AQA GCSE Combined Science - Trilogy | 8464

SPECIFICATION POINT 6.4.2.1

Radioactive decay and nuclear radiation

Mark schemes and examiner comments

Tier	**Higher**
Question groups	**13**
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

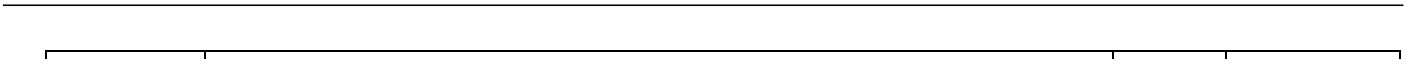
Answer 01 · Mark scheme June 2018 | 8464/P/1H | Original Q1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.1	electron		1	AO1 6.4.1.3
	atom		1	5.1.1.3
	nucleus		1	
	orbit		1	
01.2	positive charge is provided by protons		1	AO1 6.4.1.2 6.4.1.3
	(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	
01.3		an answer of 21 000 000 scores **2** marks		AO2 6.4.1.3
	$v = 300\ 00\ 000 \times \left(\frac{7}{100}\right)$	allow any correct method of determining 7% of 300 000 000	1	
	v = 21 000 000 (m/s)	allow 2.1×10^7 (m/s)	1	
01.4		an answer in the range 1.4×10^{-10} to 1.6×10^{-10} scores **2** marks		AO2 6.4.1.1
	$r = 6 \times 2.5 \times 10^{-11}$	allow a ratio in the range of 5.7–6.3 or measurements that would give this range, correctly substituted	1	
	$r = 1.5 \times 10^{-10}$ (m)	allow 1.4×10^{-10} to 1.6×10^{-10} their ratio $\times 2.5 \times 10^{-11}$ correctly calculated scores **1** mark	1	
Total			**10**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 01 · Mark scheme

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



6.4.2.1 Radioactive decay and nuclear radiation

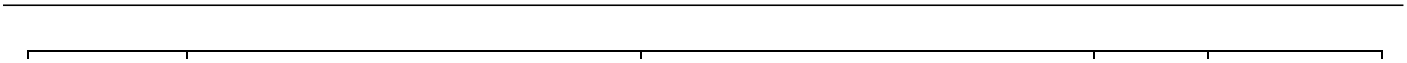
Answer 02 · Mark scheme June 2018 | 8464/P/1H | Original Q4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.1	2 charged particles and 2 neutral particles		1	AO1 6.4.2.1
04.2	it is the type of radiation with a negative charge		1	AO1 6.4.2.1
04.3	it has a very long range in air		1	AO1 6.4.2.1
04.4	risk / activity associated with iodine-131 has decreased by a large amount		1	AO3 6.4.2.3
	because of short half-life	allow many half-lives have passed allow half-life is only 8 days 2nd marking point dependent on 1st marking point	1	
	risk / activity associated with caesium-137 will not have decreased by much	allow activity has halved	1	
	because of long half-life	allow only one half-life has passed 4th marking point dependent on 3rd marking point	1	
04.5		an answer of 2136 scores **3** marks		AO2 6.4.2.3
	5 half-lives	allow any correct method eg ½ × ½ × ½ × ½ × ½ = 1/32	1	
	5 × 30 = 150		1	
	1986 + 150 = 2136	any calculation using a value of 137 scores zero	1	
Total			**10**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 02 · Mark scheme

June 2018 | 8464/P/1H | Original Q4



6.4.2.1 Radioactive decay and nuclear radiation

Answer 03 · Mark scheme June 2019 | 8464/P/1H | Original Q6

Question	Answers	Extra information	Mark	AO / Spec. Ref.	ID
06.1	mass number stays the same, charge stays the same		1	AO1.1 6.4.2.2	A
06.2	gamma radiation is only weakly ionising **or** most gamma radiation will pass through any detector	 allow gamma radiation is very penetrating	1	AO1.1 6.4.2.1	E
06.3	any two from • the radiation spreads out in all directions • only some of the radiation goes into the G-M tube • only some of the radiation passing into the GM tube is detected	allow **2** marks for only some of the radiation passing into the GM tube is detected because gamma is weakly ionising	2	AO1.1 6.4.2.4	E
06.4	to reduce the amount of radiation received because radiation increases the risk of cancer or (genetic) mutation	allow to reduce irradiation (of the teacher) allow causes cancer or (genetic) mutation ignore references to contamination	1 1	AO1.1 6.4.2.1 WS 1.4	E

6.4.2.1 Radioactive decay and nuclear radiation

Answer 03 · Mark scheme

06.5	a calculation of the product of thickness and count rate a second calculation of the product of thickness and count rate a comparison of the calculated values and a recognition that they are different **OR** A calculation of half the count rate (1) A comparison with the count rate for double that thickness (1) A recognition that the values are different (1)	examples of calculations 0.5 × 110 = 55 1.0 × 60 = 60 1.5 × 33 = 50 2.0 × 18 = 36 2.5 × 10 = 25 e.g. $\frac{110}{2}$ = 55 the first two marks may be scored for a count rate divided by 3, 4 or 5 compared with the corresponding count rate for 3, 4 or 5 times the thickness e.g. 55 ≠ 60	1 1 1	AO3.1b 6.4.2.1	E
06.6	$^{140}_{57}La \longrightarrow {}^{0}_{-1}e + {}^{140}_{58}Ce$	allow **1** mark for correct numbers on electron allow **1** mark for correct numbers on Ce	2	AO1.1 AO1 in isolation AO1.2 6.4.2.2	E

Answer 03 · Mark scheme

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

06.7		an answer of $\frac{1}{32}$ or equivalent scores **4** marks		AO3.1a 6.4.2.3	E
	half-life = 50 seconds	this may be indicated on Figure 7	1		
	250 seconds difference in age = 5 half lives	allow 100 seconds = 2 half lives **and** 350 seconds = 7 half lives	1		
	ratio = $\left(\frac{1}{2}\right)^5$ **or** ratio = $\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}\times\frac{1}{2}$	allow this mark if they have halved 1.25(× 10^{23}) five times to get 0.0390625(× 10^{23}) for example 1.25(× 10^{23}) → 0.625(× 10^{23})→ 0.3125(× 10^{23})→ 0.15625(× 10^{23}) → 0.078125(× 10^{23})→0.0390625(× 10^{23})	1		
	ratio = $\frac{1}{32}$ **or** ratio = 1:32	allow ratio = 0.031 allow 32:1 **or** 32	1		
06.8	tangent drawn on graph	do not allow a line drawn that crosses the graph line	1	AO2.2 6.4.2.1	E
	use of gradient = $\frac{(\Delta \text{ no. of atoms})}{\Delta \text{ time}}$	values must be taken from their tangent drawn at 20 seconds	1		
	gradient = 5.3 (× 10^{21}) (Bq)	allow gradient = 0.053 (× 10^{23}) (Bq) allow a range between 4.7 (× 10^{21}) (Bq) and 5.9 (× 10^{21}) (Bq)	1		
Total			**18**		

6.4.2.1 Radioactive decay and nuclear radiation

Answer 04 · Mark scheme

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

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.1	A = 206		1	AO2 6.4.2.2
02.2	Z = 82		1	AO2 6.4.2.2
02.3	89 39	numbers must be in this order	1 1	AO2 6.4.2.2
02.4	electromagnetic waves		1	AO1 6.4.2.1

6.4.2.1 Radioactive decay and nuclear radiation

Answer 04 · Mark scheme

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

Question	Answers	Mark	AO / Spec. Ref.
02.5	**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 04 · Mark scheme

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

6.4.2.1 Radioactive decay and nuclear radiation

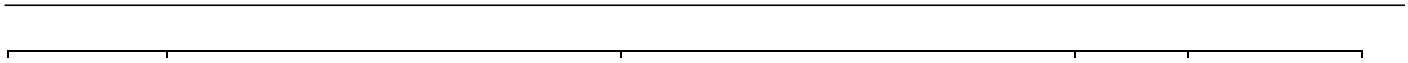
Answer 05 · Mark scheme November 2020 | 8464/P/1H | Original Q6

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.1	both are random processes	allow rolling dice is a random process allow radioactive decay is a random process	1	AO1 6.4.2.3
06.2	144 →72 → 36 →18 → 9 4 half lives $\frac{20}{4}$ = 5 (rolls of the dice)	allow the probability of not getting a 6 is 5/6 allow 144 × $(5/6)^4$ = 69 allow 69 is closest to 72 so 4 (rolls of the dice) some credible working must be shown to gain this mark	1 1 1	AO2 6.4.2.3
06.3	a dice with 8 sides will have a smaller chance of decay (in one roll) so dice with 8 sides have a greater half-life	allow answers in terms of the 6-sided dice or in terms of more or fewer sides. allow the 8 sided dice has a 1/8 chance of decay, whereas the 6 sided dice has a 1/6 chance of decay	1 1	AO1 6.4.2.3
06.4	nuclei in source **A** are more stable than nuclei in source **B**	allow nuclei in source A are less likely to decay (in a given time period)	1	AO1 6.4.2.3
Total			**7**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 05 · Mark scheme

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



6.4.2.1 Radioactive decay and nuclear radiation

Answer 06 · Mark scheme

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

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

6.4.2.1 Radioactive decay and nuclear radiation

Answer 06 · Mark scheme

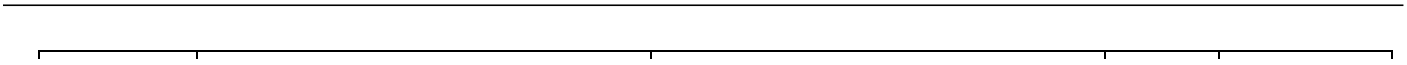
November 2021 | 8464/P/1H | Original Q2

Question	Answers	Mark	AO / Spec. Ref.
02.4	**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 06 · Mark scheme

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



6.4.2.1 Radioactive decay and nuclear radiation

Answer 07 · Mark scheme

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

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1	different temperatures emit different intensities of infrared which are represented (on the infrared camera) as different shades / colours	 allow wavelength / frequency / amount for intensity throughout	1 1	AO1 AO3 6.6.2.4
05.2	visible light		1	AO3 6.6.2.1
05.3	both ionising radiation so some risk of cancer the whole body is irradiated by gamma rays when an X-ray is taken only part of the body is exposed exposure time for gamma rays is longer		1 1 1 1	AO1 AO3 AO3 AO3 6.6.2.3
05.4	$1.2 \times 10^{-13} = F \times 0.015$ $F = \frac{1.2 \times 10^{-13}}{0.015}$ $F = 8.0 \times 10^{-12}$ N	 allow a correct rearrangement using an incorrectly / not converted value of s allow 8×10^{-12} allow a correct calculation using an incorrectly / not converted value of s	1 1 1	AO2 6.5.2

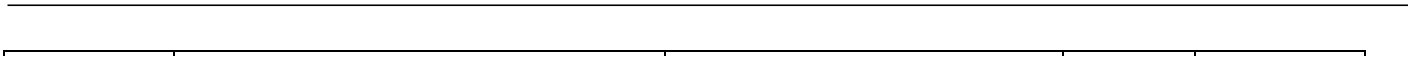
6.4.2.1 Radioactive decay and nuclear radiation

05.5	some of the energy of the electrons causes heating (therefore) increasing the temperature (so using tungsten) allows more electrons to be collided per second than using any other metal	 allow (so using tungsten) enables more energy per second to be transferred than using any other metal	1 1 1	AO1 AO3 AO3 6.5.2
Total			**13**	

6.4.2.1 Radioactive decay and nuclear radiation

Answer 07 · Mark scheme

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



6.4.2.1 Radioactive decay and nuclear radiation

Answer 08 · Mark scheme

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

Question 6

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.1	beta radiation is more penetrating (than alpha radiation)	allow beta radiation can pass through the case (but alpha radiation cannot) allow beta radiation can travel further (in air than alpha radiation) do **not** allow beta radiation is more ionising	1	AO1 6.4.2.1 6.4.2.4
	so beta radiation could irradiate people passing near the smoke detector	allow beta radiation can pass through skin	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.2	A = 227 Z = 89		1 1	AO1 AO2 6.4.2.2 6.4.2.1 6.4.1.2

6.4.2.1 Radioactive decay and nuclear radiation

Answer 08 · Mark scheme

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

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.3	(some) radiation is stopped by paper		1	AO3 6.4.2.1
	so the source emits alpha radiation	MP2 dependent on MP1	1	
	and (some) radiation passes through paper but is stopped by aluminium		1	
	so the source emits beta radiation (but does not emit gamma)	MP4 dependent on MP3	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
06.4	D B A C	all four letters must be in the correct order explanation only scores if correct order given	1	AO3 6.4.2.1 6.4.2.3
	explanation			
	a substance with a longer half-life has more stable nuclei	allow the more stable a nucleus, the less likely it is to decay (in a given time)	1	
	so answers are in order of increasing half-life		1	

Total Question 6		11

Question 4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.1	peer review		1	AO1 6.4.2.4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.2	it is ionising	ignore references to penetrating ability	1	AO1 6.4.2.4 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.3	becquerel / Bq		1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.4	not all the radiation emitted (by the sample) is detected (because) the radiation spreads out **or** (because) some radiation is absorbed before reaching the detector **or** (because) some of the radiation entering the detector is **not** detected	 allow because the radiation is emitted in all directions	1 1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.5	alpha radiation because the radiation is not detected beyond 5 cm **or** because alpha radiation cannot travel 10 cm (in air) **or** because beta **and** gamma radiation would be detected at 10 cm	 dependent on MP1 allow because alpha radiation cannot travel more than a few cm (in air)	1 1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.6	60 minutes is 4 half-lives 30 minutes is 2 half-lives X = 392	allow 15 minutes is 1 half-life allow 1568 → 784 → 392 → 196 → 98 allow $\frac{1568}{98} = 2^4$ allow $\frac{98}{1568} = \frac{1}{2^4}$	1 1 1	AO3 6.4.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.7	radioactive decay is a random process		1	AO1 6.4.2.3

Total Question 4	**11**

6.4.2.1 Radioactive decay and nuclear radiation

Answer 10 · Mark scheme

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

Question 1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.1	**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.
01.2	**Similarity** any **one** from: • same speed (in a vacuum) • both transfer energy • both transverse	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	1	AO1 6.6.2.2
	Difference any **one** from: • gamma has a higher frequency • gamma has a shorter wavelength • gamma is more ionising • gamma is more penetrating	allow gamma has more energy	1	

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

Answer 10 · Mark scheme

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

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

Question	Answers	Extra information	Mark	AO / Spec. Ref.
01.5	$3.0 \times 10^{8} = f \times 5.0 \times 10^{-7}$ $f = \frac{3.0 \times 10^{8}}{5.0 \times 10^{-7}}$ $f = 6 \times 10^{14}$ (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 1	9

6.4.2.1 Radioactive decay and nuclear radiation

Answer 11 · Mark scheme

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

Question 2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.1	2 protons and 2 neutrons	ignore helium nucleus	1	AO1 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
02.2	118		1	AO1 6.4.1.2

Question	Answers	Mark	AO / Spec. Ref.
02.3	**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 11 · Mark scheme

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

Total Question 2	**9**

6.4.2.1 Radioactive decay and nuclear radiation

Answer 12 · Mark scheme

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

Question 5

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.1		allow risk for hazard throughout		AO1 6.4.2.4
	Irradiating **EITHER** radiation enters the water	allow alpha / beta / gamma enters the water allow the water does not become radioactive	1	
	(which) does not affect the hazard	dependent on MP1	1	
	OR because radiation can kill pathogens (1)	allow named pathogens e.g. bacteria, viruses		
	(irradiating) decreases the hazard (1)	dependent on MP1		
	contaminating because radioactive isotopes will enter the water / body		1	
	(contaminating) increases the hazard	dependent on MP3	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.2	$^{52}_{23}V \rightarrow {}^{52}_{24}Cr + {}^{0}_{-1}\beta$		1	AO2 6.4.2.2

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.3	**radon-222** activity remained (almost) the same	allow the radiation emitted (each second) decreased by a small amount	1	AO3 6.4.2.3
	because 7.4 minutes is only a very small fraction of 3.8 days	allow 7.4 minutes is much smaller than 3.8 days allow the time is much less than the half-life	1	
	vanadium-52 activity decreased by a factor of 4		1	
	because 2 half-lives had passed		1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
05.4	peer review		1	AO1 6.4.2.4

Total Question 5	10

6.4.2.1 Radioactive decay and nuclear radiation

Answer 13 · Mark scheme

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

Question 4

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.1	*alpha particle* (a particle consisting of) two neutrons **and** two protons (from the nucleus) *beta particle* (a high-speed) electron (from the nucleus) *gamma ray* (a high frequency / energy) electromagnetic wave / radiation (from the nucleus)	allow helium nucleus	1 1 1	AO1 6.4.2.1

Question	Answers		Extra information	Mark	AO / Spec. Ref.
04.2	198	0	**1** mark for the top row	1	AO1 6.4.2.2
	80	–1	**1** mark for the bottom row	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.3	2.75 (days)	allow 2.7 to 2.8 allow an answer consistent with a correct pair of values for activity allow **1** mark for a horizontal line drawn from 11	2	AO2 6.4.2.3

6.4.2.1 Radioactive decay and nuclear radiation

Answer 13 · Mark scheme

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.4	activity = 6.0 (kBq)	subsequent marks may be awarded if an activity of 7.0 (kBq) is used	1	AO3
	$\frac{22-6.0}{22}\times 100$		1	AO2
	72.7…(%)		1	AO2
	73 (%)	allow a percentage calculated using data from the graph given to two significant figures	1	AO2 6.4.2.3

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.5	Any **two** from: • beta only has a short range (in tissue) • increases the chance of killing the cancer cells • decreases the risk to healthy cells		2	AO3 6.4.2.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
04.6	the risk of removing the sample is greater than the risk of leaving the sample in the patient **or** the activity will reduce to a safe level in a short time	allow the risk of leaving the sample in the patient is very small	1	AO3 6.4.2.1 6.4.2.4

Total Question 4	14

6.4.2.1 Radioactive decay and nuclear radiation

Answer 01 · Examiner comments

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

Question 1 (Standard demand)

01.1 This question required students to label diagrams with given labels and the majority gained all 4 marks.

01.2 59% of students scored zero on this item. Of the students who gained 1 mark, this was usually for identifying that a proton has a positive charge. Many answers were ambiguous.

01.3 Students were required to calculate 7 per cent of the speed of light and many students managed to do this from either multiplying by 0.07, by 7/100, or by finding 10%, 5% and 1% or similar and adding appropriately. Occasionally the latter method led to a wrong answer because adding large numbers with plenty of zeros it was possible to slip a zero somewhere and so only the method mark was gained.

The most common mistake arose when students simply multiplied 300,000,000 by 7. Problems arose when students either used a totally incorrect method, struggled with the arithmetic, or then went on to calculate 93% instead. A fifth of students scored zero marks.

01.4 Nearly 40% of students scored a mark on this question with 27% scoring two marks.

The range of values acceptable for full marks ensured that most students who knew what to do gained the two marks.

A few students obtained an incorrect ratio these could gain one mark if they then calculated correctly with their ratio value. Some students assumed that they needed to measure radii, these students were more likely to get an incorrect ratio with smaller measurements and the centre not clearly defined. Some chose a number to multiply by with no evidence of a ratio attempt, or substituted the 2.5 from the hydrogen radius with a measurement of 7.5 or similar from the magnesium diagram.

Powers of 10 were confusing for weaker students – some changed the 10^{-11} by multiplying, adding or subtracting this power

6.4.2.1 Radioactive decay and nuclear radiation

Answer 02 · Examiner comments

June 2018 | 8464/P/1H | Original Q4

Question 4 (Standard/high demand)

04.1 51% of students knew what an alpha particle consists of.

04.2 70% of students knew that a particle of beta radiation has a negative charge.

04.3 63% of students knew that gamma radiation has a very long range in air.

04.4 45% of students scored marks on this question. Students who failed to score often understood there is a risk associated with nuclear radiation but were unable to relate that to the changing levels of radiation with time. There were lots of misconceptions about half-life, the most common being that iodine-131 would not emit any radiation after two half-lives.

6.4.2.1 Radioactive decay and nuclear radiation

Answer 03 · Examiner comments

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

Question 6 (High demand)

06.1 Just under half of students gained this mark.

06.2 Slightly less than 30% of students gained this mark for identifying that gamma radiation is weakly ionising or very penetrating.

06.3 Around 10% of students gained marks on this question. There was a very common apparent misunderstanding about what is meant by the term count-rate, with many students stating that the count-rate is the total number of decays that have happened since the radioactive source was created. It was also quite common to see answers about the random nature of decay making the count-rate unpredictable.

06.4 While about a quarter of all students gained at least 1 mark on this question, very few gained both marks. The most common reason for gaining a mark was mentioning a cancer risk. Many students stated that standing away from the source would prevent irradiation completely, rather than reducing the level of irradiation and therefore reducing the risk. A common misconception was that if the teacher stood closer to the experiment then this would affect the results.

06.5 The concept of inverse proportion was not understood well. Many students incorrectly described inverse proportion as being a straight line with a negative gradient and illustrating that this was not the trend shown by pointing out that the count-rate decreased by different amounts each time an extra half centimetre of lead was introduced. Around 13% of students gained marks for their response to this question.

06.6 Around 40% of students could recall the atomic and mass numbers which go with an electron, and around a quarter of all students gained both marks on this question.

06.7 This question was aimed at the highest-attaining students, and required a high level of logical thought to arrive at the correct answer. Over a fifth of students managed to gain at least 1 mark, with just under 6% of students scoring all four marks.

06.8 This question was also aimed at the highest-attaining students and tested some of the maths content of the new science specifications at GCSE. Just under 6% of students attempted to draw a tangent on the graph, and therefore gained some credit. Many of

6.4.2.1 Radioactive decay and nuclear radiation

Answer 03 · Examiner comments June 2019 | 8464/P/1H | Original Q6

those who attempted to calculate the gradient of the tangent divided the change in x by the change in y, giving an incorrect answer.

6.4.2.1 Radioactive decay and nuclear radiation

Use of statistics

Statistics used in this report may be taken from incomplete processing data. However, this data still gives a true account on how students have performed for each 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 06 · Examiner comments November 2021 | 8464/P/1H | Original Q2

Question 02 (Standard demand)

02.1 This question was answered correctly by roughly 40% of students.

02.2 Around a third of students gained both marks, with approximately half gaining one mark.

02.3 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. The mark was gained by just under a fifth of students.

02.4 Most students struggled to answer this question, with many struggling 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 one in ten students did not attempt to answer the question, and most answers did not give enough information to move out of level 1.

Answer 07 · Examiner comments November 2021 | 8464/P/2H | Original Q5

Question 5 (standard/high demand and high demand)

05.1 Only 10% of students scored marks on this question. At high demand it is expected that where a question follows a figure, students should use information from the figure. Very few students linked the amount of infra-red radiation to temperature, or stated that different temperatures are displayed at different colours, despite that information being given in Figure 8.

05.2 This was a demanding question - students had to compare wavelengths given in nm and mm and in standard form. They then had to use their understanding of the electromagnetic spectrum. Less than 30% of students answered this question correctly.

05.3 The vast majority of the 40% of students that scored marks on this question only scored 1 mark, and that was mostly for saying that there is some risk of cancer with both.

05.4 This question performed as expected with 30% of students scoring 2 marks. Only 8% of students included the conversion to gain full marks.

6.4.2.1 Radioactive decay and nuclear radiation

Answer 07 · Examiner comments November 2021 | 8464/P/2H | Original Q5

05.5 20% of students gained at least 1 mark. Most of those stated that the energy from the electrons would cause heating and increase the temperature. Some went on to say that tungsten could be heated to a higher temperature than any other metal. No student scored full marks for explaining this meant that more electrons could be collided.

Question 06 (Standard/high and high demand)

06.1 Nearly two thirds of students gained some credit on this question, but only about one in ten students scored both marks.

Most students correctly contrasted the penetrating ability of alpha and beta radiation. There was some confusion evident between contamination and radiation in many answers. Some students suggested that beta radiation would have a chemical reaction with smoke, causing the smoke detector not to work.

06.2 Just over 40% of students gained both marks for determining the nucleon and proton numbers.

06.3 Approximately 50% of students gained some marks on this question, with most of them gaining 2 marks. Very few students gained 3 or 4 marks.

The concept of there being two different types of radiation being emitted by the same source proved to be very difficult for students. Most answers which gained two marks identified that some of the radiation passed through paper, and it was all stopped by aluminium, and therefore beta radiation must be present. It was far less common for students to recognise that most of the radiation was stopped by paper, and to then suggest that alpha radiation must be present.

A fair number of students suggested that the radiation that was transmitted through the paper and stopped by aluminium would be alpha radiation. These students still gained marking point 3, despite drawing an incorrect conclusion from the data.

Many student responses recited facts that students had learned about the different types of nuclear radiation, but failed to apply it to this situation. Stating that alpha radiation is stopped by paper, beta by aluminium, and gamma stopped by lead, for example, was not sufficient to gain any marks.

Some students demonstrated confusion about nuclear radiation, with statements that paper was emitted by alpha radiation, or that alpha radiation was emitted by paper, being suggested by a small proportion of students.

06.4 Just under 10% of students gained some credit on this question, with about half of these gaining more than one mark.

Most students did not attempt to determine the half lives of the four isotopes, and answers based on gradients of each line, the change in activity of each isotope or comparisons of the initial activity of each sample led to incorrect orders of stability, so gained no marks.

6.4.2.1 Radioactive decay and nuclear radiation

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 09 · Examiner comments June 2023 | 8464/P/1H | Original Q4

Question 04 (Standard, standard/high and high demand)

04.1 Only about a fifth of students correctly identified peer review as the process. It was common for students to suggest peer assessment, and some students wrote about double-blind trials.

04.2 About 35% of students answered this question correctly. Many students answered by giving a type of radiation (alpha, beta, or gamma) rather than stating a property.

04.3 Just under a quarter of students gave the correct unit. Phonetic spelling was acceptable, but if students abbreviated their answer to Bq, they had to use a capital B and a lower case q.

04.4 About 20% of students scored at least 1 mark on this question. Some suggested the idea of background radiation, which was not relevant to answering the question and is not mentioned on this specification. A number of students confused count-rate with half-life, and some students suggested that the radiation would be too fast for the detector to detect.

04.5 Approximately 55% of students identified that alpha radiation was emitted by the source, but only about a fifth of students could explain how the data showed this. Stating that alpha has a low range in air was too vague to gain the mark. Other answers which were insufficient for the second marking point included that it was alpha because as distance increases the count rate decreases.

04.6 Around a third of students gained all three marks on this calculation, with most other students scoring no marks. It was reasonably common for students to calculate 1568/98, and decide that 16 half-lives had passed, which scored no marks. Another common incorrect answer was to find the value halfway between 1568 and 98.

04.7 Just over 70% of students selected the correct answer, that radioactive decay is a random process.

6.4.2.1 Radioactive decay and nuclear radiation

Answer 10 · Examiner comments June 2023 | 8464/P/2H | Original Q1

Question 1 (Standard demand)

01.1 60% of students correctly identified all three parts of the electromagnetic spectrum and scored both marks. However, 30% of students scored no marks.

01.2 50% of students were able to gain at least one mark on this question. The similarity was more accessible and was how the majority of the 35% that scored one mark got the mark. Many identified that both waves are transverse. For the difference, most students did not refer to a property of electromagnetic waves.

01.3 A little over 65% of students correctly identified that the process is called refraction.

01.4 Over 99% of students gained the mark. Students were given the equation sheet, which will have contributed to the overall performance on this question.

01.5 Over 70% 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 11 · Examiner comments

Question 2 (standard demand)

02.1 Most students were unable to accurately recall the structure of an alpha particle, with about 40% giving a full description.

02.2 The number of neutrons was correctly determined by nearly 85% of students.

02.3 Most students were able to make a good attempt at this question. The majority recalled a reasonable level of detail of at least one of the two atomic models, and many students gave some account of how the evidence led to the replacement of the plum pudding model with the nuclear model.

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.

A number of students described the ionising and penetrating properties of alpha particles, which did not prevent credit from being awarded, but was not relevant to answering the question.

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.

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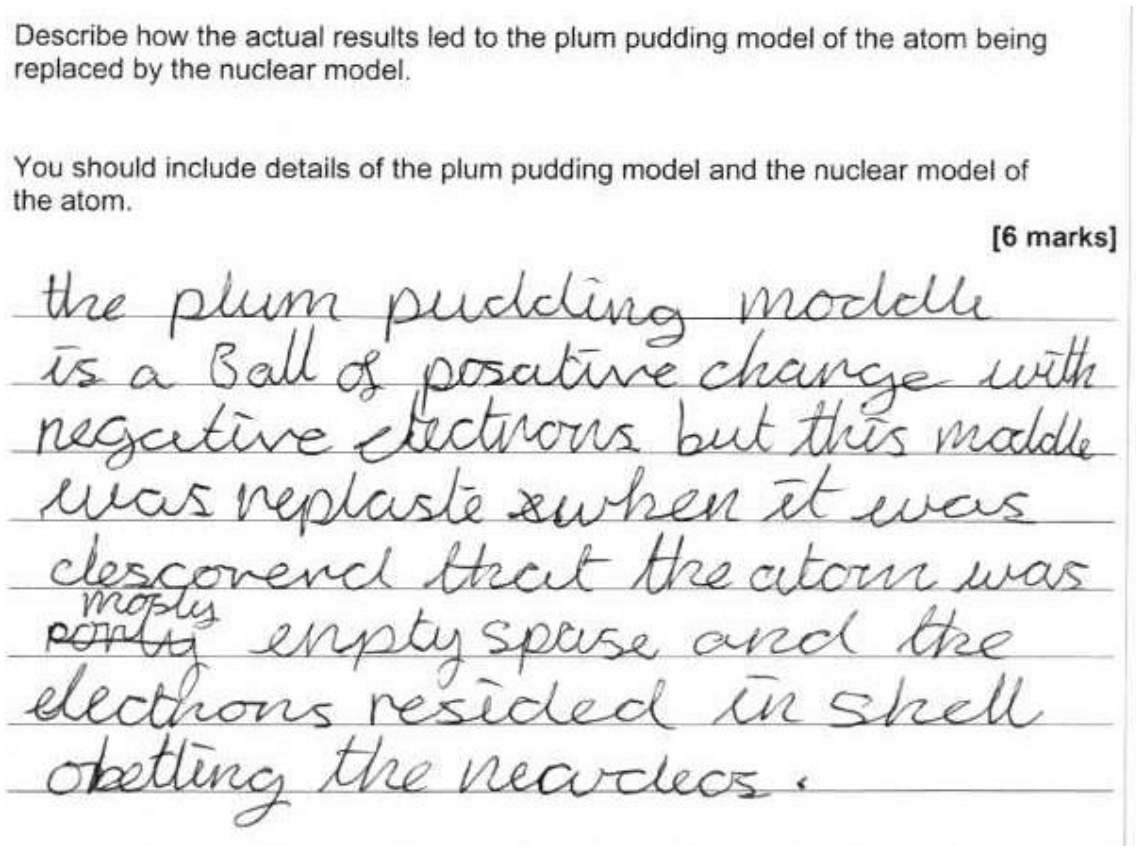
6.4.2.1 Radioactive decay and nuclear radiation

Answer 11 · Examiner comments June 2024 | 8464/P/1H | Original Q2

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 Foundation tier 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 11 · Examiner comments June 2024 | 8464/P/1H | Original Q2

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 ~~plum~~ 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.

02.4 About 55% of students correctly identified the scientist who provided evidence for the existence of neutrons.

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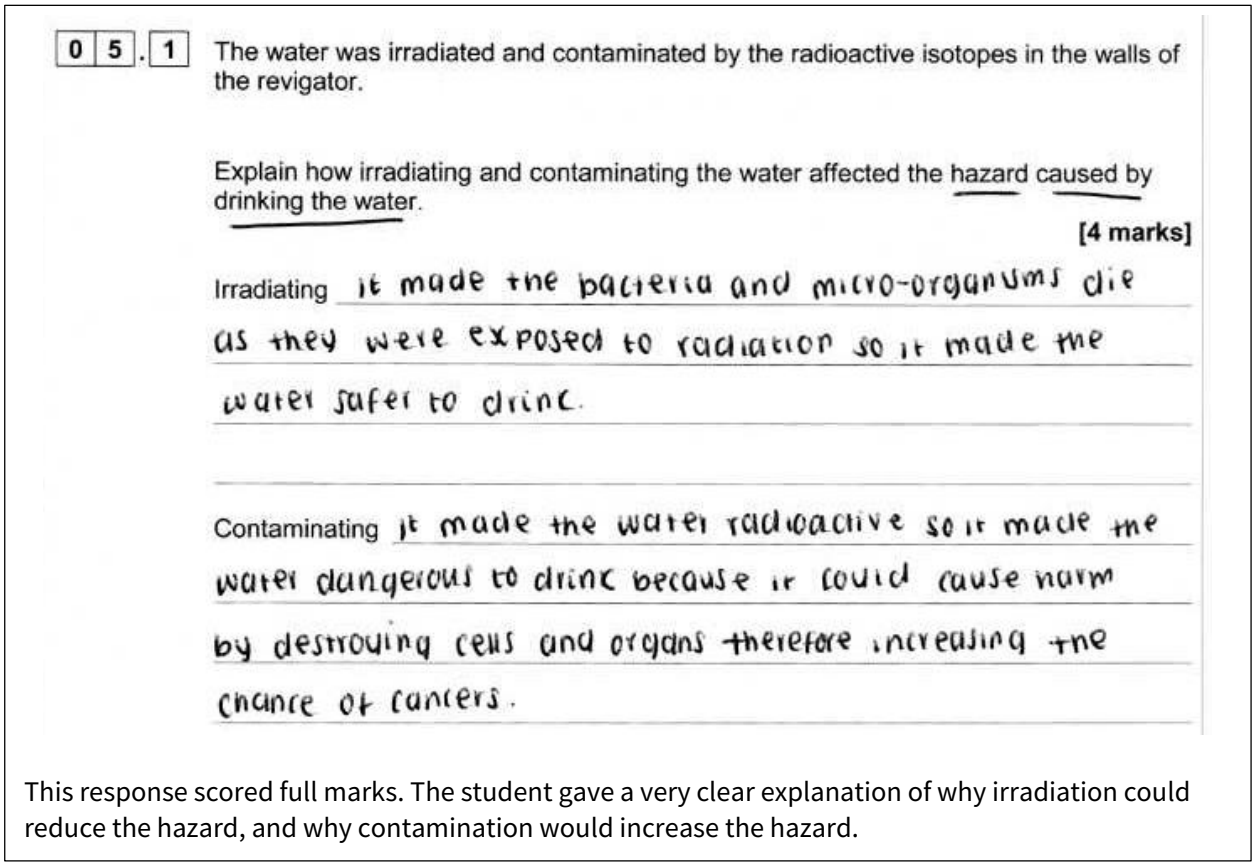
Answer 12 · Examiner comments

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

Question 5 (standard/high & high demand)

05.1 Just over 40 % of students gained some credit on this question, but very few scored full marks. Many students showed confusion between a radioactive substance and the radiation emitted by that substance.

It was quite common for students to have some grasp of the meaning of contamination, but a surprisingly large proportion of students wrote answers referring very clearly to bacterial contamination of the water, rather than contamination by the radioactive isotopes.



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

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

[4 marks]

Irradiating it made the bacteria and micro-organisms die as they were exposed to radiation so it made the water safer to drink.

Contaminating it made the water radioactive so it made the water dangerous to drink because it could cause harm by destroying cells and organs therefore increasing the chance of cancers.

This response scored full marks. The student gave a very clear explanation of why irradiation could reduce the hazard, and why contamination would increase the hazard.

05.2 Less than half of all students selected the correct nuclear equation.

05.3 While nearly two-thirds of students gained some credit on this question, less than 5% scored all 4 marks. A lot of students demonstrated some knowledge of how activity changes with time, but there were also a number of misconceptions that were revealed by answers to this question.

Some students worked out that two half-lives would have passed for vanadium, but then went on to state that this meant that a ‘full life’ had passed so no more radiation would be emitted by the sample. Other students linked the mass number of the element with the half-life, and it was common to read answers suggesting that after two half-lives, vanadium-52 would have become vanadium-13.

It was also relatively common to see answers suggesting that the activity of a sample during a half-life would remain constant until the half-life was reached. At this point activity would then suddenly halve. This misconception was demonstrated by statements such as ‘Radon has not reached a half-life, so its activity has not changed’, which would still score marking point 1.

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6.4.2.1 Radioactive decay and nuclear radiation

Answer 12 · Examiner comments June 2024 | 8464/P/1H | Original Q5

A small number of students suggested that the half-life would change as time increased, and some students suggested that activity would increase with time.

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

Table 2

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

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

The scientist repeated the measurements 7.4 minutes later.

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

[4 marks]

Radon-222 the radon-222 has not changed at all as its half life is 3.8 days this means that it won't change until that point

Vanadium-52 3.7×2=7.4 => enough time for 2 half-lifes.

• from vanadium-52 -> Vanadium-13

The response about Radon demonstrates the misconception that activity remains constant, and then suddenly halves when the half-life is reached.

The response about vanadium illustrates the misconception that the mass number of an element will decrease by a factor of two for each half-life that passes.

05.4 About a third of students identified the process as peer review.

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Answer 13 · Examiner comments

Question 4 (Standard/high and high demand)

04.1 Some students misinterpreted the question and did not describe an alpha particle, beta particle, and gamma ray, but described their properties. 50% of students were able to correctly describe one of them, but only 20% correctly described all three.

04.2 40% of students gained both marks. The majority of the 15% of students who only gained one mark, made a mistake on the bottom row.

04.3 60% of students gained a mark on this question. 10% of students correctly drew the line from 11, but either the line was not drawn accurately enough, or they then mis-read the scale on the *x*-axis. 50% of students gained both marks.

04.4 80% of students were able to get started on this question by correctly reading the activity as 6.0 (kBq) but could not get any further. Many of those that failed to gain any further calculation marks worked out what 6.0 was as a percentage of 22. 40% of students gained the 3 calculation marks. The mark for the correct significant figures was still awarded if an error had been made in the calculation.

04.5 Students found this high demand question challenging. 30% of students did gain a mark and most of those answered that the sample being very near to the cancer cells decreases the risk to healthy cells. Less than 5% of students gained two marks for also saying that beta only has a short range. Very few students stated that it increased the chance of killing the cancer cells.

04.6 20% of students gained the mark on this high demand question. There were approximately equal numbers of answers that stated the risk of removing the sample is greater than the risk of leaving the sample in the patient and answers that stated the activity will reduce to a safe level in a short time. A common incorrect answer was that it would protect the patient if the cancer returned, most students did not appreciate the short half-life of the gold-198.

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