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OCR GCSE PHYSICS A (J249): QUESTIONS BY TOPIC

Topic P6: Radioactivity (H)

GCSE Physics A Higher Tier (J249) · Topic P6

28 questions · 131 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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QUESTIONS

28 questions · 131 marks · grouped by sub-topic, lowest tariff first



SUB-TOPIC P6.1

RADIOACTIVE EMISSIONS

20 questions in this sub-topic · 111 marks · lowest tariff first



1 The atomic model has changed over time.

Why did the model need to change over time?

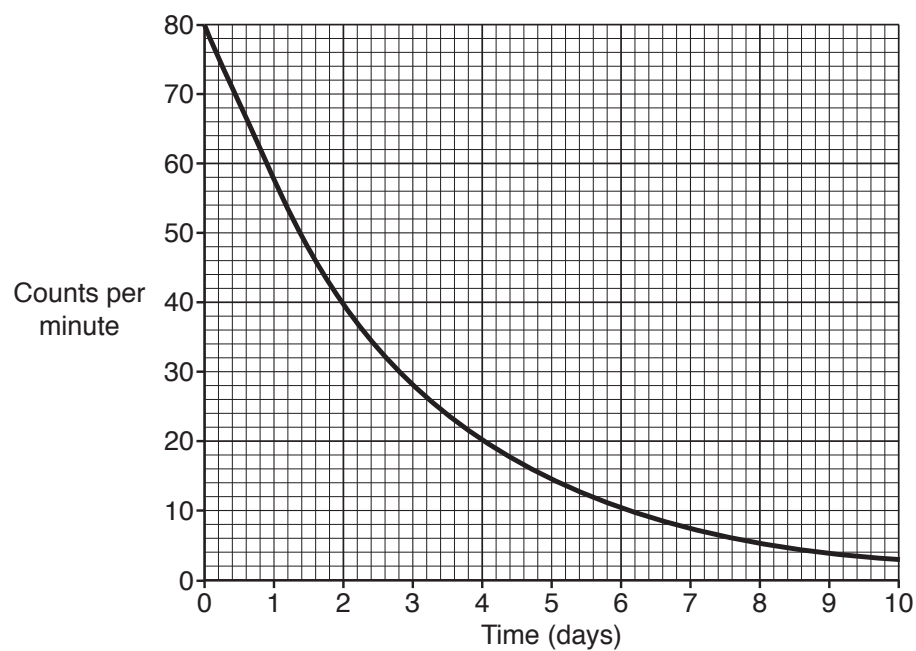
- A** Models only have a finite lifetime
- B** Computers were invented
- C** The older models could not explain new evidence
- D** Peer review

Your answer

[1]



- 5 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]

6 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]



8 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

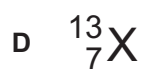
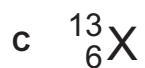
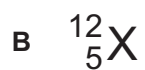
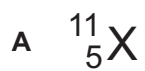
[1]



- 1 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]

- 11 A teacher measures the activity of a radioactive source. They place different materials between the radioactive source and detector.

The results are shown in the table:

Material	Activity (counts per minute)
Air only	325
Sheet of paper	337
Aluminium, 5 mm thick	26
Lead, 15 mm thick	24

Which type of radiation is emitted by the radioactive source?

- A Alpha and beta particles only
- B Alpha particles only
- C Beta particles only
- D Gamma rays and beta particles only

Your answer

[1]



- 4 A radioactive source has a count-rate of 64 counts per minute (cpm).
The half-life of the radioactive source is 10 minutes.

What is the count-rate of the radioactive source after 20 minutes?

- A 8 cpm
- B 16 cpm
- C 32 cpm
- D 48 cpm

Your answer

[1]



6 A scientist wants to publish a new theory.

Which step should the scientist take before publishing the theory?

- A** Check the new theory with a friend.
- B** Have the new theory peer reviewed.
- C** Keep the new theory secret to avoid others copying.
- D** Publish the new theory in a local magazine.

Your answer

[1]



5 Which sentence about an atom is correct?

- A** Most of the mass is in the nucleus.
- B** The nuclear radius is much larger than the rest of the atom.
- C** The nucleus has a neutral charge.
- D** The nucleus is surrounded by positively charged electrons.

Your answer

[1]



11 Which row describes how a nucleus of an atom changes when a beta particle is emitted?

	Number of neutrons	Number of protons	Total number of protons and neutrons
A	decreases	increases	changes
B	decreases	increases	stays the same
C	increases	decreases	changes
D	increases	decreases	stays the same

Your answer

[1]



23 A teacher measures the activity of different radioactive isotopes.

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

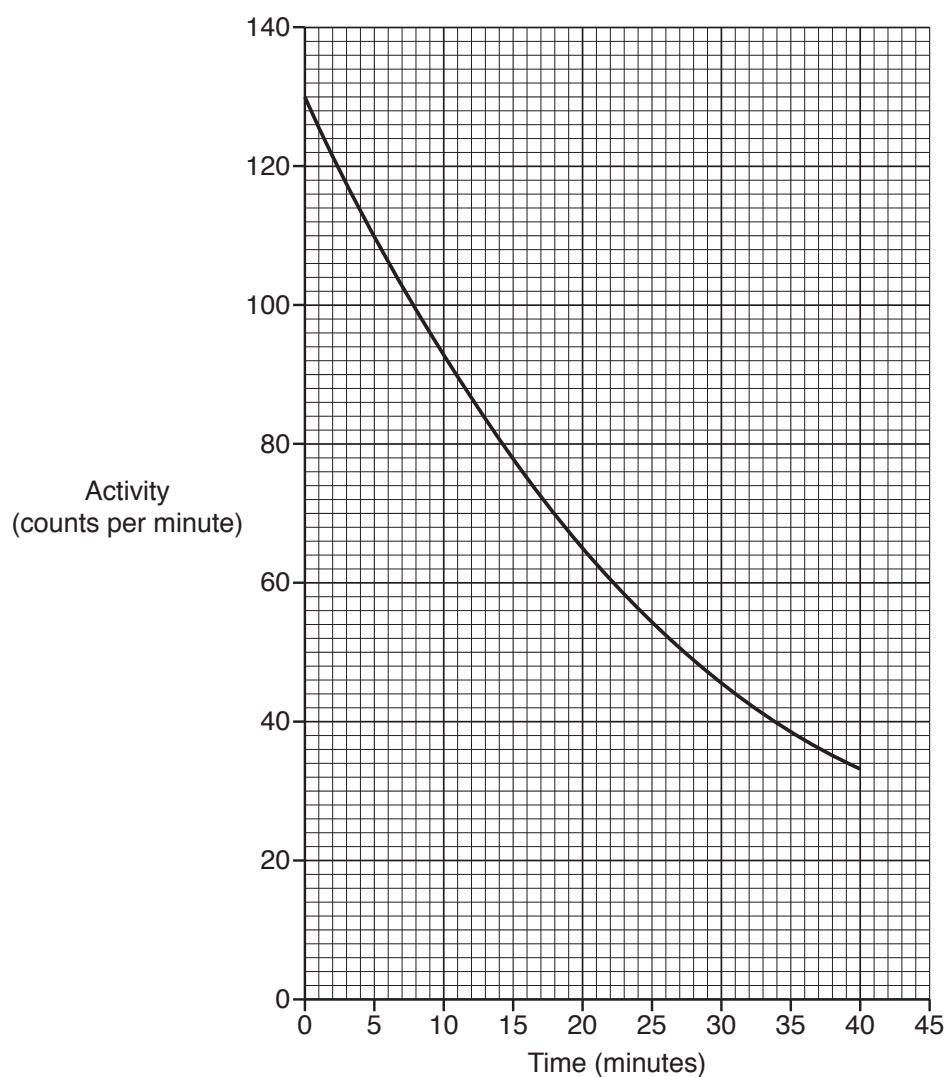


Fig. 23.1

(a) 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.

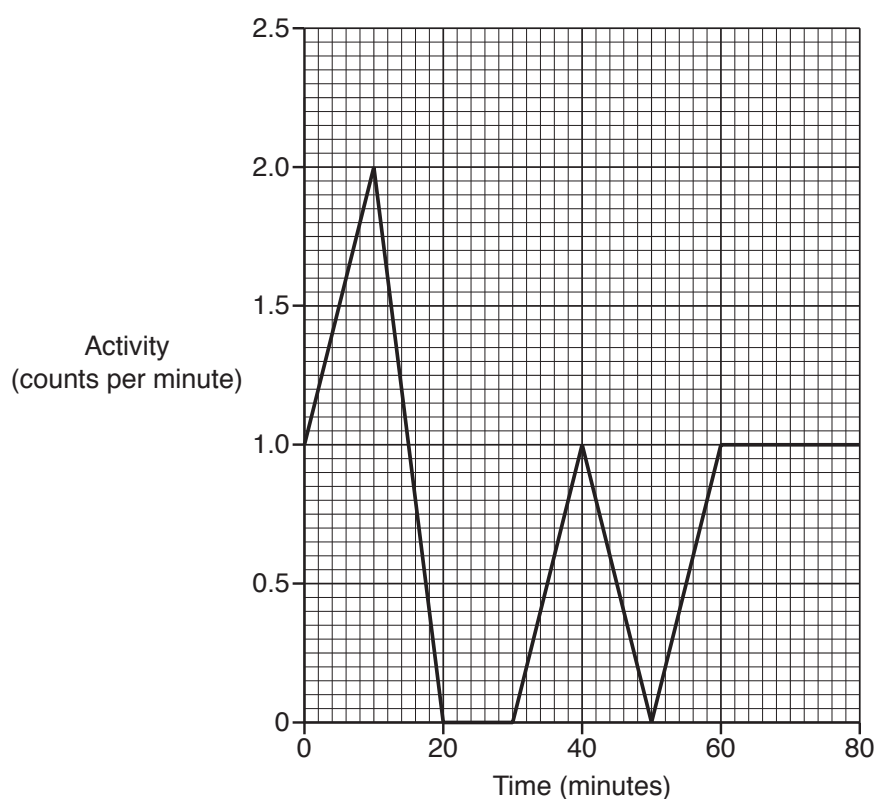


Fig. 23.2

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

.....

.....

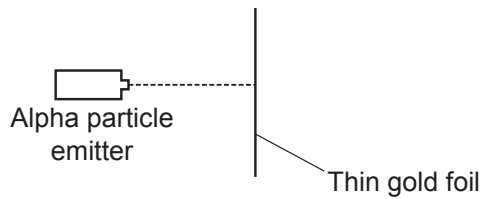
Conclusion 2

.....

..... [2]

- 19 (a)** Between 1908 and 1913, two scientists did experiments to help understand the structure of atoms.

The diagram shows how the scientists fired alpha particles at a thin piece of gold foil and detected what happened to these particles.



- (i)** The scientists detected that a very small number of particles reflected directly back, some particles were deflected, and most particles passed straight through the foil.

Describe the model of the atom following these observations.

.....

.....

.....

.....

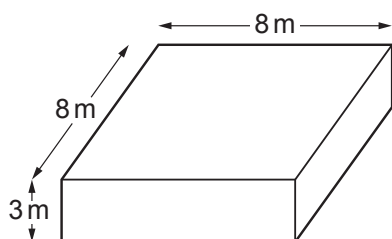
..... **[3]**

- (ii)** Explain why the previous model of the atom needed to change after this experiment.

.....

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

- (b) A classroom contains air particles. A drawing of the classroom is shown in the diagram.



- (i) Calculate the volume of the classroom.

Volume = ... m^3 [1]

- (ii) The density of air is 0.012 kg/m^3 .
Calculate the mass of air in the classroom.

Use the equation: density = mass/volume

Mass = ... kg [3]

18 The atomic model has changed over time.

Three scientists who contributed to the atomic model are Thomson, Rutherford and Bohr.

(a)

(i) Which of these scientists discovered a particle called an electron?

..... [1]

(ii) Which of these scientists developed the Plum Pudding model of the atom?

..... [1]

(iii) Which of these scientists suggested that electrons can only move in fixed orbits called electron shells?

..... [1]

(b) One of these three scientists did an experiment where alpha particles were fired at a thin piece of gold foil.

Two important observations were recorded.

What did the scientist conclude about the atom from these observations?

Observation 1: Most alpha particles passed through the gold foil.

Conclusion:

.....

Observation 2: Some of the alpha particles were deflected.

Conclusion:

.....

[3]

(c) A typical atom has a **radius** of 1.0×10^{-10} m.

A molecule consists of 20 of these atoms in a long line.

Calculate the length of this molecule.

Write your answer in **standard form**.

Length = ... m [2]

TURN OVER



18 This question is about radioactive Plutonium-238 (Pu-238).

(a) Pu-238 can be used to produce electricity:

- The Pu-238 undergoes radioactive decay.
- This causes the temperature of the plutonium to increase.
- Electricity is produced.

Complete the sentences using the words below.

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

chemical elastic potential electrostatic

gravitational potential nuclear thermal

The energy store of the plutonium decreases.

The energy store of the plutonium increases.

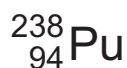
[1]

(b) (i) State why Pu-238 undergoes radioactive decay.

.....

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

(ii) A Pu-238 nucleus emits an alpha particle.



Determine the value of the mass of the nucleus **and** the number of protons **after** Pu-238 emits an alpha particle.

Mass of the nucleus

Number of protons

[2]



(c) Fig. 18.1 shows how the activity of Pu-238 changes with time.

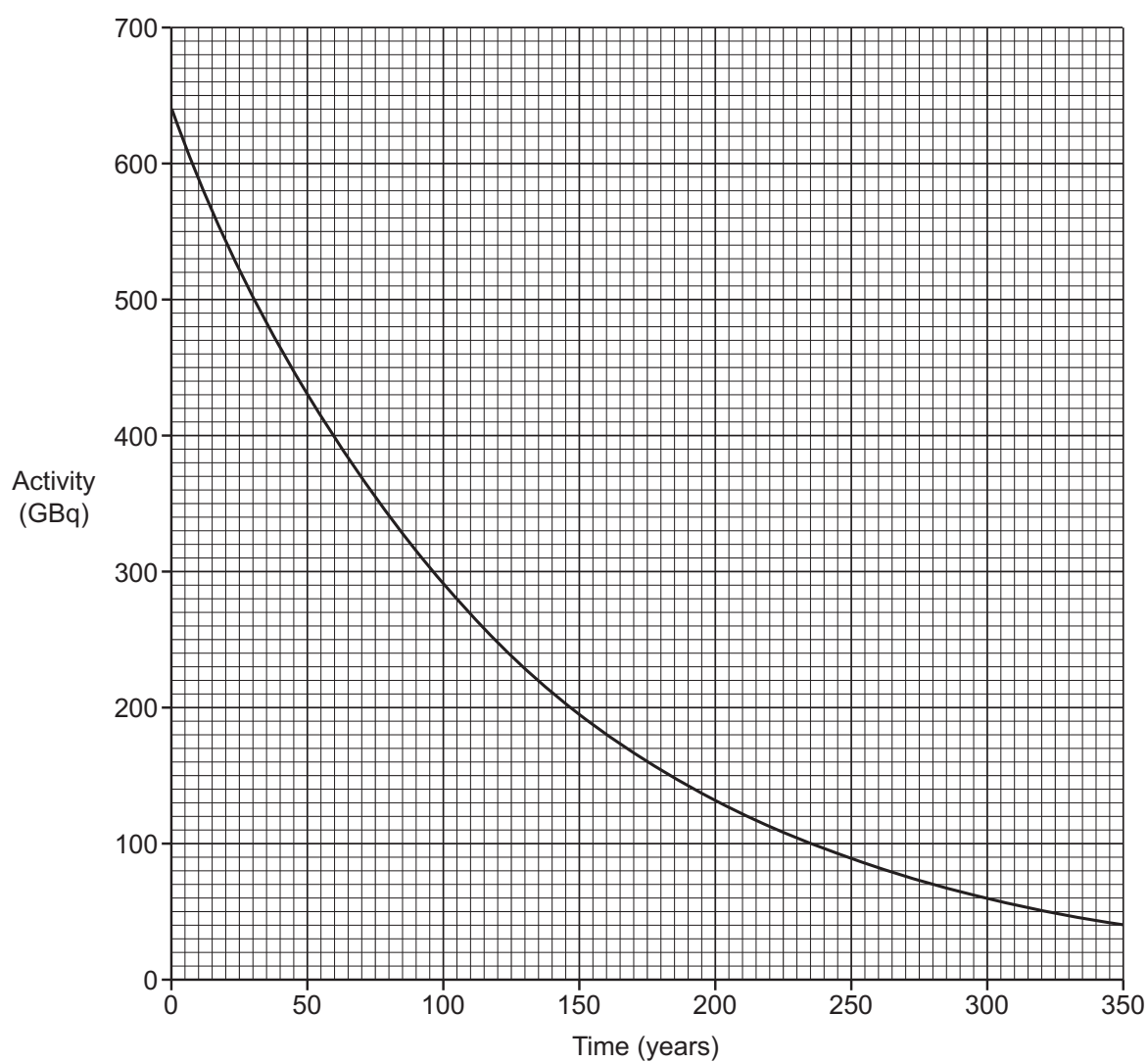


Fig. 18.1

Use Fig. 18.1 to find the half-life for Pu-238.

Show your working on the graph.

Half-life = ... years [2]



- (d) (i) A different isotope of plutonium is used in nuclear **fission**.

Describe how a chain reaction occurs in nuclear **fission**.

.....

.....

.....

..... [2]

- (ii) Nuclear **fusion** occurs in the Sun.

Describe what is meant by nuclear **fusion**.

.....

..... [1]

17 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.

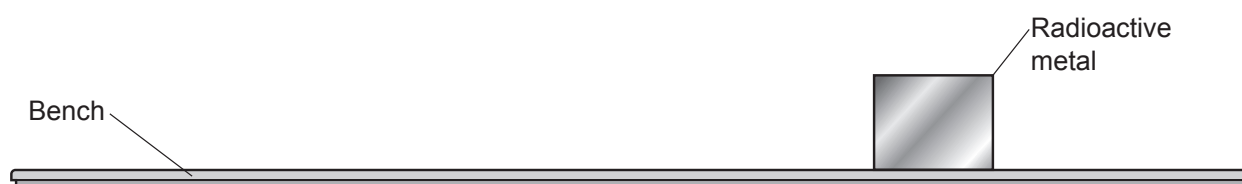
1
.....
2
.....

[2]



20 A technician investigates an unknown radioactive metal as shown in **Fig. 20.1**.

Fig. 20.1



- (a)**
(i) Describe how the technician obtains a precise measurement of the count rate from the radioactive metal.

Include the name of any extra equipment the technician uses.

You may draw on **Fig. 20.1**.

.....

.....

.....

.....

..... **[3]**

- (ii)** Explain how the technician shows that the radioactive metal emits **only** gamma radiation.

Include the name of any extra equipment the technician uses.

.....

.....

.....

.....

..... **[3]**

- (b) The technician thinks that the radioactive metal is one of the four metals shown in **Table 20.1**.

Table 20.1

Metal	Nuclear radiation emitted	Half-life
A	gamma	4 hours
B	gamma	10 years
C	gamma	2 years
D	gamma	28 days

- (i) The technician uses equal masses of each metal in **Table 20.1**.

Explain which metal in **Table 20.1** is likely to be the most hazardous to the technician while doing the experiment.

Metal

Explanation

..... [2]

- (ii) Metal **D** is considered to be safe when the count rate drops to $\frac{1}{32}$ of the original count rate.

Calculate the time required for metal **D** to be safe.

Time required = ... days [3]



20 Americium-241 is a radioactive source that is used in smoke detectors.

(a) 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.



(c) When smoke enters a detector:

- The smoke particles absorb the emitted alpha radiation.
- The alarm sounds.

Explain why beta and gamma sources are **not** suitable for use in a smoke detector.

.....
 [1]

(d) 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]

(e) 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 m^3 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]

18 (a) Polonium-210 is a radioactive material which emits alpha particles.

(i) Complete **Table 18.1** to show the composition of an **alpha particle**.

Table 18.1

Number of protons	
Number of neutrons	
Number of electrons	

[2]

(ii) A person swallows a small amount of polonium-210. Doctors examine the person using a Geiger-Müller tube outside the body.

Explain why the doctors do **not** detect the polonium-210 inside the body.

.....
 [1]

(b) Polonium-210, $^{210}_{84}\text{Po}$, can be made in a nuclear reactor in two steps.

(i) In the first step, bismuth-209, $^{209}_{83}\text{Bi}$ is bombarded with neutrons to make $^{210}_{83}\text{Bi}$.

State the name given to these different forms of the element bismuth.

..... [1]

(ii) In the second step, $^{210}_{83}\text{Bi}$ decays to form $^{210}_{84}\text{Po}$.

Complete the **balanced nuclear** equation for this decay.



[2]

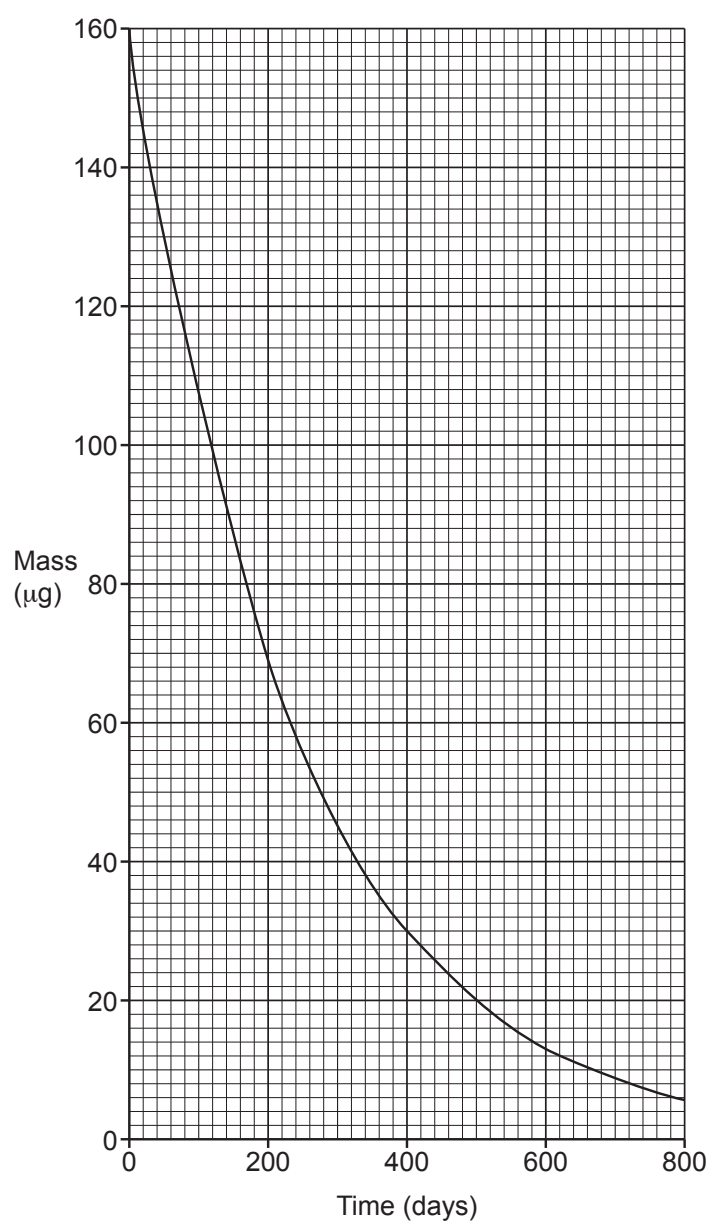
(c) 1 µg of polonium-210 is enough to kill a human being.
 210g of polonium-210 has an activity of $3.57 \times 10^{16}\text{Bq}$.

Calculate the activity of a sample of 1 µg of polonium-210.

Give your answer in **standard form**.



(d) The graph shows how the mass of a sample of polonium-210 changes with time.



- (i) Use the graph to complete **Table 18.2**. Two answers have been filled in for you.

Table 18.2

Time (days)	Mass (μg)
0	160
200	
400	30
600	

[1]

- (ii) A teacher explains half-life and radioactive decay to their class.

The teacher says,
‘For equal time periods, the ratio:

$$\frac{\text{mass at the start of the time period}}{\text{mass at the end of that time period}}$$

is constant.’

Use this ratio and your answers in **Table 18.2** to determine if the teacher is correct for the sample of polonium-210.

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



- 17** 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

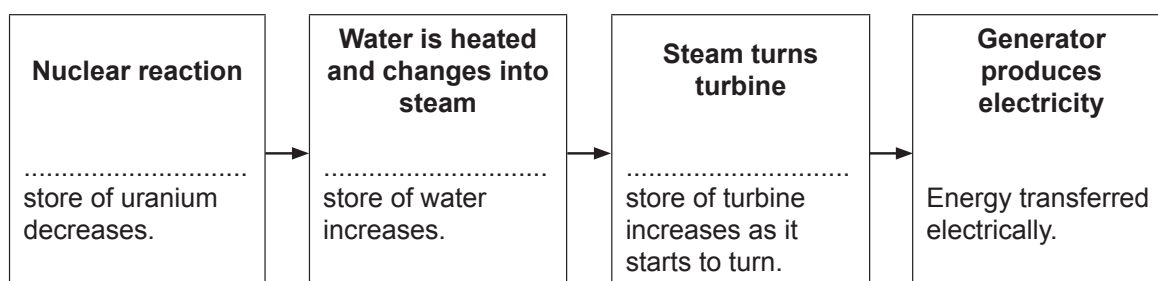
.....

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?

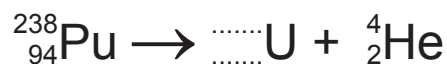
Mass = ... kg [2]

- (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]



- 19** Nuclear radiation, such as gamma, is used to irradiate some fresh food to increase its 'shelf-life' and make it last longer.

Fresh herbs and spices are dried and irradiated with gamma rays.

- (a)** Explain the difference between nuclear **irradiation** and nuclear **contamination**.

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

- (b)** Explain how the gamma rays can increase the 'shelf-life' of herbs and spices to make them last longer.

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

- (c)** Some people are worried about eating irradiated food.

Write down two **concerns** they may have about irradiated food.

1.
.....
2.
..... [2]

- (d)** 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]



(e) 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.



SUB-TOPIC P6.2

USES AND HAZARDS

8 questions in this sub-topic · 20 marks · lowest tariff first



4 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]



- 5 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]

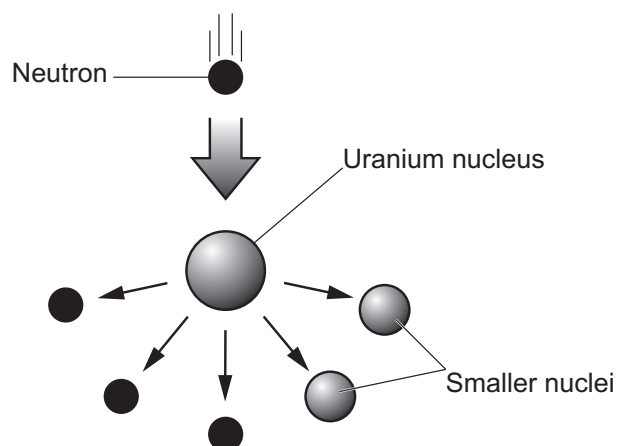


12 A student models nuclear fission using this process:

Step 1

- A uranium nucleus absorbs one neutron.
- The uranium nucleus splits releasing **three** neutrons.

The diagram shows what happens in **step 1** of this process.



The three neutrons can each repeat this process again for step 2 and step 3. How many neutrons will be released after step 3?

- A 6
- B 9
- C 18
- D 27

Your answer

[1]

3 A radioactive element emits gamma rays.

A teacher accidentally spills some of the radioactive element on their hands.

Which sentence describes what happens to the teacher?

- A** They are contaminated and irradiated.
- B** They are contaminated only.
- C** They are irradiated only.
- D** They are not contaminated and not irradiated.

Your answer

[1]



- 4 A scientist is doing an experiment using a radioactive source that emits only gamma rays.

Which safety procedure does **not** reduce irradiation of the scientist?

- A The scientist places a lead shield between themselves and the source.
- B The scientist points the source away from them.
- C The scientist uses very long tongs to handle the source.
- D The scientist wears gloves while handling the source.

Your answer

[1]



14 The energy released from the fission of a single uranium-235 nucleus is $3.2 \times 10^{-11} \text{ J}$.

A uranium-235 nucleus splits and releases 3 neutrons, causing a chain reaction.

These neutrons are absorbed by 3 further uranium-235 nuclei causing these nuclei to split.

What is the total energy released?

A $6.4 \times 10^{-11} \text{ J}$

B $9.6 \times 10^{-11} \text{ J}$

C $1.3 \times 10^{-10} \text{ J}$

D $2.9 \times 10^{-10} \text{ J}$

Your answer

[1]



19 (a) Nuclear **fusion** is a reaction that happens in stars. This equation for fusion is incomplete.



(i) What else is produced in this reaction?

.....
 [1]

(ii) Stars are formed from dust and gas.

What causes the dust and gas to undergo fusion?

.....
 [1]

(b) (i) Describe one **similarity** between nuclear fission and nuclear fusion.

.....
 [1]

(ii) Describe one **difference** between nuclear fission and nuclear fusion.

.....
 [1]

(c) Nuclear fission can be used as a power source to produce electricity.

Give one **advantage** and one **disadvantage** of using nuclear power to produce electricity.

advantage.....

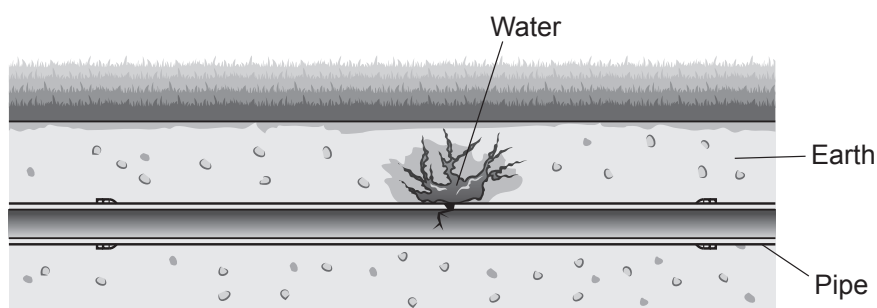
.....

disadvantage

.....

[2]

- 17 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]



MARK SCHEMES

official Pearson Edexcel mark schemes



Question				Answer	Marks	AO element	Guidance
1				C ✓	1	1.1	



Question				Answer	Marks	AO element	Guidance
5				B ✓	1	1.2	



Question				Answer	Marks	AO element	Guidance
6				B ✓	1	1.1	



Question				Answer	Marks	AO element	Guidance
8				B ✓	1	1.1	



Question			Answer	Marks	AO element	Guidance
1			C ✓	1	2.1	



Question			Answer	Marks	AO element	Guidance
11			C ✓	1	2.2	



Question				Answer	Marks	AO element	Guidance
4				B ✓	1	2.1	



Question	Answer	Marks	AO element	Guidance
6	B	1	1.1	



Question	Answer	Marks	AO element	Guidance
5	A	1	1.1	



Question	Answer	Marks	AO element	Guidance
11	B	1	1.1	



23	(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) ✓	2	2×2.2	ALLOW 19-21 (minutes) ✓✓
	(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) ✓✓	2	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 ✓
	(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 ✓	2	2×3.1b	ALLOW correct answers referring to background radiation/readings

19	(a)	(i)	Any three from: small / tiny nucleus ✓ positively charged nucleus ✓ mass is concentrated in the nucleus ✓ most of atom is empty space ✓	3	3 x 1.1	IGNORE reference to electrons ALLOW maximum 2 marks for implying nucleus but not stating nucleus ALLOW atom has empty space
		(ii)	Previous models could not explain new observations / new evidence disproves old model / AW ✓	1	1.2	ALLOW (idea of) previous/plum pudding/Thomson's model did not fit with these observations ALLOW shows there is a nucleus / empty space IGNORE reference to neutrons (1932)
	(b)	(i)	$(3 \times 8 \times 8 =) 192 \text{ (m}^3\text{)} \checkmark$	1	2.1	
		(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 2.3 / 2.30 / 2.304 award 3 marks mass = density x volume ✓ $0.012 \times 192 \checkmark$ $2.3 / 2.30 / 2.304 \text{ (kg)} \checkmark$	3	1.2 2.1 2.1	Possible ECF from 19(b)(i) Correct re-arrangement Correct substitution

18	(a)	(i)	Thomson ✓	1	1.1	
		(ii)	Thomson ✓	1	1.1	
		(iii)	Bohr ✓	1	1.1	
	(b)		1. (Most of the) <u>atom</u> is empty space / AW ✓ 2. Positively charged ✓ Nucleus ✓	3	3 × 1.1	ALLOW nucleus very small If no marks awarded, allow any correct answer in the wrong place for one mark maximum
	(c)		First check the answer on the answer line If answer = 4.0×10^{-9} (m) award 2 marks Molecule length = $2 \times 1.0 \times 10^{-10} \times 20$ ✓ Molecule length = $4(.0) \times 10^{-9}$ (m) ✓	2	2.1 2.1	ALLOW 2.0×10^{-9} (radius not doubled to diameter) for 1 mark ALLOW 0.000000004 / 40×10^{-10} for 1 mark

18	(a)	Nuclear Thermal ✓	1	2.1	BOTH required DO NOT ALLOW more than one energy store on each answer line
	(b)	(i) Any one from: The nucleus is unstable / to make the nucleus more stable ✓ So the energy of the nucleus reduces / to get rid of energy from the nucleus ✓	1	1.1	IGNORE because it is radioactive (already in the stem)
		(ii) $^{234}_{92}$ ✓	2	2×1.1	
	(c)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 85-90 (years) award 2 marks Evidence on graph (or elsewhere) of half of activity indicated ✓ Half-life = 85-90 (years) ✓	2	2×2.2	
	(d)	(i) (when neutron is absorbed, nucleus splits and) releases more / several / (>1) <u>neutrons</u> ✓ Each (additional) neutron can be absorbed by another (plutonium) nucleus ✓	2	2×1.1	IGNORE nucleus releases another neutron. ALLOW a suitable diagram for two marks. IGNORE atom/plutonium for nucleus IGNORE hits nucleus
		(ii) Two <u>nuclei</u> combine (at very high temperature) ✓	1	1.1	



17	(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/travels 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 / to be detected 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



20	(a)	(i)	Use a (radiation) detector (and counter) / GM tube (close to the metal) ✓ (Idea of) measure number of counts over a certain time and divide number of counts by the time used ✓ Repeat the measurement multiple times and calculate an average count (rate) ✓	3	1.2 3.3a 3.3a	IGNORE ideas about background radiation ALLOW shown on a diagram ALLOW measure the number of counts in a minute IGNORE measure number of counts in 1 second
	(a)	(ii)	Place material that absorbs both alpha and beta, but not gamma, between source and detector (e.g. thin aluminium sheet) ✓ (Idea that) alpha and beta radiation cannot penetrate aluminium (but gamma radiation can) / only gamma can penetrate aluminium ✓ (Idea that) reading on detector is the same with the aluminium and without aluminium ✓	3	1 × 1.2 2 × 2.2	IGNORE references to paper ALLOW use of aluminium (sheet) If no other marks awarded: ALLOW 1 mark for only gamma radiation can pass through thin lead/concrete OR ALLOW 1 mark for idea that the reading on detector does not change over a long distance if only gamma radiation is emitted

Question			Answer	Marks	AO element	Guidance
20	(b)	(i)	(Metal) A (is most hazardous) ✓ (Shorter half-life means) higher activity / ORA ✓	2	1.1 3.1a	No mark for question if A not chosen ALLOW idea that (short half-life means) more radiation emitted per second/unit time/during time of experiment / higher count rate / ORA
		(ii)	First check the answer on the answer line If answer = 140 award 3 marks (1/32 =) 5 half-lives ✓ (time required =) 28 × 5 ✓ (time required =) 140 ✓	3	3 × 2.2	ALLOW evidence of halving something 5 times e.g. $1 \rightarrow \frac{1}{2} \rightarrow \frac{1}{4} \rightarrow \frac{1}{8} \rightarrow \frac{1}{16} \rightarrow \frac{1}{32}$



20	(a)	(The nucleus contains) 95 protons ✓ (and) 146 neutrons ✓	2	2 × 1.1	IGNORE references to electrons ALLOW the nucleus has a charge of (+) 95
	(b)	$^{237}_{93}\text{He}$ / α ✓	3	2 × 2.2 1 × 1.1	
	(c)	Beta and gamma would not be absorbed/stopped (by smoke) ✓	1	1.1	ALLOW beta and gamma would pass straight through / are too penetrating / penetrate further / less ionising
	(d) (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 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	2.1	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	2 × 3.2a	ALLOW thorium decays faster / ORA

Question	Answer	Marks	AO element	Guidance
(e)	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	2 × 3.2a	IGNORE vague answers such as 'bad for the environment' ALLOW gamma is not stopped by the foil

18	(a)	(i)	2 2 0	2	2 x 1.1	All 3 correct = 2 marks 2 correct = 1 mark
		(ii)	Alpha cannot penetrate body/skin OR alpha is absorbed by the body/skin ✓	1	1.2	ALLOW skin blocks alpha IGNORE alpha is highly ionising / not very penetrating
	(b)	(i)	Isotopes ✓	1	1.1	
		(ii)	e ✓ ${}^0_{-1}$ ✓	2	2 x 2.2	ALLOW β for e Both 0 as mass number and -1 as proton number required for the mark
	(c)		First check the answer on answer line If answer = 1.7×10^8 (Bq) award 3 marks (1 μg =) 1×10^{-6} g OR 0.000001 g ✓ (activity =) $3.57 \times 10^{16} \div (2.10 \times 10^8)$ Or $3.57 \times 10^{16} \times 10^{-6} \div 210$ Or 170 000 000 (Bq) ✓ (activity =) 1.7×10^8 (Bq) ✓	3	1.2 2.2 1.2	ALLOW 1 mark for 2.1×10^8 (μg) ALLOW 1 mark for $3.57 \times 10^{16} \div 2.10 \times 10^8$ OR $3.57 \times 10^{16} \times 10^{-6} \div 210$ OR 170..... i.e., in non standard form (where there is no/incorrect unit change) ALLOW 2 marks for 1.7×10^8 (no/incorrect unit change) ALLOW this mark for clear evidence of an incorrect answer written in standard form (not a bald incorrect answer written in standard form)
18	(d)	(i)	69, 13 ✓	1	2.2	BOTH needed for 1 mark ALLOW tolerance of +/- 1
		(ii)	Calculates any one correct ratio from the table ✓ BUT Calculates at least two correct ratios and states the values are approximately the same / the teacher is correct ✓ ✓	2	2 x 2.2	ALLOW ECF from (d)(i) e.g.: $M_0 \div M_{200}$ or $160 \div 69 = 2.32$ $M_{200} \div M_{400}$ or $69 \div 30 = 2.30$ $M_{400} \div M_{600}$ or $30 \div 13 = 2.31$ ALLOW ratios calculated over 400 days, e.g., $M_0 \div M_{400}$ or $160 \div 30 = 5.3$ and $M_{200} \div M_{600}$ or $69 \div 13 = 5.3$

17	(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 → 14 → 7 → 3.5
	(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	

19	a	Contamination occurs when radioactive source / material is on or in the body / object ✓ Irradiation occurs when object is exposed to radiation (from outside of the body / object) ✓	2	1.1 1.1	ALLOW material becomes radioactive / becomes a source of radiation
	b	Bacteria is killed / AW ✓ Slows food decay / AW ✓	2	2.2 2.2	ALLOW idea that food does not go mouldy / off / rot (so quickly) IGNORE just that food lasts longer / food does not go stale / food stays fresh
	c	May cause food to become radioactive ✓ May allow food (to be sold) which is old but looks fresh / AW ✓	2	2.2 2.2	ALLOW food becomes contaminated / risk of cancer / they are taking in radiation ALLOW food might taste different / strange / out of date food might be eaten IGNORE food is poisonous / just unsafe
	d	i (Radioactive nuclei) are unstable ✓	1	1.1	ALLOW (nuclei have) too many neutrons
		ii Different numbers of neutrons ✓	1	1.1	
	e	i ${}_{90}^{226}\text{Th}$ ✓	2	2.2	
		ii ${}_{-1}^0\beta$ ✓	2	2.2	
		iii ${}_{92}^{235}\text{U} \rightarrow \gamma + {}_{92}^{235}\text{U}$ ✓	2	2.2	

Question	Answer	Marks	AO element	Guidance
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Question				Answer	Marks	AO element	Guidance
4				C ✓	1	2.1	



Question			Answer	Marks	AO element	Guidance
5			B ✓	1	1.1	



Question				Answer	Marks	AO element	Guidance
12				D ✓	1	2.2	



Question	Answer	Marks	AO element	Guidance
3	A	1	1.1	



Question	Answer	Marks	AO element	Guidance
4	D	1	1.1	



14	C	1	2.1	A: $2 \times \text{energy}$ B: $3 \times \text{energy}$ C: $(1 + 3) \times \text{energy}$ D: $3 \times 3 \times \text{energy}$
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19	(a)	(i)	Neutron(s) ✓	1	1.1	IGNORE gamma
		(ii)	Any one from: Gravity ✓ (very) high temperatures ✓ high pressure ✓	1	1.1	ALLOW (high) gravitational field strength ALLOW hot (temperatures) / lots of heat IGNORE just heat
	(b)	(i)	Any one from: Both produce energy ✓ Both convert mass to energy / have a “loss” in mass ✓ Both produce neutrons ✓	1	1.1	
		(ii)	Any one from: In fusion nuclei join / in fission nuclei split/decay/break up / AW ✓ fusion occurs at higher temperatures or pressures / fission occurs at lower temperatures or pressures ✓ larger/heavier nucleus forms in fusion / smaller/lighter/daughter nuclei forms in fission ✓ more energy released in fusion / less energy released in fission ✓ fission causes a chain reaction / fusion does not cause a chain reaction ✓ fusion does not produce (radioactive) waste / fission does produce radioactive waste ✓	1	1.1	ALLOW atom IGNORE molecules / particles / ions ALLOW only fission reactors are used at present to produce electricity

Question	Answer	Marks	AO element	Guidance
(c)	Advantage - Any one from: no carbon dioxide produced / does not contribute to global warming/climate change/acid rain / no polluting gases ✓ small quantities of fuel needed / (idea of) more energy per unit mass ✓ fuel readily available ✓ will not run out as fast (as fossil fuels) ✓ to preserve fossil fuels ✓ Disadvantage - Any one from: Radioactive/nuclear waste produced ✓ security of transport of fuel / waste ✓ expensive to build ✓ danger of exposure to radiation ✓ decommissioning is expensive ✓ risk of accident (and after-effects)/uncontrollable (chain reaction) ✓ non-renewable ✓	2	2×1.1	ALLOW a named polluting gas IGNORE (idea of) ozone layer ALLOW (idea of) risk from terrorists ALLOW (idea of) explosion IGNORE just dangerous



17	(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
17	(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