Mark scheme – Radioactive Emissions

Question			Answer/Indicative content	Marks	Guidance
1			**B** ✓	1 (AO1.1)	
			Total	**1**	
2			25(g) ✓	1 (AO 1.2)	**<u>Examiner's Comments</u>** About half the candidates correctly understood the term half-life and answered 25 g. There was evidence that other candidates either multiplied the numbers together (300) or divided the numbers (8.3).
			Total	**1**	
3			**D** ✓	1 (AO1.2)	**<u>Examiner's Comments</u>** The majority of the candidates realised that the masses and charges needed to balance.
			Total	**1**	
4			**C** ✓	**1 (AO 2.2)**	**<u>Examiner's Comments</u>** Almost half of the candidates correctly recalled that an alpha particle had 2 protons and 2 neutrons and were able to show that they understood standard nuclear notation (conventional representation for nuclei).
			Total	**1**	
5			**D** ✓	**1 (AO 1.1)**	**<u>Examiner's Comments</u>** Most candidates answered this question although a common misconception was that the nucleus was uncharged (option D).
			Total	**1**	
6			Reading would be very high (1)	1	
			Total	**1**	
7			D	1	
			Total	**1**	
8			C	1	
			Total	**1**	

9	a	i	All points correctly plotted (within + / − half a square) (1) Smooth single curve (1)	2	
		ii	140 (1)	1	**ALLOW** a tolerance of + / − 25
	b	i	Activity decreases (1) by a factor of 4 (1)	2	
		ii	4000 scores (1)	1	
			Total	**6**	
10	a	i	(Source) **A** ✓ (Source) **A** because (idea that) count rate unaffected by paper and aluminium OR only lead reduces / stops gamma ✓	**2 (AO 3.2) (AO 2.1)**	**ALLOW** cannot travel through lead **Examiner's Comments** Candidates were expected to the interpret information from the table. The first mark was credited for identifying the correct source. Candidates then needed to apply their understanding to explain why source A could be the only correct answer for part I (because there was no change in the count rate through paper and aluminium, but the radiation was absorbed by the lead). The most common misconception was to choose source D because it had the largest count rate. For part (ii), half of the candidates correctly identified source B but fewer explained their choice in terms of paper absorbing the radiation.
		ii	(Source) **B** ✓ (Source) **B** because count rate is reduced by paper ✓	**2 (AO 3.2a) (AO 2.1)**	**Examiner's Comments** Candidates were expected to the interpret information from the table. The first mark was credited for identifying the correct source. Candidates then needed to apply their understanding to explain why source A could be the only correct answer for part I (because there was no change in the count rate through paper and aluminium, but the radiation was absorbed by the lead). The most common misconception was to choose source D because it had the largest count rate. For part (ii), half of the candidates correctly identified source B but fewer explained their choice in terms of paper absorbing the radiation.

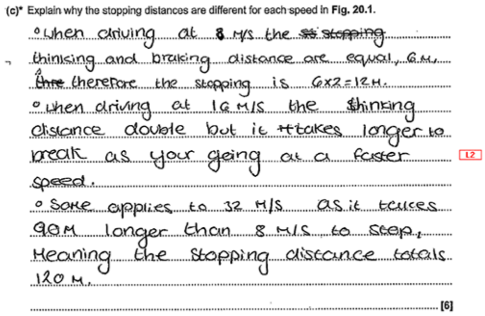
		iii	(Source) **D**✓ (Source) **D** because (idea that) count rate decreases after aluminium (beta) and after lead (gamma) ✓	**2 (AO 3.2a) (AO 2.1)**	**ALLOW** not absorbed by paper **Examiner's Comments** One in four candidates identified the source correctly as D, but few justified their choice in terms of the count rate decreasing though the aluminium and then further decreasing after the lead.
	b		**Any two from:** Radioactive decay is random ✓ Variations are more pronounced at low count rates ✓ Background radiation ✓	**2 (AO 2 x 3.1a)**	**Examiner's Comments** Candidates found this question very challenging and fewer than 5% were credited with any marks. Many candidates responded in terms of the thickness of the lead barrier. It was expected that candidates would state that there was a range of results because of the random nature of radioactivity and that what was being measured was the background radiation.
	c		**Any two from:** Larger number of counts ✓ Less variation in count rate ✓ Gives an average count rate ✓ Gives more repeatable results ✓ Makes it easier to decide what the source is ✓	**2 (AO 2 x 3.2b)**	**ALLOW** more radiation detected **ALLOW** idea of smoothing out variations **ALLOW** more reliable **IGNORE** accurate **Examiner's Comments** A large number of candidates responded by repeated the stem of the question in their own words, many just stated that the time should be increased. A number of candidates stated that the experiment would be "more accurate" without any explanation and so did not gain any. This was a practical skills question, which also assessed candidates' understanding of Working Scientifically (Appendix 5e). Candidates were expected to understand that the longer recording time would give a larger number of counts and thus there would be less variation in count rate, or it would enable an average count rate to de determined. There were also marks available for stating that the teacher's observations would give more repeatable results.

					AfL Candidates should be encouraged to interpret the question paper as to the expected length of their answers. In this question there were three answer lines and two marks available, which indicated that at least two improvements needed to be explained and that a short three-word answer was unlikely to gain both marks.
	d		**Any two from:** Keeping a safe distance (from source) ✓ Use tongs ✓ Point sources away from people ✓ Keep sources in sealed containers ✓ Keep exposure time as short as possible ✓	**2 (AO 2 x 1.2)**	**ALLOW** behind (lead) screen **IGNORE** gloves/goggles **ALLOW** lead box **Examiner's Comments** Many candidates answered this question in general terms suggesting general laboratory rules rather than specific safety precautions relevant to the experiment. A large number of candidates suggested keeping a safe distance from the source. Some candidates were confused about whether the barrier was part of the experiment or a safety device. Higher ability candidates gave relevant precautions including the use of tongs to hold the source (in effect adding some distance), using the sources for a short period of time (to minimise exposure) and storing the sources in lead lined boxes.
			Total	**12**	
11			Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. **Level 3 (5–6 marks)** **Explains quantitatively why the stopping distances are different for each speed in the table in terms of braking distance and thinking distance.** *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and*	**6 (AO 2 x 1.1) (AO 2 x 2.1) (AO 2 x 3.2b)**	**AO1.1a Demonstrates knowledge and understanding of thinking, braking and stopping distance** • Thinking distance is the distance the car travels while the driver reacts • Braking distance is the distance travelled while the brakes are applied • Stopping distance is thinking distance + braking distance

			substantiated. **Level 2 (3–4 marks)** **Explains qualitatively why the stopping distances are different for each speed in the table in terms of braking distance or thinking distance increasing with speed from the table** *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** **States basic ideas about thinking distance / braking distance / stopping distance OR identifies variation of thinking distance / braking distance / stopping distance with speed** *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks -** *No response or no response worthy of credit.*		**AO2.1 Applies knowledge and understanding of thinking, braking and stopping distance in relation to the details in the table** • Increasing the speed, increases the thinking distance • Increasing the speed, increases the braking distance • Increasing the speed, increases the stopping distance **AO3.2b Analyses information to make judgements and draw detailed conclusions from table** • Thinking distance is directly proportional to the speed • When speed doubles, thinking distance doubles • Braking distance is proportional to speed2 • When speed doubles, braking distance quadruples **<u>Examiner's Comments</u>** This question gave candidates the opportunity to apply their knowledge and understanding of stopping distances. The question is deliberately set to be open ended so that candidates had the opportunity of structuring their answers logically. Higher ability candidates explained that the stopping distance was equal to the sum of the thinking distance and braking distance before stating that the stopping distances increased with speed. Often candidates demonstrated the change in stopping distance using the data from the table. For the highest marks, candidates were expected to analyse the data quantitatively from the table. A few candidates used part (a) and stated that thinking distance doubled with speed and carried out a similar analysis for braking distance, stating that as speed doubled, braking distance quadrupled. Common misconceptions included thinking time increasing with speed, drivers being under greater pressure at high speed, braking forces increasing with speed. Other candidates discussed factors that affected

thinking distance and braking distance rather than using the data in the table.

Exemplar 2

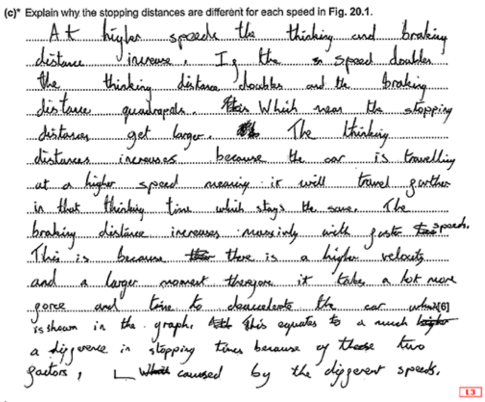

(c)* Explain why the stopping distances are different for each speed in Fig. 20.1.

• When driving at 8 M/S the ~~ss stopping~~ thinking and braking distance are equal, 6 M, ~~thre~~ therefore the stopping is 6x2=12 M.
• When driving at 16 M/S the thinking distance double but it takes longer to break as your going at a faster speed.
• Same applies to 32 M/S as it takes 90 M longer than 8 M/S to stop, Meaning the stopping distance totals 120 M.

[6]

This is a four mark, Level 2 response. The candidate has calculated the stopping distance for each speed and provided a limited analysis. They have made good use of mathematical expressions to show that stopping distance is equal to the product of thinking and breaking distance. The information presented is relevant, however there are limited links made between the bullet points. To progress to a Level 3 response the candidate could have added a short introduction and a final bullet point linking the analysis at each speed together in a summary sentence.

Exemplar 3

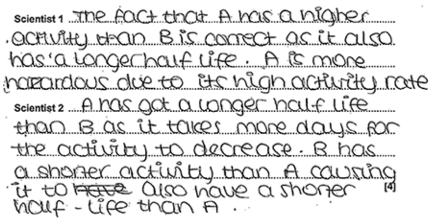

(c)* Explain why the stopping distances are different for each speed in Fig. 20.1.

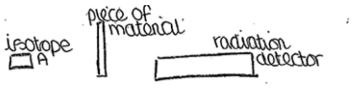
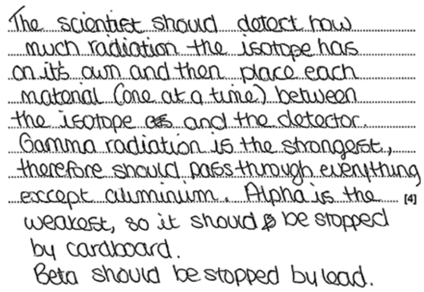
At higher speeds the thinking and braking distance increase. If the speed doubles the thinking distance doubles and the braking distance quadruples. Which mean the stopping distances get larger. The thinking distances increases because the car is travelling at a higher speed meaning it will travel further in that thinking time which stays the same. The braking distance increases massively with faster speeds. This is because there is a higher velocity and a larger moment therefore it takes a lot more force and time to decelerate the car which is shown in the graph. This equates to a much a difference in stopping times because of these two factors, caused by the different speeds.

[6]

This is a six mark Level 3 response. This is very clear analysis of the data in the table that is linked together in a clear logical structured way. Although the candidate has not annotated their script (except in their response to (a) it is clear that they have processed the data in the table. They have described the complex mathematical relationships (for example ‘if the speed doubles the thinking distance doubles and the breaking distance quadruples’) although it

					would have been easier to present this conclusion numerically.
			Total	**6**	
12	a		**Any two from:** Electron absorbs or gains energy / AW ✓ Electron becomes 'excited' / moves to a higher energy level / moves to outer path / AW ✓ Electron escapes / leaves the atom / AW ✓	2 (AO 2×1.1)	**ALLOW** atom becomes ionised / charged **<u>Examiner's Comments</u>** This question tested candidates understanding of the effect on an electron that has absorbed electromagnetic radiation. Some candidates stated that the electron could gain energy and also the election could lose energy. It was expected that candidates would understand that the electron gains energy and may become excited and move to a higher energy level or escape from the atom. Credit was given for candidates who stated that the atom became ionised. For this type of questions, candidates need to be precise in the use of terms. There was some confusion between atom and electron. Many candidates suggested that the electron lost charge. Candidates also need to take care over the use of "it". In this question, it was not always clear whether candidates were referring to the electron or the atom.
	b		**Any two from:** Electromagnetic radiation is being absorbed by electrons not nucleus ✓ Alpha emitted from the nucleus / electrons not present in the nucleus / AW ✓ Alpha emitted from unstable radioactive nuclei ✓ Alpha does not have electrons / has protons and neutrons only / AW ✓	2 (AO 2×1.1)	**<u>Examiner's Comments</u>** The mark bracket for this question indicates [2], which means that candidates need to answer by giving two points. Few candidates understood that alpha particles are emitted from the nucleus and that alpha particles do not have electrons.
			Total	**4**	
13		i	C ✓	1 (AO 2.2)	**ALLOW** answer from diagram if clear **<u>Examiner's Comments</u>** A large majority of the candidates correctly

					identified C as taking the longest time to decay. The common error was A.
		ii	**Any four from:** A is more hazardous / B is safer (for most of the time on the graph) ✓ A has a higher activity (for most of the time) ✓ B is more hazardous at the beginning ORA ✓ B has a higher activity at the beginning ORA ✓ A has a longer half-life / B has a shorter half-life ✓	4 (AO 4×3.1b)	**<u>Examiner's Comments</u>** This type of question gives candidates opportunities to demonstrate their knowledge of radioactivity as well as their skills in interpreting graphical information. In answering this type of question, candidates should look at the information from the graph and discuss what happens initially while B had the higher activity and then discuss what happened after the two graphs crossed. There should also be a link between activity and hazardousness. For the highest marks, there needed to be a comparison between the relative activity / hazardousness of the isotopes initially during the first day compared to activity / hazardousness of the isotopes after two days. Candidates could not gain the same mark twice, i.e. A had a longer half-life and B had a shorter half-life would only gain one mark. Again, the physics term "half-life" was expected to be seen. **Exemplar 4**  Scientist 1 The fact that A has a higher activity than B is correct as it also has a longer half life. A is more hazardous due to its high activity rate Scientist 2 A has got a longer half life than B as it takes more days for the activity to decrease. B has a shorter activity than A causing it to ~~have~~ also have a shorter half-life than A. [4] This candidate makes the link clearly between hazardous and activity and also clearly states on two occasions that A has the longer half-life. The candidate says that A has a higher activity which is assumed as overall. The writing at the end has been ignored and it would seem that the candidate did not fully understand the term half-life. To improve on this answer, some comment should have been made with regard to the graph initially during the first day. This answer was given 3 marks.
		iii	**Maximum two from:** One absorber placed between detector and isotope A ✓ (Idea of) change absorber and repeat	4 (AO 2×2.2) (AO 2×1.2)	May be described or drawn in a diagram

			experiment ✓ Measures (background) count with no source✓ **Maximum two from:** Drop in count rate with cardboard indicates alpha ✓ Drop in count rate with aluminium indicates beta ✓ Drop in count rate with lead OR cardboard and aluminium / all materials are penetrated indicates gamma ✓		**ALLOW** stopped / absorbed for drop in count rate **<u>Examiner's Comments</u>** Good candidates drew a diagram to indicate the experimental set-up. Many candidates were able to describe how they would place the absorbers in front of the detector. It would be better if they had stated in turn. A few candidates under the procedure section stated that they would take a reading with no absorber present. A few candidates also stated that would take a reading without a source, i.e. taking a background count. Several candidates were confused as to which absorber would stop which type of radiation. **Exemplar 5**   This candidate has a clear diagram, indicating the piece of material placed between the isotope and the detector. In the text, the candidate clearly states that each of the materials should be placed between the detector and isotope in turn ("one at a time"). The candidate's understanding of the likely results is muddled and not always correct (gamma radiation stopped by thin aluminium), but the candidate does correctly state that alpha should be stopped by cardboard. This answer was given 3 marks.

					AfL Candidates should be able to explain experimental procedures using a labelled diagram.
			Total	**9**	
14	a	i	The time it takes the number of undecayed/radioactive nuclei to halve ✓	1 (AO1.1)	**ALLOW** count-rate or activity for number of undecayed nuclei
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 40 (counts per minute) award 3 marks** 10y = 2 half lives ✓ 160 / 2 = 80 (counts per minute) ✓ 80 / 2 = 40 (counts per minute) ✓	3 (AO2 × 2.1)	
	b	i	Radioactivity is a random process ✓	1 (AO1.1)	**ALLOW** background radiation fluctuates
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 209 (counts per minute) award 2 marks** (191 + 224 + 212) ÷ 3 ✓ = 209 (counts per minute) ✓	2 (AO2 × 1.2)	
		iii	The count-rate stays the same ✓	1 (AO2.1)	**ALLOW** the count-rate goes down slightly **DO NOT ALLOW** the count-rate goes down
	c	i	27 ✓	2 (AO1.1)	
		ii	The same number of protons / atomic number / they both have 27 protons ✓ Co-60 has 3 more neutrons **ORA**/ Co-60 has 33 neutrons and Co-57 has 30 neutrons / mass number is different ✓	2 (AO2 × 1.1)	**ALLOW** Co-57 has 27 neutrons 0
			Total	**11**	