AQA GCSE Combined Science - Trilogy | 8464

SPECIFICATION POINT 6.4.2.1

Radioactive decay and nuclear radiation

Mark schemes and examiner comments

Tier	**Foundation**
Question groups	**17**
Available paper years	**2018–2025**

Using this booklet

1. Booklet answer numbers match the question booklet.
2. Use the original question number within marking tables.
3. Examiner comments are included where available.

Name: _____ **Date:** _____

Where a precise marking extract is unavailable, the full source document is included in an appendix. Any missing mark scheme is explicitly identified.

6.4.2.1 Radioactive decay and nuclear radiation

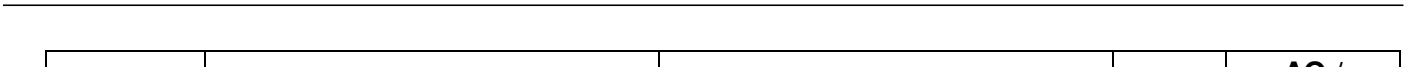
Answer 01 · Mark scheme June 2018 | 8464/P/1F | Original Q5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	gamma		1	AO1 6.4.2.1
05.2	alpha		1	AO1 6.4.2.1
05.3	gamma		1	AO1 6.4.2.1
05.4	<table><tr><th>isotope</th><th>number of neutrons</th><th>number of protons</th></tr><tr><td>uranium-238</td><td>146</td><td>**92**</td></tr><tr><td>thorium-234</td><td>**144**</td><td>90</td></tr></table>		1 1	AO2 6.4.1.2
05.5	$\Delta\theta = 80\ ^\circ C$ $E = 150 \times 4200 \times 80$ $E = 50\ 400\ 000$ (J)	an answer of 50 400 000 scores **3** marks allow 50 000 000 (J) allow **max 2** marks for correct calculation using incorrect value of $\Delta\theta$ allow **1** mark for correct calculation using $\theta = 20$ **or** $\theta = 100$	1 1 1	AO2 6.3.2.2
Total			**8**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 01 · Mark scheme

June 2018 | 8464/P/1F | Original Q5



6.4.2.1 Radioactive decay and nuclear radiation

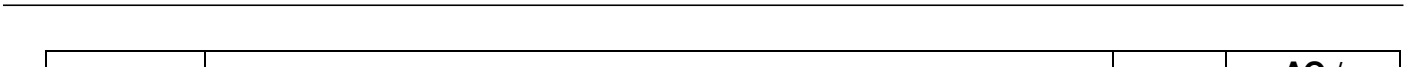
Answer 02 · Mark scheme June 2018 | 8464/P/1F | Original Q6

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.1	electron atom nucleus orbit		1 1 1 1	AO1 6.4.1.3 5.1.1.3
06.2	positive charge is provided by protons (every atom of the same element contain the) same number of protons	 do **not** accept same number of protons and neutrons ignore reference to electrons	1 1	AO1 6.4.1.2 6.4.1.3
06.3	 $v = 300\ 00\ 000 \times \left(\frac{7}{100}\right)$ v = 21 000 000 (m/s)	an answer of 21 000 000 scores **2** marks allow any correct method of determining 7% of 300 000 000 allow 2.1×10^7 (m/s)	 1 1	AO2 6.4.1.3
06.4	 $r = 6 \times 2.5 \times 10^{-11}$ $r = 1.5 \times 10^{-10}$ (m)	an answer in the range 1.4×10^{-10} to 1.6×10^{-10} scores **2** marks allow a ratio in the range of 5.7–6.3 or measurements that would give this range, correctly substituted allow 1.4×10^{-10} to 1.6×10^{-10} their ratio $\times 2.5 \times 10^{-11}$ correctly calculated scores **1** mark	 1 1	AO2 6.4.1.1
Total			**10**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 02 · Mark scheme

June 2018 | 8464/P/1F | Original Q6



6.4.2.1 Radioactive decay and nuclear radiation

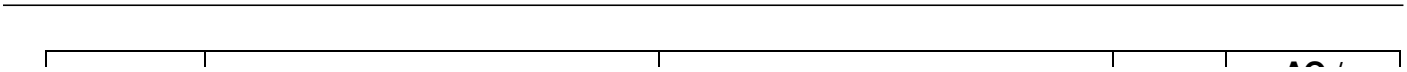
Answer 03 · Mark scheme June 2018 | 8464/P/2F | Original Q4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.1	R		1	AO1 6.6.2.1
04.2	they have the same wave speed as visible light they have a lower frequency than gamma rays		1 1	AO1 6.6.2.1
04.3	any **two** from: • ageing of the skin • skin cancer • eye damage	 allow sunburn burn unqualified is insufficient cancer is insufficient allow mutation of genes in skin cells allow blindness	2	AO1 6.6.2.3
04.4	any **two** from: • gamma (rays) • X-rays • ultraviolet		2	AO1 6.6.2.4
Total			**7**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 03 · Mark scheme

June 2018 | 8464/P/2F | Original Q4



6.4.2.1 Radioactive decay and nuclear radiation

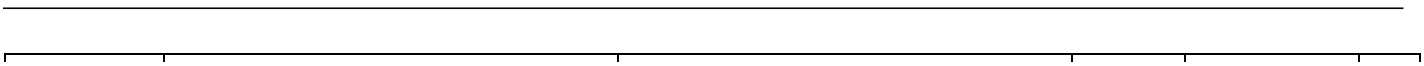
Answer 04 · Mark scheme June 2019 | 8464/P/1F | Original Q3

Question	Answers	Extra information	Mark	AO / Spec. Ref.	ID
03.1	they changed direction	allow deflected/reflected/repelled	1	AO 1/1 6.4.1.3	E
03.2	diameter = $\frac{0.18}{6000}$ = 0.000 030 (nm)	an answer of 0.000 03 (nm) or 3.0×10^{-5} (nm) scores **2** marks allow 3.0×10^{-5} (nm)	1 1	AO2/2 6.4.1.1	E
03.3	A		1	AO 1/1 6.4.1.1	A
03.4	1100 (°C)		1	AO3/2b 6.3.2.3	G
03.5	8 (minutes)	allow 12 (minutes)	1	AO3/2b 6.3.2.3	G
03.6	the rate of change of temperature of the gold		1	AO3/1a 6.1.1.3, 6.3.2.2	A
Total			**7**		

6.4.2.1 Radioactive decay and nuclear radiation

Answer 04 · Mark scheme

June 2019 | 8464/P/1F | Original Q3



6.4.2.1 Radioactive decay and nuclear radiation

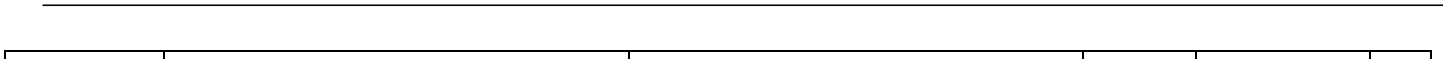
Answer 05 · Mark scheme June 2019 | 8464/P/1F | Original Q4

Question	Answers	Extra information	Mark	AO / Spec. Ref.	ID
04.1	$^{234}_{91}Pa$		1	AO1/1 6.4.1.2	A
04.2	points correctly plotted to within 1 mm a curved line of best fit passing within 1 mm of all 5 points	 ignore any line beyond 200 seconds	1 1	AO2.2 6.4.2.3 WS 3.2	E
04.3	70 (s)	allow an answer between 65 and 75 (s) allow an answer consistent with their drawn line	1	AO2/2 6.4.2.3 WS 3.5	E
04.4	70 (s)	allow an answer between 65 and 75 (s) allow their answer to question **04.3**	1	AO3/2b 6.4.2.3	E
04.5	beta		1	AO1.1 6.4.2.1	A
04.6	articles in scientific journals are peer reviewed	allow articles in scientific journals are based on evidence/data allow newspaper articles may be oversimplified/inaccurate/biased	1	AO1.1 6.4.2.4 WS 1.6	E
Total			**7**		

6.4.2.1 Radioactive decay and nuclear radiation

Answer 05 · Mark scheme

June 2019 | 8464/P/1F | Original Q4



6.4.2.1 Radioactive decay and nuclear radiation

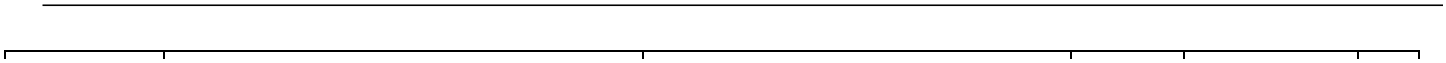
Answer 06 · Mark scheme June 2019 | 8464/P/2F | Original Q5

Question	Answers	Extra information	Mark	AO / Spec. Ref.	ID
05.1	velocity frequency wavelength		1 1 1	AO1 6.6.2.3	G
05.2	so people are not exposed to (as much) gamma radiation because gamma radiation can damage human tissue	allow less gamma radiation reaches the Earth's surface allow increases the risk of cancer or (cell) mutation allow gamma rays are ionising ignore any reference to temperature / heating of the atmosphere	1 1	AO1 6.6.2.3	E
05.3	(microwaves) are used in (satellite) communications	ignore any reference to temperature / heating of the atmosphere	1	AO2 6.6.2.4	E
05.4	can cause skin cancer / premature ageing	allow sunburn allow eye / skin damage cancer on its own is insufficient	1	AO1 6.6.2.3	E
05.5	risk from UV radiation is highest in July / summer two correct readings from the bar chart which support their comparison	allow any sensible comparison of named months / seasons if no other mark scored, two correct readings from the graph scores **1** mark	1 1	AO3 6.6.2.3	E
Total			**9**		

6.4.2.1 Radioactive decay and nuclear radiation

Answer 06 · Mark scheme

June 2019 | 8464/P/2F | Original Q5



6.4.2.1 Radioactive decay and nuclear radiation

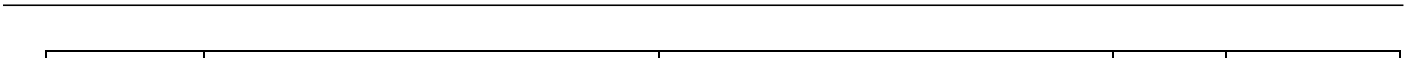
Answer 07 · Mark scheme November 2020 | 8464/P/1F | Original Q2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.1	contamination		1	AO1 6.4.2.4
02.2	2007-1992 = 15 35 (Bq)	allow an indication of the student reading from 15 years on the graph allow an answer between 34 and 36 (Bq)	1 1	AO2 6.4.2.3
02.3	12.5 (years)		1	AO2 6.4.2.3
02.4	12.5 (years)	allow the same value as their answer to 02.3	1	AO1 6.4.2.3
02.5	$\frac{36\ 000\ 000\ 000}{45\ 000\ 000\ 000}$ (× 100) 80 (%)	allow $\frac{36}{45}$ (× 100)	1 1	AO2 6.4.2.3
02.6	radioactive decay is a random process		1	AO1 6.4.2.3
02.7	use long tongs to handle the materials		1	AO1 6.4.2.4
02.8	peer review		1	AO1 6.4.2.4
Total			**10**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 07 · Mark scheme

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



6.4.2.1 Radioactive decay and nuclear radiation

Answer 08 · Mark scheme November 2020 | 8464/P/1F | Original Q6

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.1	A = 206		1	AO2 6.4.2.2
06.2	Z = 82		1	AO2 6.4.2.2
06.3	89 39	numbers must be in this order	1 1	AO2 6.4.2.2
06.4	electromagnetic waves		1	AO1 6.4.2.1

6.4.2.1 Radioactive decay and nuclear radiation

Answer 08 · Mark scheme

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

Question	Answers	Mark	AO / Spec. Ref.
06.5	**Level 3:** Relevant points (reasons/causes) are identified, given in detail and logically linked to form a clear account.	5–6	AO1 6.4.1.2 6.4.2.1 6.4.2.2
	Level 2: Relevant points (reasons/causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear.	3–4	
	Level 1: Points are identified and stated simply, but their relevance is not clear and there is no attempt at logical linking.	1–2	
	No relevant content	0	
	Indicative content <u>alpha radiation</u> • an alpha particle is the same as a helium nucleus • alpha is the least penetrating • alpha is stopped by paper or skin • alpha has the shortest range in air • alpha will travel a few cm in air • because alpha is most ionising • because alpha has a charge of +2 <u>beta radiation</u> • a beta particle is an electron (emitted from the nucleus) • beta penetrates less than gamma and more than alpha • beta is stopped by a thin sheet of aluminium • beta has a shorter range than gamma • beta will travel up to 1m in air • because beta is more ionising that gamma and less ionising than alpha • because beta has a charge of -1 <u>gamma radiation</u> • gamma radiation is an electromagnetic wave • gamma is the most penetrating • gamma is reduced/stopped by several cm of lead or thick concrete • gamma has the largest range in air • gamma will travel very large distances in air • because gamma is least ionising • because is uncharged to access level 3 the answer should compare alpha, beta and gamma radiation and provide some explanation of their properties		

Total			11

6.4.2.1 Radioactive decay and nuclear radiation

Answer 09 · Mark scheme November 2020 | 8464/P/2F | Original Q3

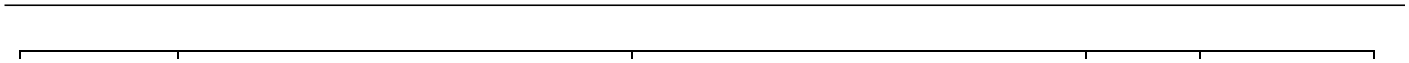
Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	skin		1	AO1 6.6.2.4
03.2	dose is much lower than even slight increased risk of cancer dose	allow much less than 100 mSv	1	AO3 6.6.2.3
03.3	to reduce the dose of radiation (they are exposed to)	allow reduce the risk	1	AO3 6.6.2.3
03.4	sterilising medical equipment		1	AO1 6.6.2.3
03.5	they are ionising		1	AO1 6.6.2.3
03.6	**microwaves** data is transmitted / detected by (mobile) phone / WiFi / satellite **visible light** example of device / system description of how light is used	 allow signal / information for data allow bluetooth e.g. the internet transfers information via visible light in fibre optics e.g. image produced / seen on a TV / mobile phone	 1 1 1 1	AO1 6.6.2.4

		allow any sensible suggestion for visible light, but the two marks must be linked		
Total			**9**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 09 · Mark scheme

November 2020 | 8464/P/2F | Original Q3



6.4.2.1 Radioactive decay and nuclear radiation

Answer 10 · Mark scheme

November 2021 | 8464/P/1F | Original Q6

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.1	more than 10 000 times bigger		1	AO1 6.4.1.1
06.2	the atom becomes a positive ion the atom loses an electron		1 1	AO1 6.4.1.2
06.3	beta radiation is only weakly ionising		1	AO3 6.4.2.1

6.4.2.1 Radioactive decay and nuclear radiation

Answer 10 · Mark scheme

November 2021 | 8464/P/1F | Original Q6

Question	Answers	Mark	AO / Spec. Ref.
06.4	**Level 3:** The method would lead to the production of a valid outcome. The key steps are identified and logically sequenced.	5–6	AO3 6.4.2.1
	Level 2: The method would not necessarily lead to a valid outcome. Most steps are identified, but the method is not fully logically sequenced.	3–4	
	Level 1: The method would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.	1–2	
	No relevant content	0	
	Indicative content • move the detector very close to the source • record the count rate • position the paper between the source and the detector • record the new count rate • alpha radiation will not penetrate through paper • if the count rate with the paper is (significantly) less than without then the source emits alpha radiation • remove the paper and position the aluminium between the source and the detector • record the new count rate • (alpha and) beta radiation will not penetrate through the aluminium • if the count rate has (significantly) reduced compared with using paper then beta radiation is present • if radiation penetrates through the aluminium then gamma radiation is present • the experiment should be repeated and mean results calculated because radioactivity is a random process To access level 3, the candidate must use the paper sheet, the aluminium sheet and no sheet, and describe how the results would indicate the presence of alpha, beta or gamma radiation.		
Total		**10**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 11 · Mark scheme November 2021 | 8464/P/2F | Original Q5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	(air resistance) increases		1	AO1 6.5.4.1.5
05.2	less than		1	AO3 6.5.4.1.5
05.3	s = 35 × 14 s = 490 (m)		1 1	AO2 6.5.4.1.2
05.4	work done = force × distance **or** W = Fs		1	AO1 6.5.2
05.5	54 000 000 = F × 270 $F = \frac{54\,000\,000}{270}$ F = 200 000 (N)		1 1 1	AO2 6.5.2

6.4.2.1 Radioactive decay and nuclear radiation

Answer 11 · Mark scheme

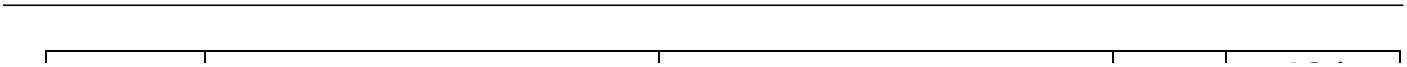
November 2021 | 8464/P/2F | Original Q5

Question	Answers	Mark	AO / Spec. Ref.
05.6	**Level 2:** Scientifically relevant features are identified; the way(s) in which they are similar/different is made clear and (where appropriate) the magnitude of the similarity/difference is noted.	4–6	AO3 6.5.4.1.2
	Level 1: Relevant features are identified and differences noted.	1–3	
	No relevant content	0	
	Indicative content • distance travelled is the same for each aeroplane • time in the air is much greater for jet aeroplane • speed of rocket plane is much greater • speed of rocket plane is 32 times greater • radiation dose each hour greater for rocket aeroplane • radiation dose each hour is 2 times greater for rocket aeroplane • overall radiation dose is less for rocket plane • dose in jet aeroplane is 16 times greater overall • much higher risk in jet aeroplane • increased risk of skin cancer • increased risk of gene mutation and cancer To access level 2, there must be a relevant calculation.		
Total			**14**

6.4.2.1 Radioactive decay and nuclear radiation

Answer 11 · Mark scheme

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



6.4.2.1 Radioactive decay and nuclear radiation

Answer 12 · Mark scheme

June 2022 | 8464/P/1F | Original Q3

Question 3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	$^{241}_{95}Am \longrightarrow {}^{237}_{93}Np + {}^{4}_{2}He$	first box ticked	1	AO2 6.4.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.2	a few centimetres		1	AO1 6.4.2.1

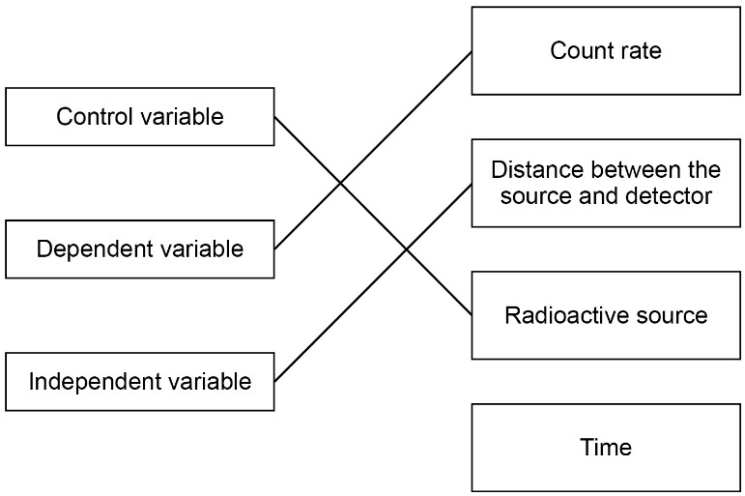
Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.3	paper stops alpha radiation		1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.4	$^{0}_{-1}e$		1	AO1 6.4.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.5	112		1	AO2 6.4.2.1

6.4.2.1 Radioactive decay and nuclear radiation

Answer 12 · Mark scheme June 2022 | 8464/P/1F | Original Q3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.6	 do **not** accept more than one line from a box on the left		1 1 1	AO3 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.7	as distance increases the count rate decreases (between 40 cm and 50 cm) the count rate becomes zero		1 1	AO3 6.4.2.1

Total Question 3		10

6.4.2.1 Radioactive decay and nuclear radiation

Answer 13 · Mark scheme

June 2023 | 8464/P/1F | Original Q1

Question 1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.1	alpha		1	AO1 6.4.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.2	2		1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.3	82		1	AO2 6.4.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.4	50		1	AO1 6.4.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.5	$\frac{1500}{30}$ 50 (counts per second)		1 1	AO2 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.6	the count-rate decreased because (gamma) radiation is absorbed by lead	allow decreased to (almost) zero allow (gamma) radiation cannot penetrate (thick) lead	1 1	AO1 6.4.2.1

6.4.2.1 Radioactive decay and nuclear radiation

Answer 13 · Mark scheme June 2023 | 8464/P/1F | Original Q1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.7	the lead was exposed to gamma radiation		1	AO1 6.4.2.4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.8	electromagnetic waves		1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.9	any one from: • (longer tongs give) a greater distance between the scientist and the radioactive source • (longer tongs) reduce the amount of radiation the scientist is exposed to • (longer tongs) reduce the risk of cell mutation	allow (longer tongs) reduce the risk of cancer	1	AO1 6.4.2.4

Total Question 1	11

6.4.2.1 Radioactive decay and nuclear radiation

Answer 14 · Mark scheme

June 2023 | 8464/P/2F | Original Q6

Question 6

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.1	**A** radio waves **B** microwaves **C** X-rays	allow **1** mark if 2 correct	2	AO1 6.6.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.2	**Similarity** any **one** from: • same speed (in a vacuum) • both transfer energy • both transverse **Difference** any **one** from: • gamma has a higher frequency • gamma has a shorter wavelength • gamma is more ionising • gamma is more penetrating	allow both can travel through a vacuum allow both are ionising allow both can harm living tissue allow both can be used for medical treatment / imaging allow gamma has more energy	1 1	AO1 6.6.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.3	refraction		1	AO1 6.6.2.2

Answer 14 · Mark scheme

June 2023 | 8464/P/2F | Original Q6

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.4	wave speed = frequency × wavelength **or** $v = f\lambda$		1	AO1 6.6.1.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.5	$3.0 \times 10^{8} = f \times 5.0 \times 10^{-7}$ $f = \frac{3.0 \times 10^{8}}{5.0 \times 10^{-7}}$ $f = 6 \times 10^{14}$ (Hz)	 allow a correct rearrangement using incorrect powers of 10 allow a correct calculation of f using incorrect powers of 10 allow 6.0×10^{14} (Hz)	1 1 1	AO2 6.6.1.2

Total Question 6	9

6.4.2.1 Radioactive decay and nuclear radiation

Answer 15 · Mark scheme June 2024 | 8464/P/1F | Original Q3

Question 3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.1	radium-228 atoms have two more neutrons		1	AO1 6.4.1.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.2	6 years		1	AO2 6.4.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.3	decrease the distance between the toothpaste and the detector		1	AO3 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.4	2940 3180	answers may be in either order	1	AO3 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.5	the tube of toothpaste used		1	AO3 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.6	the activity of the toothpaste		1	AO3 6.4.2.1

6.4.2.1 Radioactive decay and nuclear radiation

Answer 15 · Mark scheme

June 2024 | 8464/P/1F | Original Q3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.7	there is less risk		1	AO3 6.4.2.4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
03.8	nuclear radiation is ionising		1	AO1 6.4.2.1 6.4.2.4

Total Question 3	**8**

Answer 16 · Mark scheme

June 2024 | 8464/P/1F | Original Q7

Question 7

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.1	2 protons and 2 neutrons	ignore helium nucleus	1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.2	118		1	AO1 6.4.1.2

Question	Answers	Mark	AO / Spec. Ref.
07.3	**Level 2:** Scientifically relevant facts, events or processes are identified and given in detail to form an accurate account.	4–6	AO1 AO3 6.4.1.3
	Level 1: Facts, events or processes are identified and simply stated but their relevance is not clear.	1–3	
	No relevant content	0	
	Indicative content Plum pudding model • the atom is a ball of positive charge • electrons are embedded in the ball Reasons why the plum pudding model was replaced • the results were not correctly predicted by the plum pudding model • the plum pudding model did not predict that some particles would be deflected • the large angle deflections suggest that the atom contains a nucleus • all deflections suggest that the nucleus is charged • most alpha particles were not deflected suggesting that atoms are mostly empty space Nuclear model • mass is concentrated in the nucleus • the nucleus is charged • the atom is mostly empty space • electrons orbit the nucleus in the nuclear model		

6.4.2.1 Radioactive decay and nuclear radiation

Answer 16 · Mark scheme

June 2024 | 8464/P/1F | Original Q7

Question	Answers	Extra information	Mark	AO / Spec. Ref.
07.4	James Chadwick		1	AO1 6.4.1.3

Total Question 7	**9**

6.4.2.1 Radioactive decay and nuclear radiation

Answer 17 · Mark scheme June 2025 | 8464/P/1F | Original Q1

Question 1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.1	the number of neutrons		1	AO1 6.4.1.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.2	lead-210 has unstable nuclei		1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.3	high speed electrons ejected from nuclei		1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.4	50 (kBq)	allow an answer in the range 49 (kBq) to 50 (kBq)	1	AO2 6.4.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.5	25 (kBq)	allow ecf from question **01.4**	1	AO2 6.4.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.6	age = 50 (years)		1	AO3 6.4.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.7	the estimated age would be lower		1	AO3 6.4.2.1 6.4.2.3

6.4.2.1 Radioactive decay and nuclear radiation

Answer 17 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.8	gamma		1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.9	alpha		1	AO1 6.4.2.1

Total Question 1	**9**

6.4.2.1 Radioactive decay and nuclear radiation

Answer 04 · Examiner comments June 2019 | 8464/P/1F | Original Q3

Question 3

03.1 Only about 30% of students could describe alpha particles as deflecting or rebounding from the gold atom. Many described the alpha particles as not going through, which was insufficient as it was given in the question. Some students thought alpha particles would be absorbed or destroyed.

03.2 A good attempt at this question to calculate the size of a nucleus using the ratio to the size of the atom was made by around 40% of students, with approximately 30% gaining both marks. A common mistake was to divide instead of multiplying. Some students tried to do the correct sum, but instead calculated 0.18 ÷ (1/6000) instead of calculating 0.18/6000. Nearly 10% of students made no attempt at this question. Using ratios is a mathematical skill in the specification.

03.3 This question testing knowledge of electron energy levels was correctly answered by just over 30% of students.

03.4 This question required students to identify that the temperature remains constant while a substance melts, and then read this temperature from the graph. 45% of students were able to do this correctly. Some student did not associate the constant temperature with the change of state, but more commonly they failed to correctly determine the scale on the temperature axis.

Answer 04 · Examiner comments June 2019 | 8464/P/1F | Original Q3

03.5 About 35% of students could determine the time for the change of state from the graph. Reading values from graphs and using those values are required mathematical skills.

03.6 Nearly 60% of students correctly identified the gradient of the graph as the rate of change of temperature.

6.4.2.1 Radioactive decay and nuclear radiation

Answer 05 · Examiner comments June 2019 | 8464/P/1F | Original Q4

Question 4

04.1 The content of this question is shared with the chemistry specification and was answered correctly by just over 35% of the students.

04.2 Almost 70% of students gained at least 1 mark and about a third of gained both marks. Points were often plotted within acceptable tolerances but the line – which should have been a smooth curve – was often drawn dot-to-dot or as a straight line.

04.3 Almost half of the students were able to read the time value correctly from their graphs. A value consistent with their line, or with a correct line of best fit, was acceptable.

04.4 Fewer than one in four students were able to associate the answer to the previous question with the half-life of the isotope.

04.5 Just under 40% of students knew that beta particles have a range of up to a metre.

04.6 This question produced a wide range of responses but only about 30% of students scored the mark. Students were expected to describe peer review but this was rarely seen. Acceptable alternatives about data or evidence in scientific journals, and newspaper articles being inaccurate or biased enabled more students to gain the mark. Many students simply stated that articles in scientific journals are written by scientists and articles in newspapers are not, that scientists know what they are talking about, or scientists are more reputable than journalists, but these responses were not sufficient for credit. There was also a misconception, which was less common, in which students appeared to misunderstand what a scientific journal is.

Answer 10 · Examiner comments November 2021 | 8464/P/1F | Original Q6

Question 06 (Standard demand)

06.1 This question was answered correctly by roughly one in three students.

06.2 Around 15% of students gained both marks, with slightly over half gaining just one mark.

06.3 Many students gave answers which were too vague, such as “beta radiation is not strong enough”, or stated that beta radiation is not ionising, which is incorrect. Very few students answered correctly.

6.4.2.1 Radioactive decay and nuclear radiation

Answer 10 · Examiner comments November 2021 | 8464/P/1F | Original Q6

06.4 Most students struggled to answer this question, with many unable to write answers containing any relevant content. Many answers suggested placing the piece of paper or aluminium into the radioactive source holder, for example. A fair proportion of students did not read the question carefully, and suggested changing the radioactive source to test the equipment using one source of just alpha radiation, one of just beta, and one that emits just gamma radiation, although it was still possible to gain full credit if they did this.

Some students recalled that paper stops alpha radiation, that aluminium stops beta radiation, and that gamma would penetrate both, but didn't describe how to set up the equipment. Others described how to set up the equipment, but not how to use any measurements to draw conclusions.

Nearly a quarter of students did not attempt to answer the question.

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the Results Statistics page of the AQA Website.

6.4.2.1 Radioactive decay and nuclear radiation

Answer 11 · Examiner comments — November 2021 | 8464/P/2F | Original Q5

Question 5 (Low demand and standard demand)

05.1 Over 50% of students correctly stated that the air resistance would increase. Of those that didn't, many of them failed to answer the question, and wrote answers such as 'the acceleration will overcome the air resistance'.

05.2 Only 15% of students correctly identified that the lift force on the wings will be the same as the weight of the rocket aeroplane.

05.3 This low demand calculation was very well answered, with the vast majority of students scoring 2 marks.

05.4 Over 50% of students correctly recalled the equation.

05.5 This standard demand calculation was reasonably well answered. Nearly 75% were able to substitute into the correctly rearranged equation, and the vast majority of those went on to correctly evaluate the answer and score full marks.

05.6 This question was an extended response question that was marked with a level of response mark scheme. Over 10% of students did not attempt the question. Of those that did 35% did not write any relevant content. Nearly all these students failed to include any

Answer 11 · Examiner comments — November 2021 | 8464/P/2F | Original Q5

information from the question. Where students are given an additional instruction such as 'Use values from Table 2', they must do so. Of the 35% of students that did score mark the majority made simple statements that the radiation dose for the rocket aeroplane was greater. Very few appreciated that because the rocket aeroplane was much faster, it spent much less time in the air. Only a handful of students wrote level 2 answers.

6.4.2.1 Radioactive decay and nuclear radiation

Answer 12 · Examiner comments

June 2022 | 8464/P/1F | Original Q3

Question 03 (Low demand and standard demand)

03.1 Just under half of all students were able to identify the correct nuclear equation.

03.2 Slightly less than 45% of students recalled that alpha radiation can travel a few centimetres in air.

03.3 Nearly three quarters of the students knew that paper stops alpha radiation.

03.4 Only about 40% of students identified the symbol for a beta particle.

03.5 Approximately a quarter of students gained the mark for this calculation.

Many students added 7 to 119, while a large number of students appeared not to understand the symbol ±, and divided or multiplied the two numbers.

03.6 Only about 5% of students correctly identified all three variables, with about 10% giving two correct answers. Approximately 55% of students gained at least one mark.

03.7 Nearly 60% of students gained at least one mark on this question, with the vast majority of these describing the decreasing count rate with increased distance from the source.

Some students incorrectly identified this as an inversely proportional relationship. The range in air of nuclear radiation helps to distinguish between alpha, beta, and gamma radiation, but very few students commented on the maximum distance travelled.

6.4.2.1 Radioactive decay and nuclear radiation

Answer 13 · Examiner comments June 2023 | 8464/P/1F | Original Q1

Question 01 (Low demand)

01.1 Approximately half of all students identified the type of radiation.

01.2 Slightly more than 40% of students recognised that an alpha particle has 2 protons.

01.3 About two-thirds of students chose the correct value for X.

01.4 Just under two thirds of students chose the correct activity.

01.5 Nearly 80% of students scored full marks in this simple calculation, with the majority of the remaining students gaining no credit. Common mistakes were losing a zero somewhere in the working, multiplying the two numbers together rather than dividing.

01.6 Nearly 50% of students gained some credit on this question, although only about a fifth of students scored both marks.

Many students did not state the effect of the lead on the count-rate, with a fair proportion writing that there were fewer counts and making no reference to rate or a time-frame. A small minority of students stated that the lead stopped the gamma from being emitted by the source, which is incorrect and gained no credit.

It appeared that some students misread the question and described the effect of the radiation on the lead, giving a description of the lead being irradiated rather than describing the effect on the count-rate.

01.7 Around 40% of students knew that the lead was exposed to gamma radiation, with the remaining students being split more or less equally between the other two options.

01.8 Just over 40% of students identified that gamma radiation consists of electromagnetic waves.

Answer 13 · Examiner comments June 2023 | 8464/P/1F | Original Q1

01.9 Roughly a third of students gave a correct answer. It was very common for students to state that using the long tongs made it less likely for the radioactive source to touch the skin. Many students stated that the radioactivity could travel through the tongs. It was reasonably common for students to think that it was being held by tongs so that it could be safely held above a bunsen burner. A small, but noticeable, proportion of students gave statements indicating that they thought the radioactive source was hot, or could electrocute you, or could explode, which was why the tongs were needed.
There was some confusion from a small proportion of students about the difference between radiation and radioactivity. These students tended to give answers describing longer tongs reducing the exposure of the scientist to radioactivity, rather than to radiation, which was not creditworthy.

6.4.2.1 Radioactive decay and nuclear radiation

Answer 14 · Examiner comments

June 2023 | 8464/P/2F | Original Q6

Question 6 (standard demand)

06.1 Fewer than 25% of students could identify all the missing parts of the spectrum. 70% of students either scored zero marks or did not attempt the question. A significant number of students wrote answers that were nothing to do with the electromagnetic spectrum.

06.2 Only 2% of students we able to give a similarity and a difference. The similarity was more accessible and was how the majority of the 15% that scored one mark got the mark. Many

Answer 14 · Examiner comments

June 2023 | 8464/P/2F | Original Q6

identified that they are both transverse. For the difference, most students did not refer to a property of electromagnetic waves. A little over 15% of students did not attempt the question.

06.3 Approximately 20% of students knew that the process is refraction. A little over 15% of students did not attempt the question.

06.4 This question was well answered with over 90% of students getting the mark. Students were given the equation sheet, which will have contributed to the overall performance on this question.

06.5 25% of students were able to substitute correctly and give the correct answer to the question to the correct order of magnitude. Approximately 20% of students correctly rearranged and substituted but did not use their calculator to evaluate the numbers in standard form, so scored 2 marks.

Answer 15 · Examiner comments

June 2024 | 8464/P/1F | Original Q3

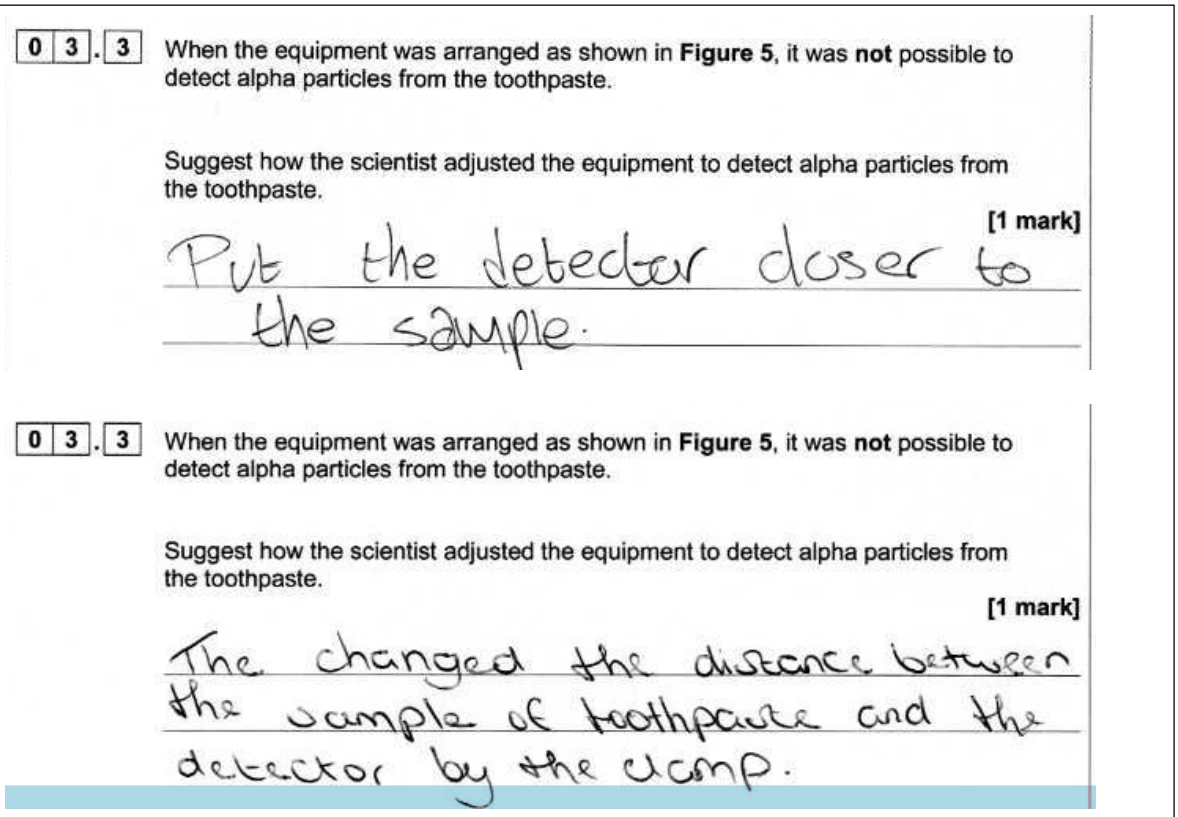
Question 3 (low demand)

03.1 The most common answer to this question was from students who incorrectly selected the second option (radium-228 atoms have two more protons than radium-226 atoms). Slightly over a third of students identified that the difference is only in the number of neutrons.

03.2 Only about 30% of students were able to identify the half-life from the graph. Over half of all students selected 7 years, half the maximum time shown on the *x*-axis of the graph.

03.3 This question was answered correctly by nearly 60% of students.

Incorrect answers that were relatively common included suggestions to use more toothpaste or to use a more sensitive detector. Some students showed a lack of familiarity with a Geiger-Muller tube, mistaking the detector for a microscope and leading to incorrect answers.



0 3 . 3 When the equipment was arranged as shown in **Figure 5**, it was **not** possible to detect alpha particles from the toothpaste.

Suggest how the scientist adjusted the equipment to detect alpha particles from the toothpaste.

[1 mark]

Put the detector closer to the sample.

0 3 . 3 When the equipment was arranged as shown in **Figure 5**, it was **not** possible to detect alpha particles from the toothpaste.

Suggest how the scientist adjusted the equipment to detect alpha particles from the toothpaste.

[1 mark]

The changed the distance between the sample of toothpaste and the detector by the clamp.

The first student gave a correct answer. However, the second student did not give enough detail about whether the distance should be increased or decreased, so scored zero.

03.4 Nearly three-quarters of all students gave the correct range.

03.5 Just over a third of students correctly identified the independent variable.

03.6 Slightly less than 40% of students correctly identified the dependent variable.

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6.4.2.1 Radioactive decay and nuclear radiation

Answer 15 · Examiner comments June 2024 | 8464/P/1F | Original Q3

03.7 Just under half of all students could identify how the level of risk changed.

It was reasonably common for students to describe what happened to the activity of the toothpaste rather than the risk. It was also common to state that there would be no risk, but this contradicted the results from the scientist's investigation so did not score. Descriptions of a reduction in the rate of emission of radiation were not enough to score a mark.

Some students misinterpreted the question and, instead of referring to the risk from the radioactive toothpaste, described the risk from toothpaste generally. Statements that referred to modern toothpaste being safer did not answer the question.

03.8 Nearly 40% of students correctly identified that the ionising nature of nuclear radiation makes it hazardous. About a third of students showed the misconception that nuclear radiation makes objects radioactive.

Answer 16 · Examiner comments

Question 7 (standard demand)

07.1 Most students were unable to accurately recall the structure of an alpha particle, with less than one in 10 students giving a full description.

07.2 The number of neutrons was correctly determined by just under half the students.

07.3 Foundation tier students tended to struggle with this question. Most were unable to describe details of either the plum pudding model or the nuclear model of the atom, and so made very little progress with their answers. The question was not attempted by about a fifth of students, and about a third gained any credit.

Some students used diagrams of the two models as part of their answers. Clearly labelled diagrams could help students to gain credit, but many diagrams were not labelled at all. However, many answers which included unlabelled diagrams had then gone on to describe features of each model, and the diagrams may have helped these students to recall the relevant details and to structure their answers.

There were a few misconceptions, which were demonstrated by a number of students. Descriptions of the plum pudding model as a proton with embedded electrons was common. A small proportion of answers alluded to positive electrons and negative electrons being present in atoms. A similar proportion referred to atoms being neutral because they contain neutrons.

It was relatively common for students to be unable to distinguish between the predicted results and the actual results, with many answers treating both of these as results gained by experiment.

A significant minority of students stated that the nuclear model was so called because it contains neutrons. Such statements may have been caused by students looking ahead at question 07.4 and incorrectly guessing that neutrons were discovered by conducting alpha particle scattering experiments.

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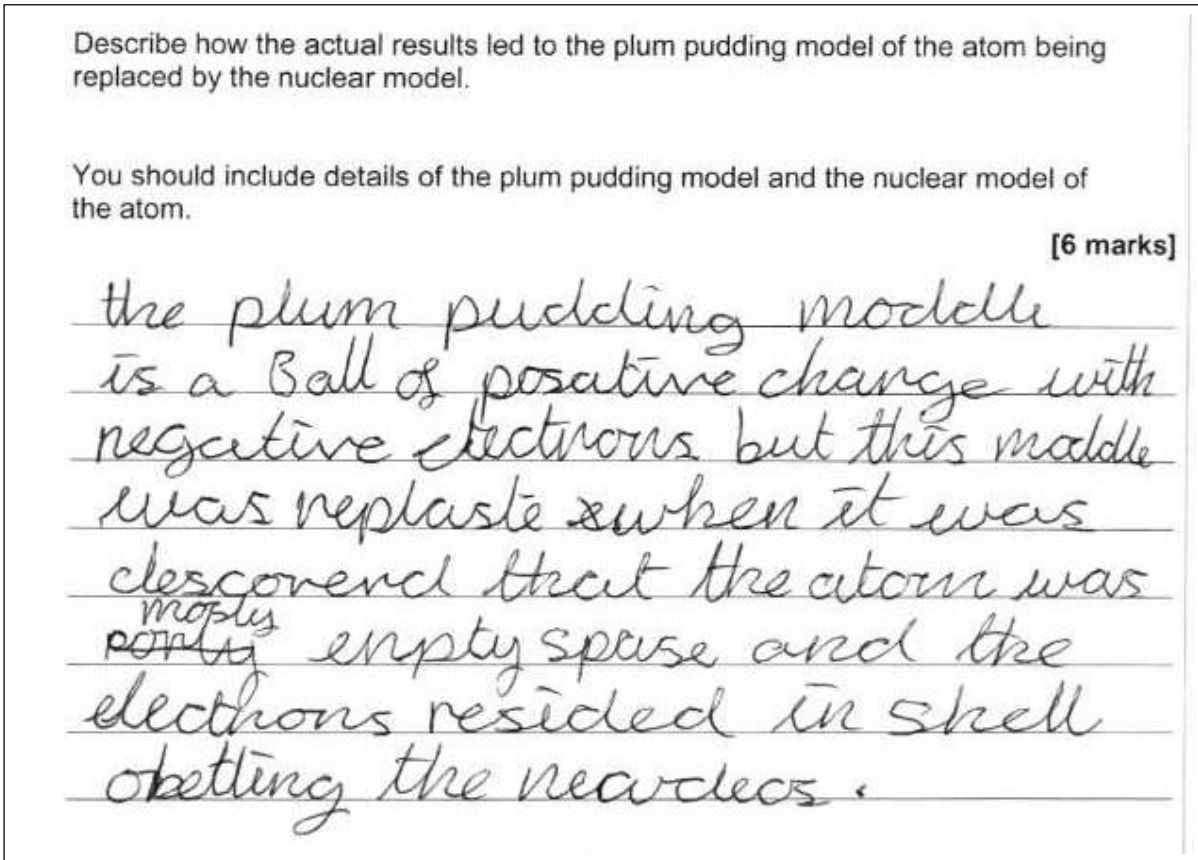
6.4.2.1 Radioactive decay and nuclear radiation

Answer 16 · Examiner comments June 2024 | 8464/P/1F | Original Q7

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

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

[6 marks]



This response is at the top of Level 1, gaining 3 marks. There is a description of the plum pudding model, but the description of the nuclear model lacks any detail about the massive and charged nature of the nucleus. Had the answer also included some detail about the nucleus or referred to how the actual results led to the rejection of the plum pudding model, the answer would have been in Level 2.

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6.4.2.1 Radioactive decay and nuclear radiation

Answer 16 · Examiner comments June 2024 | 8464/P/1F | Original Q7

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

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

[6 marks]

- The ~~pudd~~ plum pudding model was a solid sphere of positive charge, with negatively charged electrons throughout.
- Some alpha particles passed straight through, showing it is mainly empty space, not a solid ball.
- Some were slightly deflected showing there are the electrons circling the positive charge in the middle.
- Some completely ~~deflected~~ deflected back as they were repelled by the positive charge at the centre of the atom.
- The nuclear model was made to show these findings. It had a positive nucleus in the centre, a cloud of electrons orbitting it and the rest is mainly empty space.

In order to achieve the top mark on 'extended response' type questions, answers do not have to be completely correct, and neither do they need to address every single point in the indicative content on the mark scheme.

This response (from a Higher tier paper) gives a complete description of the plum pudding model. It describes how the evidence led to an understanding both that the atom is mostly empty space and that the nucleus is positively charged. However the statement that some alpha particles were deflected by electrons is incorrect, and there is no mention of the nucleus being massive.

However, taken as a whole, there is a reasonably detailed description of the plum pudding model, relevant points made about how the evidence led to the nuclear model, and a reasonably detailed description of the nuclear model, which was enough to allow this student to gain the maximum mark of 6 on this question.

07.4 About 40% of students correctly identified the scientist who provided evidence for the existence of neutrons.

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6.4.2.1 Radioactive decay and nuclear radiation

Contact us

Our friendly team will be happy to support you between 8am and 5pm, Monday to Friday.

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6.4.2.1 Radioactive decay and nuclear radiation

Answer 17 · Examiner comments

June 2025 | 8464/P/1F | Original Q1

Question 1 (Low demand)

01.1 Approximately one third of students knew the difference between the atoms of different isotopes of lead.

01.2 Approximately two thirds of students knew what is meant by 'lead-210 is radioactive'.

01.3 Approximately one third of students knew what beta radiation is.

01.4 80% of students were able to read the initial activity correctly from the graph.

01.5 Just under 20% of students answered this question correctly. There was a very wide range of incorrect answers indicating that many students struggled to understand how to answer the question.

01.6 This question was well answered with a little over 50% giving the correct age of the painting.

01.7 Half of the students knew that the estimated age would be lower if the other radioactive substances were not removed.

01.8 60% of students correctly selected gamma as the type of radiation with the greatest range in air.

01.9 80% of students correctly selected alpha as the type of radiation that is the least penetrating.