of neutrons

238

[2]

(b) (i) A scientist measures the activity of a sample of Pu-238.

The scientist takes five different measurements.

Table 19.1 shows their results:

Measurement	1	2	3	4	5
Activity (GBq)	227	235	234	227	232

Table 19.1

What is the **mode** of the activity?

Mode = ... GBq [1]

(ii) An alpha particle is emitted by Pu-238.

Complete the radioactive decay equation for Pu-238 decay.



[2]



(iii) A student says, 'Alpha radiation is safer than beta.'

Do you agree with this student?

Tick (✓) **one** box.

Yes ☐

No ☐

Explain your answer.

.....
.....
..... [2]

(c) A scientist is using a radioactive element. The scientist accidentally touches the radioactive element and becomes **contaminated**.

The scientist stops using the radioactive element.

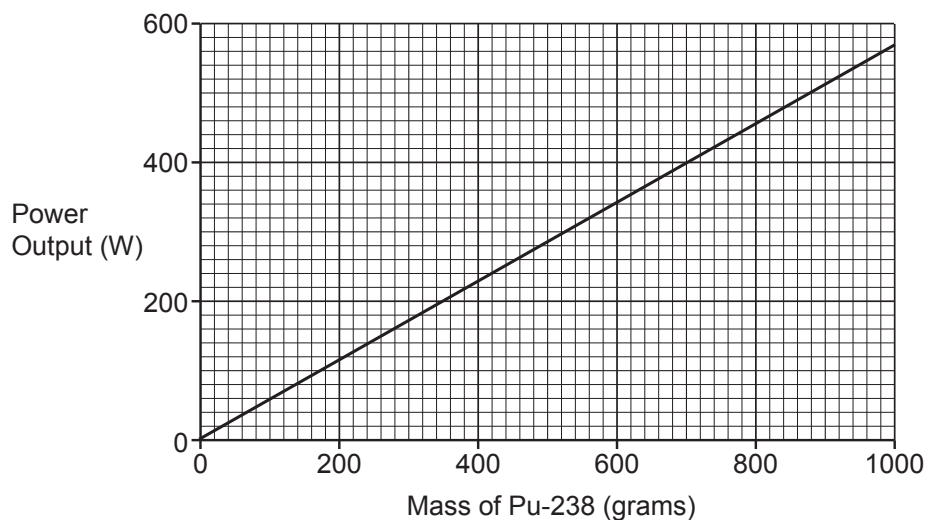
Explain why the scientist is still at risk.

.....
.....
.....
..... [2]

(d) Pu-238 can be used to generate electricity.

(i) The power output generated increases with the mass of Pu-238.

This is a graph of power output against mass of Pu-238:



Use the graph to find the mass of Pu-238 needed for a power output of 460 W.

Mass = ... grams [1]

(ii) Pu-238 was used to generate electricity on a probe that went to Neptune.

The half-life of Pu-238 is 88 years.

Suggest why Pu-238 was used on the probe that went to Neptune.

.....
.....
.....
..... [2]

23 In 1986, there was an accident when a nuclear reactor in a power station exploded.

In the explosion, radioactive materials from inside the reactor were spread over the power station.

(a) Explain why workers at the power station were both contaminated **and** irradiated in the accident.

Contaminated because

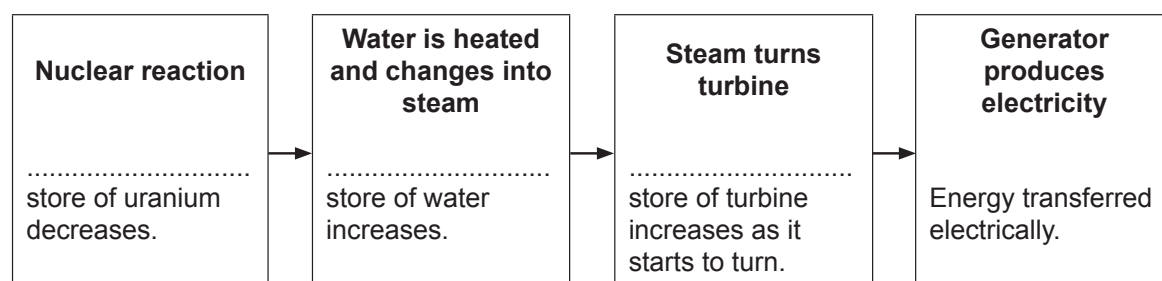
.....

Irradiated because

.....

[2]

(b) The flow diagram shows energy transfers when electricity is generated in a nuclear power station.



Complete the flow diagram to show the changes in energy stores.

[3]

- (c) One of the elements released in the accident when the nuclear reactor exploded was caesium-137.

Caesium-137 has a half-life of 30 years.

- (i) Explain what is meant by the phrase 'a half-life of 30 years'.

.....
 [1]

- (ii) Which sentence explains why we use the idea of half-life in radioactive decay?

Tick (✓) **one** box.

Radioactive decay is a random process.

☐

When a nucleus decays, it splits in half.

☐

With large numbers, it is easier to count half of the nuclei.

☐

[1]

- (iii) In the accident, 28 kg of caesium-137 was released into the atmosphere.

What mass of caesium-137 remains undecayed after 90 years?

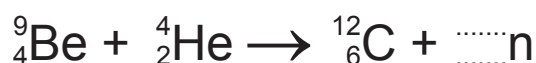
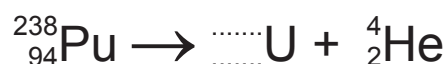
Mass = ... kg [2]

- (d) A nuclear reactor needs neutrons to start a nuclear fission reaction.

A plutonium nucleus (Pu) decays into a uranium nucleus (U) and an alpha particle (${}^4_2\text{He}$).

The alpha particle then joins with a beryllium nucleus (Be) to produce a carbon nucleus (C) and a neutron (n).

Complete the equations.



[3]

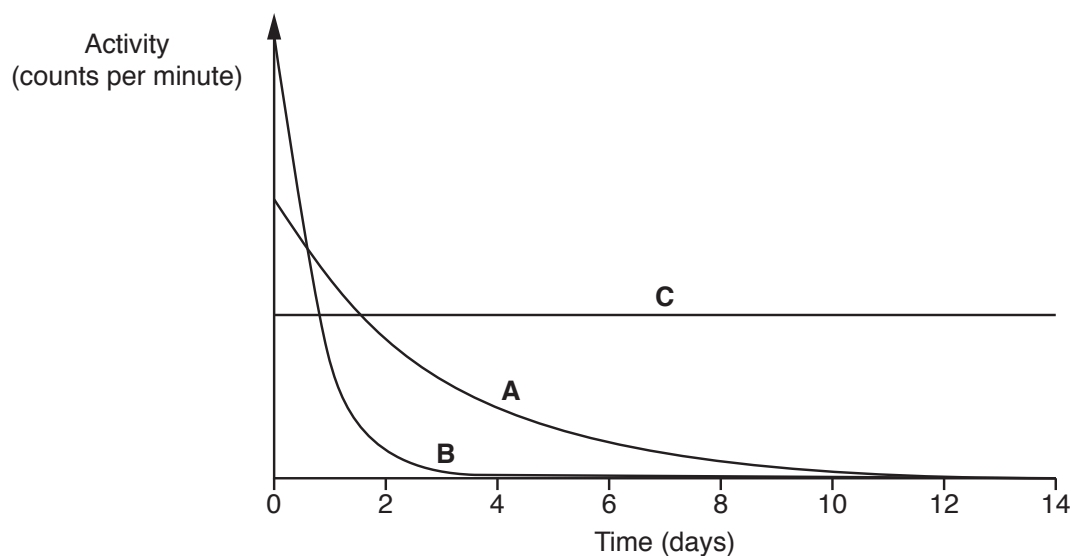
23 (a) A radioactive isotope has a half-life of 6 hours.

50g 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?

[1]

Tick (✓) **one** box.

A ☐

B ☐

C ☐

(ii) Two scientists discuss the isotopes in the graph.

Scientist 1	Scientist 2
'I think isotope A is more hazardous than B . A has a higher activity than B .'	'I think isotope B is more hazardous than A . B has a longer half-life than A .'

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
- piece of cardboard
- piece of aluminium.

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

You may include a diagram in your answer.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(c) This is a diagram to show a nuclear fusion reaction:



(i) Explain why this is nuclear fusion.

.....
 [1]

(ii) It is difficult for nuclear fusion reactions to occur on Earth.

Explain why nuclear fusion reactions occur in the Sun.

.....

 [2]

(iii) What will happen to our Sun when it runs out of hydrogen?

.....
 [1]

(d) Some scientists say nuclear fission is renewable. Other scientists say it is non-renewable.

Suggest why the scientists disagree.

.....

 [1]

- 18 (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 = ... [1]

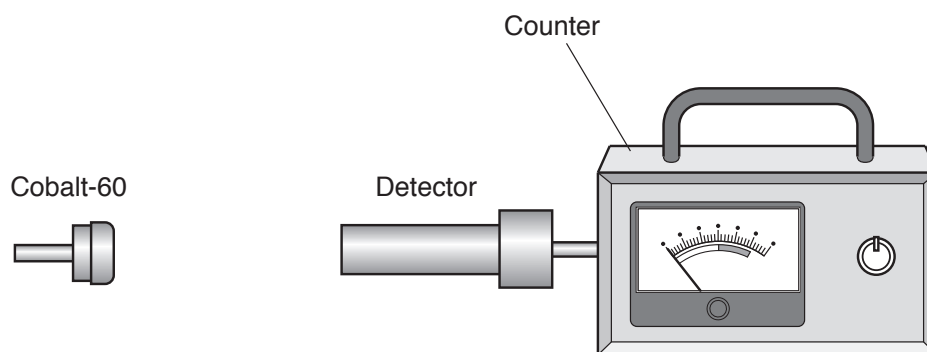
- (ii) Give **one** similarity and **one** difference between the nucleus of Co-57 and the nucleus of Co-60.

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]



- (d) A radioactive isotope can be used as a tracer in a patient's body. It is monitored by a radiation detector outside the body.

Four possible radioactive isotopes are shown in **Table 18.2**.

Radioactive isotope	Type of radiation emitted	Half-life
Radon-222	Alpha	4 days
Iodine-131	Gamma	8 days
Cobalt-60	Gamma	5 years
Plutonium-238	Alpha	88 years

Table 18.2

- (i) Doctors wear a lead apron when they use radioactive isotopes.

Explain why.

.....

.....

..... [2]

- (ii) Which radioactive isotope from **Table 18.2** is best to use as a radioactive tracer in a patient's body?

Tick (✓) **one** box.

Radon-222	☐
Iodine-131	☐
Cobalt-60	☐
Plutonium-238	☐

Explain your answer.

.....

.....

.....

..... [3]

SUB-TOPIC P6.2

USES AND HAZARDS

5 questions in this sub-topic · 25 marks · lowest tariff first



10 Which statement about nuclear **fission** is correct?

- A** An example is when hydrogen is converted to helium.
- B** It may happen when a nucleus absorbs a neutron.
- C** The Sun uses fission to generate its energy.
- D** Two nuclei join to make a heavier nucleus.

Your answer

[1]



8 What happens in the process of nuclear fusion?

- A** A chain reaction starts.
- B** A heavy nucleus splits and releases energy.
- C** A uranium nucleus absorbs a neutron.
- D** Light nuclei join to form a heavier nucleus.

Your answer

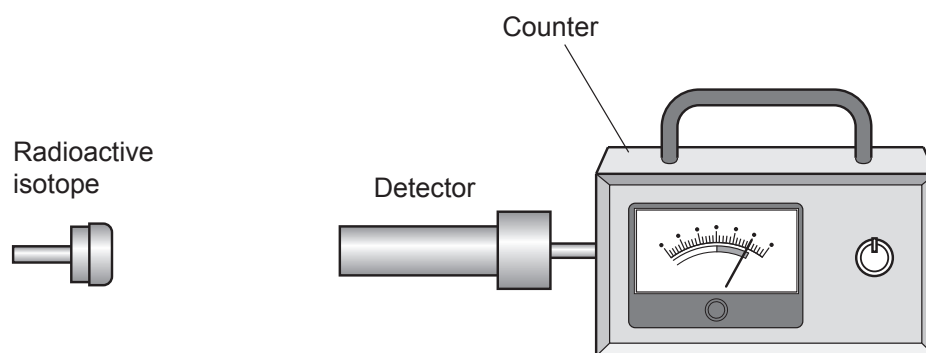
[1]



21

(a) A scientist measures the activity, in counts per minute (cpm), of different radioactive isotopes.

The diagram shows the equipment the scientist uses.



The scientist:

- Records the activity on the counter before the detector is switched on.
- Switches on the detector and records the activity with the radioactive isotope nearby.

The table shows the scientist's results.

	Activity (cpm)
Detector switched off	5
Detector switched on	420

(i) How can the scientist make the results more accurate?

Tick (✓) **one** box.

Handle the radioactive isotope using tongs.

Move the radioactive isotope further away from the detector.

Place lead in front of the radioactive isotope.

Zero the counter and take another reading.

☐
☐
☐
☐

[1]

(ii) The activity of a different radioactive isotope is 480 counts per minute (cpm).

Calculate the activity in counts per second.

Activity = ... counts per second [1]



(b) A radioactive isotope called yttrium-90 can be used to treat liver cancer.

(i) Yttrium-90 has a short half-life of 64 hours.

Explain why a short half-life is important for the patient.

.....

.....

..... [2]

(ii) Problems of using yttrium-90 to treat liver cancer include:

- poor appetite, abdominal pain, fever or sickness
- people in contact with the patient can be exposed to small doses of radiation.

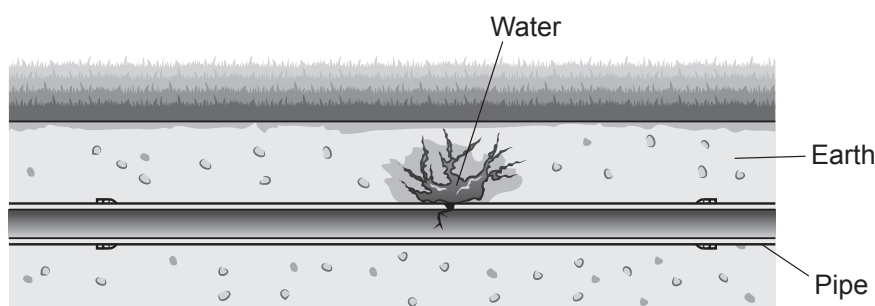
Explain why patients are treated with yttrium-90 despite these problems.

.....

.....

..... [2]

23 An underground water pipe has a leak, as shown in the diagram.



A tracer called sodium-24 is used to detect leaks in underground pipes.

(a) (i) Sodium-24 has a half-life of 15 hours.

Give **two** reasons why this is useful.

- 1
-
- 2
-
- [2]

(ii) Sodium-24 emits beta and gamma radiation.

Explain why this makes sodium-24 a good tracer.

-
-
- [1]

(iii) Sodium-24 decays to form a stable isotope.

Explain why this is important.

-
-
- [1]

(b) The tracer is monitored using a gamma radiation detector.

How is the location of the leak found?

-
-
-
-
- [2]

(c) A 12 mg mass of sodium-24 is added to water.

The half-life of sodium-24 is 15 hours.

What mass of sodium-24 remains in the water after 30 hours?

Mass remaining = ... mg [2]



21 A nuclear power station uses fission to produce electricity.

(a) The total power output of the nuclear power station is 1.0 GW.

The average power output of **one** fission reaction is $3.2 \times 10^{-11} \text{ W}$.

Calculate the number of fission reactions that occur per second.

Use the equation:

$$\text{number of fission reactions per second} = \frac{\text{total power output}}{\text{average power output per fission reaction}}$$

Number of fission reactions per second = ... **[3]**



MARK SCHEMES

official Pearson Edexcel mark schemes



Question				Answer	Marks	AO element	Guidance
3				D ✓	1	1.1	



Question				Answer	Marks	AO element	Guidance
13				C ✓	1	2.2	



Question	Answer	Marks	AO element	Guidance
12	D ✓	1	1.2	



Question				Answer	Marks	AO element	Guidance
1				D	1	1.1	



Question			Answer	Marks	AO element	Guidance
2			B ✓	1	1.1	



Question				Answer	Marks	AO element	Guidance
1				D ✓	1	1.1	



Question			Answer	Marks	AO element	Guidance
7			C ✓	1	1.1	



Question			Answer	Marks	AO element	Guidance
4			B ✓	1	2.1	



Question				Answer	Marks	AO element	Guidance
7				B ✓	1	1.2	



Question			Answer	Marks	AO element	Guidance
14			C ✓	1	2.1	



Question				Answer	Marks	AO element	Guidance
5				D ✓	1	2.1	



Question	Answer	Marks	AO element	Guidance
2	D	1	1.1	



Question	Answer	Marks	AO element	Guidance
12	D	1	2.1	



Question	Answer	Marks	AO element	Guidance
1	C	1	1.1	



Question	Answer	Marks	AO element	Guidance
12	D	1	1.1	



Question	Answer	Marks	AO element	Guidance
1	C	1	1.1	



Question	Answer	Marks	AO element	Guidance
3	C	1	1.1	



Question	Answer	Marks	AO element	Guidance
7	A	1	2.1	



Question	Answer	Marks	AO element	Guidance
6	B	1	2.1	



Question	Answer	Marks	AO element	Guidance
8	B	1	1.1	



22	(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	2×1.1	ALLOW atom becomes ionised / charged
	(b) (ii)	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	2×1.1	



16	(a)	(i)	Nucleus ✓	1	1.1	
		(ii)	Proton ✓ Neutron ✓	2	2 x 1.1	In either order
		(iii)	Electron ✓	1	1.1	
		(iv)	Neutral ✓	1	1.1	ALLOW 0 / no charge /AW
	(b)		Any two from: More/new information available ✓ More experiments completed ✓ New models/theories ✓ Better equipment / new technology ✓ Collaboration between scientists ✓ Peer-review ✓	2	2 x 1.2	



17	(a)	(i)	Any two from: The old model has no protons / ORA ✓ The old model has no neutrons / ORA ✓ There is no nucleus in the old model / ORA ✓ The electrons are in fixed positions in the old model / ORA ✓ The positive particles are in a nucleus in the current model ✓ The negative particles/electrons are outside / surround the nucleus in the current model ✓	2	2 x 1.1	
		(ii)	Any two from: new evidence ✓ more experiments completed ✓ previous model couldn't explain new observations ✓	2	2 x 1.1	ALLOW mention of Rutherford, Geiger/Marsden
	(b)	(i)	All points correctly plotted ✓ line of best fit drawn correctly ✓	2	2 x 1.2	± 0.5 small squares e.c.f. plotting errors
		(ii)	As the mass increases/goes up the density increases ✓ (Direct) proportionally ✓	2	2 x 3.1a	ORA Needs word 'proportion(al)' or equivalent e.g. density ÷ mass is same

16	(a)		Positively ✓ Negatively ✓ Neutrons ✓ Nucleus ✓	4	1.1 x 4	
	(b)	(i)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 997 (kg/m³) award 2 marks 9970 ÷ 10 ✓ = 997 (kg/m ³) ✓	2	2.1 2.1	
		(ii)	C B A	1	1.1	Correct order only
		(iii)	Any one from: C has more/the most particles (for the same volume) ✓ A has fewer/the least particles (for the same volume) ✓	1	1.1	ALLOW C has particles closest together/least spread out/most tightly packed ALLOW A has particles furthest apart/most spread out/least tightly packed ALLOW correct identification of C = solid, (B = liquid,) A = gas

22	(a)	(i)	$^{32}_{15}\text{P}$ ✓	1	2.1	Both numbers in the correct order needed for the mark.
		(ii)	Relative charge: (+) 16 ✓ Relative mass: (+) 32 ✓	2	2×2.1	ALLOW increases by 1 ALLOW stays the same
	(b)		(the) same (as B) ✓ less (than B) ✓	2	2×2.1	
	(c)	(i)	Gamma / beta ✓ As it is the <u>most/more</u> penetrating / can be detected outside the body / ORA for alpha ✓	2	2×1.2	Mark independently ALLOW this mark if alpha is chosen ALLOW (gamma/beta) passes through the body/skin (easily) ALLOW very/highly penetrating ALLOW least/less ionising ALLOW alpha and/or beta would be (mostly) absorbed by the body / gamma can leave body IGNORE ideas about effects on the body
		(ii)	(Idea that half-life is) long enough to allow the isotope to circulate around the body / ORA for ideas about half-life of 4 minutes ✓ (Idea that half-life is) short enough for less damage/harm (to patient's cells/body) / patient will not be contaminated/radioactive for a long time / ORA for ideas about half-life of 18 days ✓	2	$2 \times 3.2a$	ALLOW long enough to get results/information / take observations / explore organs / get to the patient from the lab ALLOW (idea that) four minutes is not long enough to take observations / look at patients / do experiments with / for it to work IGNORE it can be used for a long time ALLOW (idea that) 18 days is too harmful / too long for patient to be contaminated/radioactive IGNORE it won't emit too much radiation / it is dangerous

18	(a)	✓✓	2	2 × 1.1	ALLOW 1 mark for 1 or 2 correct
	(b)	Any one from: More/new information ✓ Peer review/Checks from other scientists ✓	1	3.1b	ALLOW technology advances / make the model more accurate / better equipment / correcting mistakes in the model / have a better model / have more knowledge / scientific research gets better / older models have limitations or a new theory
	(c)	A ✓ B ✓	2	2 × 1.1	
	(d)	positively charged ✓ negatively charged ✓	2	2 × 1.1	
	(e)	First check the answer on the answer line If answer = 5×10^{-9} (m) award 2 marks Length = $50 \times 1 \times 10^{-10}$ ✓ Length = 5×10^{-9} (m) ✓	2	2 × 2.1	ALLOW 0.000 000 005 / 50×10^{-10} / 0.5×10^{-8} etc.

18	(a)	Similarity: (same) number of protons Difference: (different) number of neutrons	2	2 × 1.1	ALLOW same number of electrons ALLOW carbon-12 has 6 protons ALLOW atomic number DO NOT ALLOW same number of neutrons for carbon-12 ALLOW mass number ALLOW different number of nucleons ALLOW carbon-12 has 6 neutrons DO NOT ALLOW different number of protons for carbon-12 or different number of protons and neutrons (unclear as to meaning)
	(b)	Mass: stays the same / unchanged ✓ Charge: increases ✓	2	2 × 1.1	IGNORE 14 ALLOW +1
	(c)	(i)	2	1.1 2.1	ALLOW radiation for <u>beta</u> particles IGNORE particles unqualified / "it" ALLOW metal / container absorbs <u>beta</u> particles / radiation
		(ii)	1	2.1	DO NOT ALLOW beta particles / radiation coming into contact (with technicians) ✓
		(iii)	2	2 × 1.1	ALLOW any recognisable spelling of Geiger-muller ALLOW Geiger counter for two marks

17	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	2 x 1.2	ALLOW behind (lead) screen IGNORE gloves/goggles ALLOW lead box
	b	i	(Source) A ✓ (Source) A because (idea that) count rate unaffected by paper and aluminium OR only lead reduces / stops gamma ✓	2	3.2a 2.1	ALLOW cannot travel through lead
		ii	(Source) B ✓ (Source) B because count rate is reduced by paper ✓	2	3.2a 2.1	
		iii	(Source) D ✓ (Source) D because (idea that) count rate decreases after aluminium (beta) <u>and</u> after lead (gamma) ✓	2	3.2a 2.1	ALLOW not absorbed by paper
	c		Any two from: Radioactive decay is random ✓ Variations are more pronounced at low count rates ✓ Background radiation ✓	2	2 x 3.1a	

Question	Answer	Marks	AO element	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	2 x 3.3b	ALLOW more radiation detected ALLOW idea of smoothing out variations ALLOW more reliable IGNORE accurate

19	(a)	Mass number No. of protons No. of neutrons 94 144 238 ✓ ✓	2	2 × 1.1	1 mark for one correct connection
	(b)	(i) (Mode =) 227 (GBq) ✓	1	1.2	
		(ii) (mass number of alpha =) 4 ✓ (atomic number of U =) 92 ✓	2	2 × 2.1	
		(iii) Either: Yes AND alpha is less penetrating / more easily absorbed (than beta) / ORA ✓ So, cannot get into the body / get through the skin (so less likely to damage cells) ORA ✓ Or: No AND alpha is more ionising than beta ✓ So can cause more damage to cells (if inside the body) ✓	2	2 × 3.1b	
	(c)	Any two from: They have some of the radioactive source on them ✓ So, they are (still) being irradiated (AW) ✓ So, their cells could (continue to) be damaged ✓	2	2 × 2.1	

Question		Answer	Marks	AO element	Guidance
(d)	(i)	820 (grams) ✓	1	2.2	ALLOW 810-830
	(ii)	Any two from: Neptune is far away / the furthest planet from the Sun / it would take a long time to get to Neptune ✓ (So) electricity needs to be generated for a long time / power source needs to last a long time ✓ Pu-238 would still be generating (lots of) power/half-life is (much) longer than the time to get to Neptune ✓	2	2 × 3.1b	ALLOW batteries would have run out / Solar panels would not get enough sunlight

23	(a)	Contaminated because radioactive material touched the workers / was breathed in ✓ Irradiated because workers were exposed to radiation (from outside of the body) ✓	2	2 × 1.1	ALLOW it is in contact with (workers) / went on/inside them DO NOT ALLOW answers which also include ideas about irradiation e.g. radiation touches the workers/is inhaled ALLOW in presence of radiation/radiation passes into body DO NOT ALLOW answers which also include ideas about contamination
	(b)	Nuclear ✓ → Thermal ✓ → Kinetic ✓	3	3 × 2.1	IGNORE heat
	(c) (i)	(It takes) 30 years / (average) time taken for number of (un-decayed or unstable) nuclei to halve / for activity to halve / for count rate to halve / for mass of undecayed nuclei to halve ✓	1	1.1	ALLOW atoms for nuclei ALLOW mass (of it/caesium) to halve / half of it/substance to decay IGNORE reactivity / time taken for a nucleus to halve
	(ii)	Radioactive decay is a random process. ☒ When a nucleus decays, it splits in half. ☐ With large numbers, it is easier to count half of the nuclei. ☐ ✓	1	1.1	
	(iii)	First check the answer on the answer line If answer = 3.5 (kg) award 2 marks (idea that 90 years ⇒ 3 (half-lives) ✓ (mass = $28 \times (\frac{1}{2})^3 = 3.5$ (kg) ✓	2	2 × 2.2	ALLOW evidence of 3 half-lives e.g. $28 \rightarrow 14 \rightarrow 7 \rightarrow 3.5$
23	(d)	$\begin{array}{c} {}^{238}_{94}\text{Pu} \rightarrow {}^{234}_{92}\text{U} + {}^4_2\text{He} \\ {}^9_4\text{Be} + {}^4_2\text{He} \rightarrow {}^{12}_6\text{C} + {}^1_0\text{n} \end{array}$ Correct mass for U ✓ Correct atomic number for U ✓ Correct mass and atomic number for n ✓	3	3 × 2.2	

23	(a)		25(g) ✓	1	1.2	
	(b)	(i)	C ✓	1	2.2	ALLOW answer from diagram if clear
		(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 OR A ✓ B has a higher activity at the beginning OR A ✓ A has a longer half-life / B has a shorter half-life ✓	4	4×3.1b	
		(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	2×2.2 2×1.2	May be described or drawn in a diagram ALLOW stopped / absorbed for drop in count rate

Question			Answer	Marks	AO element	Guidance
	(c)	(i)	Nuclei join (in fusion) ✓	1	1.1	ALLOW fuse / combine
		(ii)	Any two from: High temperature ✓ High pressure ✓ Large gravitational forces (due to large mass) ✓	2	2×2.1	IGNORE heat
		(iii)	The sun will expand / become a red giant / (ultimately) become a white dwarf ✓	1	1.1	ALLOW fusion of helium / heavier elements
	(d)		Any one from: supplies of uranium are large enough / will not run out to consider it renewable / AW ✓ Uranium is not being replaced / used quicker than it is being replaced to consider it non-renewable	1	2.1	



18	(a)	(i)	27 ✓	1	1.1	
		(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	2 × 1.1	ALLOW Co-57 has 27 neutrons 0
	(b)	(i)	Radioactivity is a random process ✓	1	1.1	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	2 × 1.2	
		(iii)	The count-rate stays the same ✓	1	2.1	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	1.1	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	2 × 2.1	
	(d)	(i)	So (most of) the radioactivity / gamma rays are absorbed by the lead/do not get to the doctor. ✓ So the doctor is not irradiated/to prevent the doctor's cells being damaged. ✓	2	2 × 1.1	ALLOW will absorb alpha and beta radiation ALLOW to stop the doctor getting cancer

Question			Answer	Marks	AO element	Guidance
18	(d)	(ii)	Iodine-131 ✓ Gamma can pass through the body to the detector / alpha cannot pass through the body. ✓ Use a short half-life so patient's cells are less damaged. ✓	3	3.2 2.2 2.2	ALLOW this mark if Cobalt-60 or Iodine-131 is chosen ALLOW this mark if Radon-222 or Iodine-131 is chosen. 1

Question			Answer	Marks	AO element	Guidance
10			B ✓	1	1.1	



Question	Answer	Marks	AO element	Guidance
8	D	1	1.1	



21	(a)	(i)	Handle the radioactive isotope using tongs. ☐ Move the radioactive isotope further away from the detector. ☐ Place lead in front of the radioactive isotope. ☐ Zero the counter and take another reading. ☒ ✓	1	3.3b	
		(ii)	8 (counts per second) ✓	1	1.2	ALLOW 7.9(1) (candidate has subtracted 5 from activity in cpm)
	(b)	(i)	activity decreases quickly / little radiation emitted after a few half-lives / doesn't stay radioactive for too long / does not emit radiation for too long ✓ Less damage to tissue / organs / cells ✓	2	2 × 1.2	DO NOT ALLOW no radioactivity after 64 hours IGNORE side effects unqualified
		(ii)	Any two from: (some) side-effects are temporary AW ✓ (idea that) benefits outweigh the risks AW ✓ other (radioactive) isotopes have more harmful side-effects ✓ other (radioactive) isotopes have longer half-lives ✓	2	2 × 3.2a	IGNORE reference to short half-life without qualification

23	(a)	(i)	(Idea that half-life is short enough) so water/surroundings don't remain radioactive for too long ✓ (Idea that half-life is long enough) to allow repeat readings / for examination to take place ✓	2	2 × 3.1b	ALLOW so it doesn't contaminate/irradiate/emit radiation/stay unstable for too long IGNORE less damage/harm ALLOW (idea that) it stays in pipe long enough to detect the leak / enough time to be detected / enough time to reach leak IGNORE it lasts for a long time / long enough to be used/useful
		(ii)	(Tracer/radiation/beta/gamma) can be detected above earth/ground ✓	1	1.2	ALLOW beta/gamma can penetrate/pass through/get through the ground/earth IGNORE beta/gamma are very penetrating IGNORE ideas about alpha
		(iii)	(Stable isotope) does not emit (ionising) radiation / ORA ✓	1	3.2b	ALLOW (stable isotope) is not radioactive / does not contaminate/irradiate/decay / ORA IGNORE so it is no longer dangerous / so it becomes safe
	(b)		Any two from: Tracer is added to pipe/water / detector is moved along the surface of the ground ✓ Reading (on the detector) will increase (above the leak) ✓ (Reading on the detector will increase when the detector is) above/around the leak ✓	2	2 × 2.2	ALLOW detector is placed above the ground/pipe ALLOW more radiation is detected (above the leak) ALLOW (more radiation is detected) above/around the leak
	(c)		First check the answer on answer line If answer = 3 (mg) award 2 marks (30 ÷ 15 =) 2 (half-lives) ✓ (Mass remaining = 12 × (0.5) ² = 3 (mg) ✓	2	2.1 2.1	ALLOW any indication of two halvings shown, e.g., of 24 or 15

21	(a)	First check the answer on the answer line If answer = 3.1×10^{19} award 3 marks unit conversion: $1.0\text{GW} = 1 \times 10^9 \text{ W}$ ✓ substitute: (number =) $1.0(\times 10^9) \div 3.2 (\times 10^{-11})$ ✓ evaluation: $3.1(25) \times 10^{19}$ ✓	3	1.2 2.1 2.1	ALLOW $3.1(25) \times 10^n$ for 2 marks (missing or incorrect conversion)
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Question		Answer	Marks	AO element	Guidance
21	(b)*	Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) A detailed description of differences between fission and fusion reactions AND a detailed description of the benefits of fusion. <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) A clear description of differences between fission and fusion reactions AND a clear description of the benefits of fusion. OR A detailed description of differences between fission and fusion reactions AND a basic description of the benefits of fusion. OR A basic description of differences between fission and fusion reactions AND a detailed description of the benefits of fusion. <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) A basic description of a difference between fission and fusion reactions OR a basic description of the benefits of fusion.	6	2 × 1.1 2 × 3.1a 2 × 3.2b	AO1.1– Demonstrate knowledge and understanding of difference between fission and fusion reactions - fission is splitting (of nucleus) - fusion is combining two (nuclei) - fission is (splitting) large nucleus - fusion is (combining) small nuclei AO3.1a– Analyse information from the table and interpret and make a comparison - fusion power station will (likely) output more power ORA - fission fuel is mined - fission fuel is non-renewable - fusion fuel is available from water. - fission waste products are more radioactive ORA. - fission waste products have a longer half-life ORA. AO3.2b– Analyse information from the table and interpret to draw conclusions (fusion power station will (likely) output more power ORA) so fewer needed / can be smaller / don't need to use other resources (fission fuel is mined), which damages the environment, (fusion fuel extracted from water) is readily available (fission waste products are more radioactive), which makes them more dangerous (Fission waste products have a longer half life) so they stay dangerous for longer

Question		Answer	Marks	AO element	Guidance
		<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 <i>No response or no response worthy of credit.</i>			

