1. Mike works in a laboratory where there are radioactive materials.

He must not touch these materials.

Some emit beta particles, others emit alpha particles.

He has to stand behind a shield when dealing with beta particles.

He does not need the shield when dealing with alpha particles.

Explain the need for these safety precautions and why they are different for alpha and beta particles.

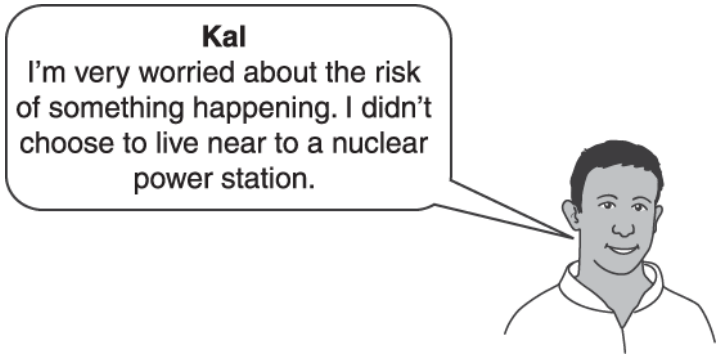
The quality of written communication will be assessed in your answer.

---

[6]

2. Kal lives near to a site where it is proposed to build a new nuclear power station.

Kal discusses his concerns with his friend Mary.



Suggest some ideas that Mary could use to reassure Kal.

--- [3]

3(a). Radioactive materials are used in hospitals.

Radioactive tracers allow the doctor to investigate organs in a patient's body without surgery.

The radioactive tracer can be injected into a patient's vein.

The doctor has this information about the activity from three radioactive tracers that emit gamma rays.

Tracer	Activity (counts per minute)		
	At start	After 1 hour	After 2 hours
A	1000	700	500
B	1000	500	250
C	1000	250	60

The doctor wants to use a tracer with a half-life of 1 hour.

Which tracer should the doctor choose?
Justify your choice.

[2]

(b). The doctor wants Sally to be investigated using this radioactive tracer. Sally is anxious about this. She knows that gamma rays can cause cancer.

Suggest what the doctor might say to Sally to reassure her.

[3]

4(a). People working with radioactive sources often wear detectors to measure how much ionising radiation they are exposed to.

One type of detector is a badge with photographic film covered by three different materials.

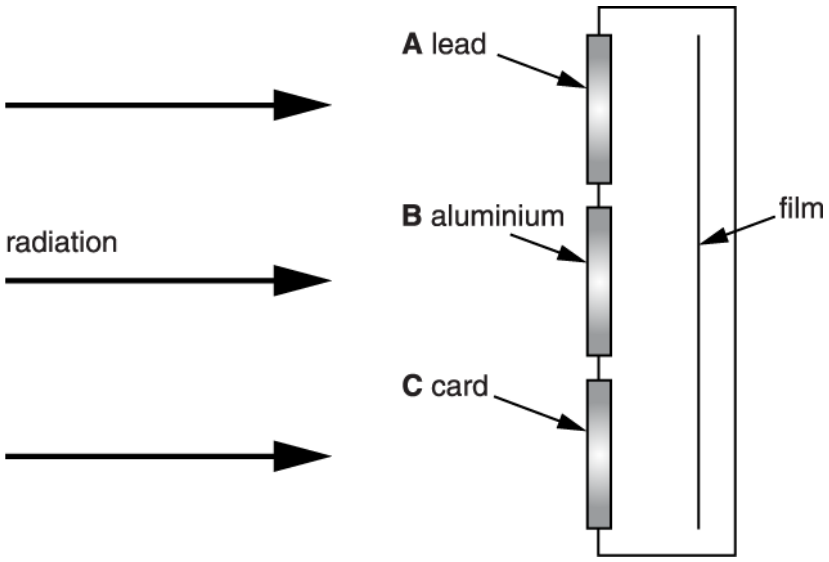
The photographic film records the amount of radiation that reaches it.

The badge has three sections.

Section **A** is covered with lead.

Section **B** is covered with aluminium.

Section **C** is covered with card.



(i) Which two sections will let gamma radiation through? _____ and _____

[1]

(ii) Which section will let beta radiation through? _____

[1]

(iii) How many sections will let alpha radiation through?

Put a (ring) around the correct answer.

0 1 2 3

[1]

(b). A different film badge has four sections.

Section **P** only allows gamma through.
Section **Q** allows gamma and X-rays through.
Section **R** allows gamma, X-rays and beta radiation through.
Section **S** allows gamma, X-rays, beta radiation and visible light through.

The amount of beta radiation can be found by comparing the film behind two sections.
Which sections can be used to detect the amount of beta radiation?
Explain your answer.

---

[2]

5. Read the following article.

> Some cancers are treated with a form of radiation therapy called brachytherapy. A small piece of material that is radioactive is placed inside a tumour. The radioactive material then decays, releasing ionising radiation that destroys the tumour.

(i) Write down words or phrases **from the article** that mean the following:

breaks down over time ---

produces ionising radiation ---

[2]

(ii) The three types of ionising radiation from radioactive materials travel different distances.

Write **alpha, beta** and **gamma** in the boxes to show how far each type of ionising radiation travels through the body.

travels the **shortest** distance → travels the **greatest** distance		
---	---	---

[1]

6(a). Radon gas comes from the ground and emits alpha radiation.

The government has regulations about how buildings must be built.

Some of these regulations are about including protection against radon gas when a house is built.

Why would radon gas in houses be dangerous to humans?

---

[2]

(b). The following chart shows the risk of cancer from exposure to different levels of radon gas.

Indoor radon level	Lifetime risk of cancer
low	less than 1 in 200
medium	1 in 190
high	1 in 100

The building regulations insist that houses in high level radon areas have radon protection measures installed.

A politician proposes that people in areas with medium levels of indoor radon should also install the protection measures and that the government should pay for the change.

How would different groups of people be affected by this change?

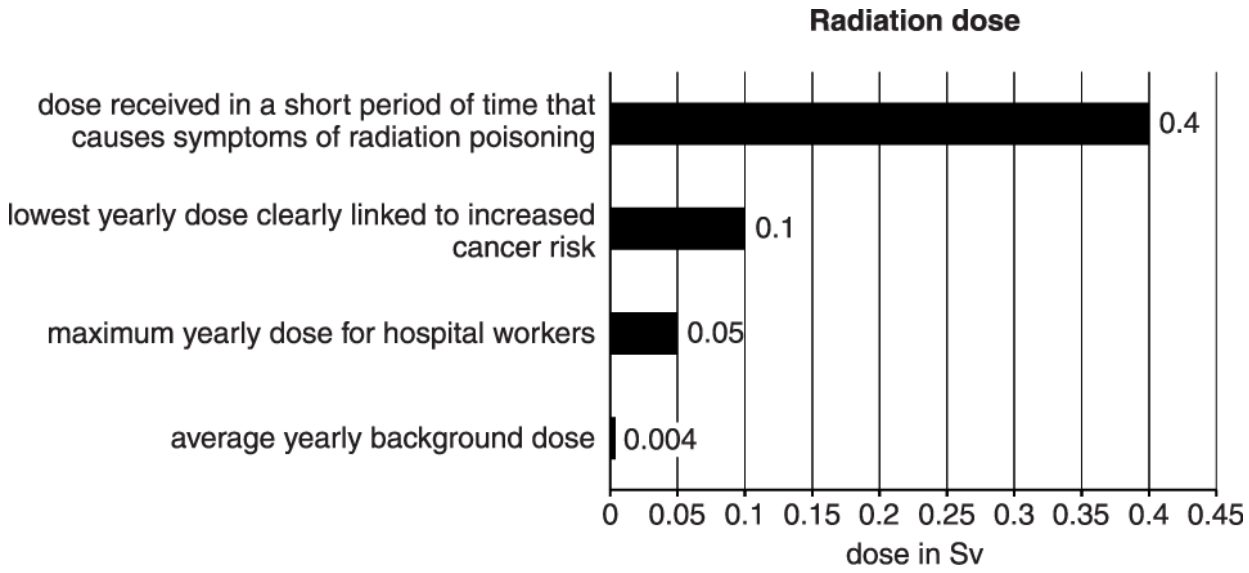
---

[3]

7. Zoe is trying to decide what job she wants to do.

She likes the idea of working in the radiology department of a hospital, but is worried about the increased risk from the radiation.

She finds the following chart.



Zoe says she does not understand what the chart is showing.
Explain what the chart shows and how it can help her to compare the risks and benefits of working in a radiology department.

The quality of written communication will be assessed in your answer.

[6]

8(a). Nuclear power stations produce radioactive waste.

The waste is categorised as high level, intermediate level and low level.

Draw a straight line from each **level of waste** to its **method of disposal**.

Level of waste	Method of disposal
High	Mix with concrete; put in steel drums; keep in purpose-built stores.
Intermediate	Store under water for many years; put in drums in an underground store.
Low	Put in drums; surround by concrete; keep in landfill sites.

[2]

(b). Wayne has been thinking about the risk to humans from radioactive nuclear waste.

Do you think this is a good idea?

Justify your answer.

---

[2]

9. A teacher handles a radioactive source very carefully to avoid the risk of **irradiation** and **contamination**.

What is meant by **irradiation** and **contamination**?

irradiation

---

contamination

---

[2]

10. Ryan has been advised by doctors that he needs to have a full-body CT scan.

The CT scan uses ionising radiation in order to produce an image of his internal organs.

Ryan is concerned as he has heard that ionising radiation can damage the body.

He has found the following information about doses of ionising radiation.

	Dose (millisievert)
Average background dose per year	2.7
Lowest dose per year definitely linked to an increase in cancer later in life	100
Fatal dose	5000
Recommended highest dose per year	50
Chest X-ray	0.10
Dental X-ray	0.01
Eating one banana or 100 g of Brazil nuts	0.01

The doctors have told Ryan that the CT scan will give him a dose of 10 millisievert.

Describe how ionising radiation can damage the body and explain why the doctors say that the benefits of a CT scan outweigh the risks.

Use the data in your answer.

The quality of written communication will be assessed in your answer.

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[6]

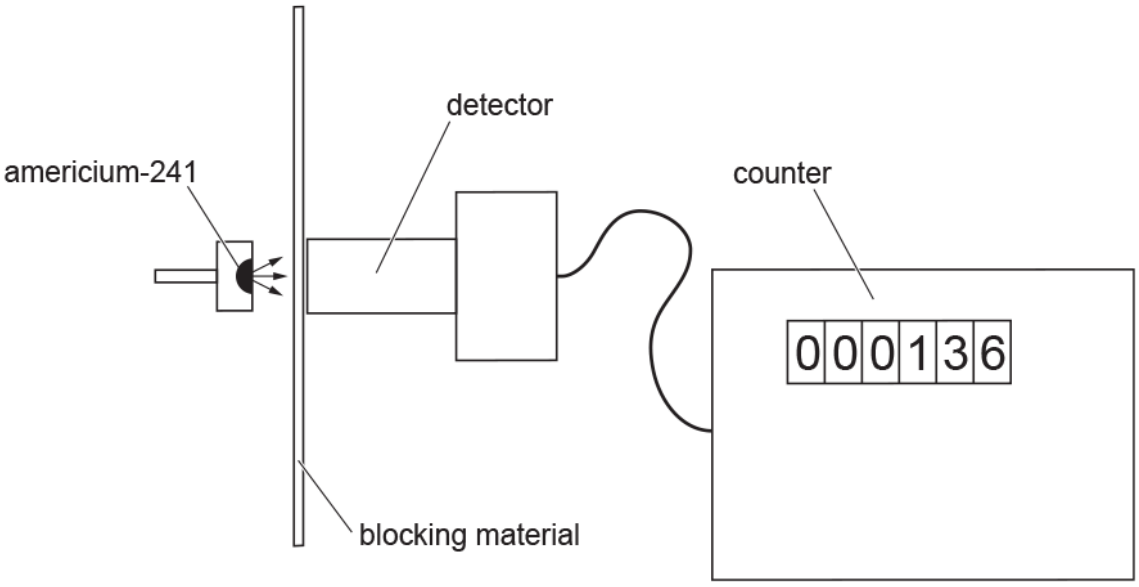
[Total: 6]

11(a) Some smoke alarms contain the radioactive isotope americium-241.

.

Two students investigate the radiation emitted by americium-241.

The diagram shows their equipment.



They recorded the number of counts detected in one minute with different blocking materials.

The table shows their results.

Blocking material	Counts per minute
nothing (just air)	620
paper	23
thin aluminium	23

(i) The students agree that americium-241 emits alpha radiation but not beta radiation.

Explain how the evidence supports this conclusion.

---

[2]

(ii) They cannot tell from their results whether americium-241 emits gamma radiation.

What should they do to decide whether the source emits gamma radiation?

[2]

(b). In fact, americium-241 emits both alpha radiation **and** gamma radiation.

Evaluate how dangerous it is to have a small amount of americium-241 in a smoke alarm.

[2]

12. There is a film about an astronaut named Mark Watney. He is left alone on the planet Mars. He has to use science to stay alive until he can be rescued.

Mars is a cold planet. Watney uses a radioactive thermal generator to heat himself. The generator contains radioactive plutonium-238 which emits alpha-particles (α).

(i) Complete the radioactive decay equation for plutonium-238.

$$^{238}_{94}\mathrm{Pu} \longrightarrow {}^{\ldots\ldots}_{\ldots\ldots}\mathrm{U} + {}^{4}_{2}\alpha$$

[2]

(ii) The radioactive plutonium-238 is sealed inside a case with thin walls made of aluminium.
The plutonium-238 emits a large number of high energy alpha-particles each second.

Two of the following statements, taken together, explain why Watney is not at any risk from irradiation.

Tick (✓) **two** boxes

Alpha particles cannot penetrate a thin sheet of paper. ☐

Alpha radiation is never dangerous. ☐

Alpha radiation is not part of the electromagnetic spectrum. ☐

The aluminium in the case is thicker and denser than thin paper. ☐

He always wears safety glasses when he handles the plutonium-238. ☐

[2]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			[Level 3] Gives reason for precautions **AND** states a feature of alpha **AND** states a feature of beta. Quality of written communication does not impede communication of the science at this level. (5 – 6 marks) [Level 2] Gives two from: reason for precautions **OR** states a feature of alpha **OR** states a feature of beta. Quality of written communication partly impedes communication of the science at this level. (3 – 4 marks) [Level 1] Gives one from: reason for precautions **OR** states a feature of alpha **OR** states a feature of beta. Quality of written communication impedes communication of the science at this level. (1 – 2 marks) [Level 0] Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)	6	This question is targeted at grades up to E Indicative scientific points may include: Need for precautions: • radiation is ionising • damage living cells / mutate • avoids contamination • kill living cells • cause cancer • break molecules into bits (ions) • ? can get through skin and get to internal organs • makes you ill / harmful (partial credit) Reasons for difference: Alpha • ? stopped by a few cm of air • ? stopped by thin sheet of paper / outer layer of skin • ? cannot get to internal organs Beta • ? can travel about 1m through air • ? stopped by thin sheet of aluminium • ? can penetrate skin • ? travels further than ? comparative - so both types of radiation mentioned but only partial credit. **Ignore** references to gamma and X-rays Use the L1, L2, L3 annotations in RM ASSESSOR; do not use ticks. Examiner's Comments

Question			Answer/Indicative content	Marks	Guidance
					Candidates who stated what they knew about the alpha and beta radiation scored well on this question. Reference to cancer was a common correct answer, although many candidates gave vague answers about radiation being dangerous. There was widespread misunderstanding of "ionisation" and many candidates saying that beta was more ionising than alpha, and that this was the reason for the need for shielding.
			Total	6	
2			any **THREE** from: risks of accident very small; lots of other things he does carry a greater risk; very little radiation escapes from power station / radiation is contained; monitoring (of radiation levels) around station; safety features (such as shielding / control rods / highly skilled staff); there is background radiation all around us;	3	**accept** lots of security / waste is safely stored away. **Examiner's Comments** Many candidates wrote about the small chances and low risk of an accident, with the more able giving some details about the safety features / control systems in the power station.
			Total	3	

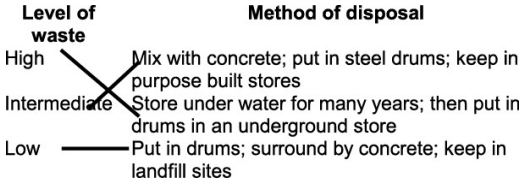
Question			Answer/Indicative content	Marks	Guidance
3	a		B (1); activity halves in 1 hour owtte (1)	2	1000 halves or gets to 500 (in one hour) **Not accept** half life is1 hour **Examiner's Comments** It was very pleasing to see the large number of candidates who understood the term half-life, could apply this to the data in the table, choose B as the correct answer, and justify their answer clearly using the data from the table.
	b		Any three from: activity decreases with time / short half life; most gamma exit body; the benefit outweighs risk; leads to a diagnosis; leads to a cure.	3	**Allow** radiation / gamma rays get weaker / not as strong /less intense / fewer gamma rays **Allow** Dr is an expert / should be trusted **Allow** chances of harm are low **Reject** gamma / radiation does not cause cancer **Examiner's Comments** Many candidates confused the use of the tracer in the question with the use of radiation to treat cancer. The idea that the risk of getting cancer from the tracer was small was understood by many candidates and gained a mark. Some of the better candidates were fully able to give good arguments that the benefits of using the tracer out-weighed the risks and that this could lead to diagnosis and then treatment of the problem.
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
4	a	i	**B** and **C**	1	**accept** card and aluminium
		ii	**C**	1	**accept** card
		iii	Ring around 0	1	Examiner's Comments This question was about the transmission of different types of ionising radiation through different materials. Most candidates correctly identified the materials which transmitted gamma and beta radiation, and some realised that none would transmit alpha radiation.
	b		**Q** and **R** **R** lets through same as **Q**, but with beta as well	1 1	 **accept** the difference between them is beta Examiner's Comments Very few candidates were able to use the information provided to write a sensible answer; although the question asked them to identify two sections of the badge which could be used to measure beta radiation, the majority of candidates chose just one. Of those who selected two sections, the vast majority plumped for those which transmitted beta radiation instead of one which did and one which didn't.
			Total	**5**	

Question			Answer/Indicative content	Marks	Guidance
5		i	decays (1) (is) radioactive (1)	2	**allow** material decays (1) **allow** radioactive material (1) **NOT** radioactive material decays **Examiner's Comments** This question was about radioactivity. Candidates were expected to recall and use ideas about ionising radiation, interpret a graph to justify a choice of radioactive substance and use ideas about benefit and risk. Overall this question differentiated well. In (i) most candidates were able to select at least one correct definition from the article. The common error here was to quote too much.
		ii	alpha – beta – gamma	1	**allow** correct symbols or a mixture of words and symbols **Examiner's Comments** The common error in (ii) was to put beta as having a shorter traveling distance than alpha radiation.
			Total	3	

Question			Answer/Indicative content	Marks	Guidance
6	a		when inside the body (1) could cause (lung) cancer / damage DNA or cells / cause cells to mutate / alpha highly ionising (1)	2	ignore reference to ionising cells Examiner's Comments Many candidates were able to give an effect of radon such as causing cancer, but less related this to the action of breathing in the gas for the second mark.
	b		max 2 marks from any one group economic argument residents	3	economic arguments idea of cost / who pays consequence of less money for other areas / services reduced healthcare costs (as less cases of cancer) increase in local employment residents reduced risk (of cancer for medium radon level) correct use of data to discuss level of risk idea that not everyone benefits disruption during fitting Examiner's Comments This question was not answered well. Many just quoted data from the table or said that the government paid for the installation, which was in the question. Some had not recognised the phrase 'this change' in the question or chose to ignore it. Answers that did gain credit by answering the question included: increased taxes so government could pay; reduced risk of cancer; disruption to residents during installation; work for installers. Answers were not succinct and many only provided one valid comment, though the mark for the question was clearly stated as 3.
			Total	5	

Question			Answer/Indicative content	Marks	Guidance
7			**(Level 3)** Candidate shows understanding of what the chart shows **or** compares some risks or benefits. Quality of written communication does not impede communication of the science at this level. (5–6 marks) **(Level 2)** Candidate describes some feature of the chart **or** makes a valid comment about a risk or a benefit. Quality of written communication partly impedes communication of the science at this level. (3–4 marks) **(Level 1)** Candidate makes a valid comment about the topic. Quality of written communication impedes communication of the science at this level. (1–2 marks) **(Level 0)** Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)	6	This question is targeted at grades up to E Indicative scientific points may include: • radiation dose is a measure of the amount of possible harm to the body • Sv is sieverts • dose for radiation workers is much higher than for the average person • dose for radiation workers is lower / half that definitely linked to cancer • radiation workers are monitored more than other people • may be willing to accept the risks for a more interesting job • a benefit is helping others • benefit of a well-paid job. Accept: • example of how workers' dose is reduced • discussion of monitoring of radiation workers' exposure. • discussion of how people are happier to accept risks if they have a choice • discussion of how radiation is used in a hospital. Ignore: • reference to types of radiation • discussion of contamination vs irradiation. Use the L1, L2, L3 annotations in Scoris; do not use ticks. Examiner's Comments This Level of Response question was about using data in the bar chart to compare risks and benefits. A few candidates achieved level 3 by demonstrating an understanding of the chart or compared risks or benefits using data from the chart. Others achieved level 2 by stating a risk or benefit related to data in the chart (e.g. radiographer receives half

Question			Answer/Indicative content	Marks	Guidance
					the yearly dose linked to increased cancer risk) or showed some understanding of part of the data. Level 1 was achieved by making a valid comment about the topic not necessarily using the data, such as 'helping others by treating cancer' or 'radiographer wears protective clothing'. Many answers failed to reach level 1 because they were just a paraphrase of the chart or question and made no comment or comparison. Some answers showed a misunderstanding of the idea of dose and others thought it would be good to get the 0.4Sv dose in a short time so that you could build up immunity.
			Total	6	
8	a			2	All correct = 2 marks 2 or 1 correct line = 1 mark **Examiner's Comments** Only half of the candidates correctly linked each type of waste to its method ofits disposal; most knew what to do with high level waste, but many confused the treatment for low and intermediate waste.
	b		**ANY TWO** from: • waste is harmful (e.g. causes cancer) • radiation can't reach people from space • rocket could explode on launch • spreading the waste around (the land or atmosphere)	2	**Examiner's Comments** Few candidates were able to answer this question about the proposal to put radioactive waste in space, with many concerned that this would contaminate space andspoil it for us if we needed to be there some time in the future.
			Total	4	
9			irradiation: (exposure to radiation) from sources outside the body or clothing (1); contamination: (exposure to radiation) from sources inside the body or on clothing (1)	2	**Examiner's Comments** Only a small minority of candidates were able to explain the meanings of the terms "irradiation" and "contamination" in the context of radioactive safety.
			Total	2	

Question			Answer/Indicative content	Marks	Guidance
10			[Level 3] Give two harmful effects **AND** a benefit **AND** compares dose for CT with at least one of the values given in table. Quality of written communication does not impede communication of the science at this level. (5–6 marks) [Level 2] Give two harmful effects **and** a benefit **OR** compares dose for CT with at least one of the values given in table. Quality of written communication partly impedes communication of the science at this level. (3–4 marks) [Level 1] Give one harmful effects **OR** gives benefit. Quality of written communication impedes communication of the science at this level. (1–2 marks) [Level 0] Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)	6	This question is targeted at grades up to E Indicative scientific points may include: Harm to body: • Damage (DNA in) living cells • kill living cells • cause cancer • break molecules into ions Benefit: • CT scan is useful for diagnosis/can find out what is wrong with you. • Can help work out your treatment Use of data • CT (10) less than recommended limit (50) • CT much less than lowest indicating cancer later (100) • Background (2.7) plus CT (10) less than recommended limit (50) • other correct numerical comparison Use the L1, L2, L3 annotations in RM Assessor; do not use ticks.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
11	a	i	EITHER: Paper blocked (most of) the radiation / reduces count rate ✓ Alpha radiation is stopped by paper / Beta radiation passes through paper.✓ OR There is no difference in count rate between paper and aluminium. ✓ Beta radiation would be stopped by aluminium. ✓	2 (AO 3.1b ×2)	<u>Examiner's Comments</u> Candidates seemed to find the questions assessing AO3 difficult. Candidates first had to interpret the information given about the experiment to identify a relevant observation and then link it to knowledge about the different types of radiation. There were several ways to gain the marks in this question, but many candidates tended to confuse the penetrating powers of alpha and beta or did not understand the significance of using two different blocking materials. Exemplar 4 From the table we can see that the counts per minutes decreases to 23 when paper is used as blocking material hence americium 241 emits alpha radiation but not beta radiation. [2] This response identifies a relevant observation that the count rate is reduced when paper is used as a blocking material so gains the first marking point. In order to gain the second mark the response should have stated that as alpha radiation is blocked by paper or as beta is not stopped by paper, the radiation emitted must have been alpha.
		ii	Use lead (as blocking material) ✓ gamma radiation is absorbed by lead ✓	2 (AO 3.3a ×2)	<u>Examiner's Comments</u> Many candidates did suggest using lead as a blocking material so were able to gain the first marking point. The second mark was more subtle as candidates couldn't just state that if the radiation was stopped by lead, there must be gamma radiation, as both alpha and beta radiation would also be stopped by lead. Candidates needed to specifically state that gamma radiation is absorbed by lead.

Question			Answer/Indicative content	Marks	Guidance
	b		EITHER (It is not dangerous because) Alpha radiation is not penetrating ✓ So is absorbed/ stopped by case of smoke alarm ✓ OR (It is not dangerous because) The amount of (gamma) radiation is very small / gamma is not very ionising ✓ So people in houses will absorb very little gamma radiation ✓	2 (AO 3.1b ×2)	<u>Examiner's Comments</u> This was another AO3 question which candidates found difficult. Many did state that having americium-241 in smoke detectors was very dangerous, or that it would mean that the smoke detector would be unable to detect a fire. The first marking point could have been gained by making a statement about the relative penetrating power of alpha or gamma radiation, and the second mark was for some analysis about why that meant it was not considered to be dangerous. Exemplar 5 It is not very dangerous as the alpha radiation will most likely be blocked by the plastic on the smoke alarm and by your skin. Gamma radiation will pass through you and will not become dangerous unless you stand under it for a long time. [2] This response gains one mark for giving information about the penetrating power of alpha radiation – it can be stopped by plastic. In order to gain the second mark it needs to go on to state that this means that it would not come out of the smoke detector, which makes it safe enough.
			Total	**6**	
12		i	U has A = 234 ✓ U has Z = 92 ✓	2 (AO 2.2 ×2)	
		ii	Alpha particles cannot penetrate a thin sheet of paper ✓ The aluminium in the case is thicker and denser than thin paper ✓	2 (AO 1.1) (AO 2.1)	1st and 4th boxes
			Total	**4**	