AQA GCSE Combined Science - Trilogy | 8464

SPECIFICATION POINT 6.4.2.3

Half-lives and the random nature of radioactive decay

Mark schemes and examiner comments

Tier	**Higher**
Question groups	**6**
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.

6.4.2.3 Half-lives and the random nature of radioactive decay

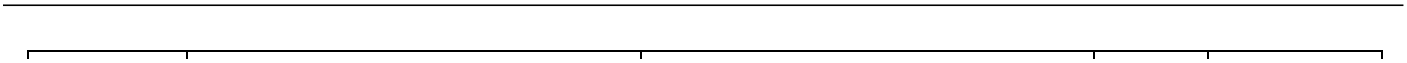
Answer 01 · Mark scheme June 2018 | 8464/P/1H | Original Q4

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**	

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 01 · Mark scheme

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



6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 02 · 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

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 02 · 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

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Answer 02 · 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**		

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 03 · Mark scheme

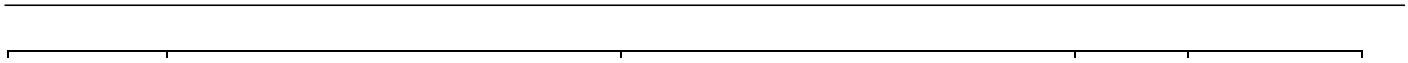
November 2020 | 8464/P/1H | Original Q6

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**	

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 03 · Mark scheme

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



6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 04 · Mark scheme

June 2023 | 8464/P/1H | Original Q4

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

Answer 04 · Mark scheme

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**

6.4.2.3 Half-lives and the random nature of radioactive decay

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

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 05 · Mark scheme

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

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 06 · 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 80 –1	**1** mark for the top row **1** mark for the bottom row	1 1	AO1 6.4.2.2

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

Answer 06 · 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**

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 01 · 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.

Answer 02 · 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

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 02 · 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.

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 02 · Examiner comments

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.

6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 04 · 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.

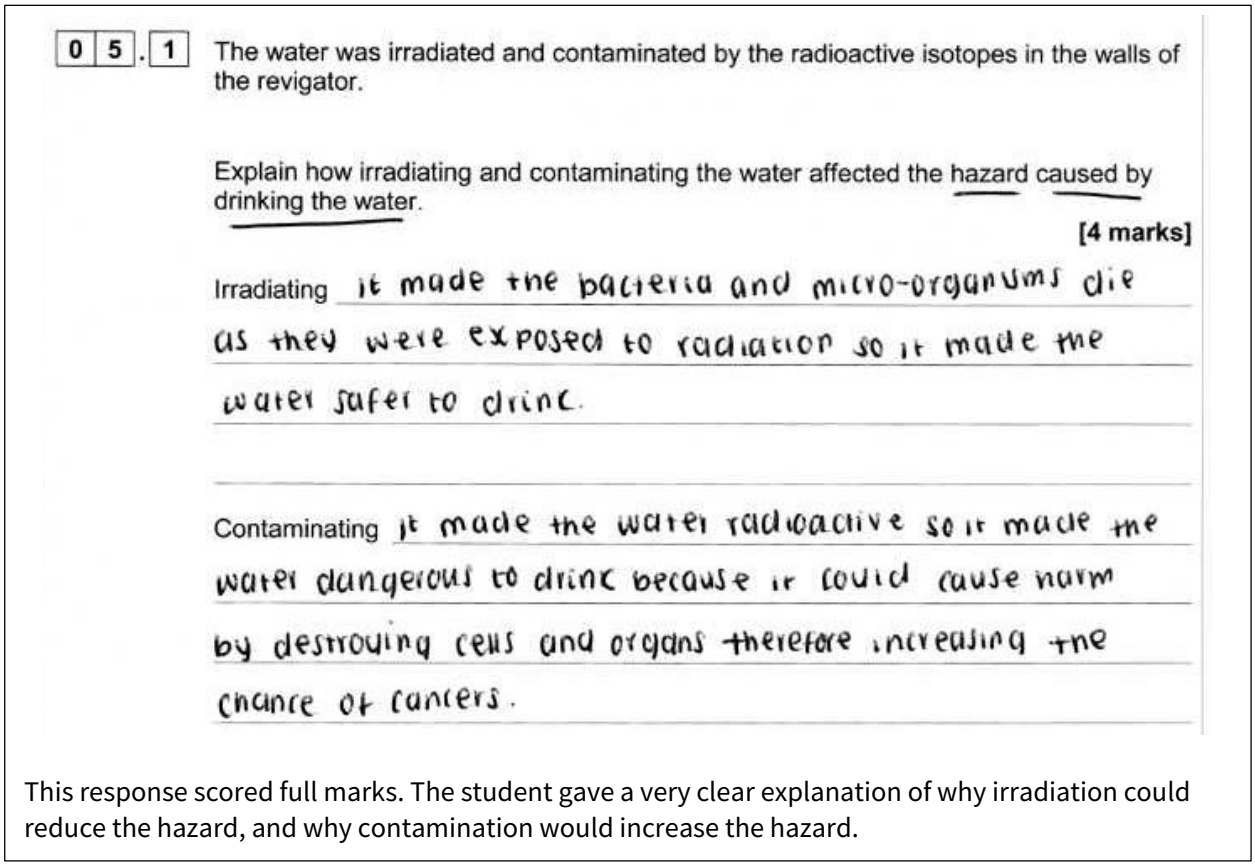
Answer 05 · Examiner comments

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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6.4.2.3 Half-lives and the random nature of radioactive decay

Answer 05 · 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 06 · 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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