OCR GCSE GATEWAY PHYSICS A · J249

PHYSICS



MARK SCHEME

P6.1 RADIOACTIVE EMISSIONS

SCORE	PERCENTAGE
/167	%

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Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	**1**	
2			D	1	
			Total	**1**	
3	a		Reading would be very high (1)	1	
	b	i	All points correctly plotted (within + / – half a square) (1) Smooth single curve (1)	2	
		ii	140 (1)	1	**ALLOW** a tolerance of + / – 25
	c	i	Activity decreases (1) by a factor of 4 (1)	2	
		ii	4000 scores (1)	1	
			Total	**7**	
4			C	1	
			Total	**1**	
5			D	1	
			Total	**1**	
6			B	1	
			Total	**1**	
7			C	1	
			Total	**1**	
8	a		Any one from: Gamma can get out of body / least amount of time to do damage to the body / reasonable half-life (1)	1	
	b		Any two from: Alpha has short range (1) Highest ionising power (1) Longer half-life than D (1)	2	

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Question			Answer/Indicative content	Marks	Guidance
			Total	3	
9	a		Distance doubles count rate is 4 × less / count rate is inversely proportional to the square of the distance / as distance triples activity is 9 × less / **AW** (2)	2	**ALLOW** distance doubles count rate per minute is reduced by more than half (1)
	b		If the pattern was followed, 160 cm (ideally) should be 4 / 320 cm (ideally) should be 1 (1) Radiation / activity is random (1) Randomness is amplified at low readings / **AW** (1)	3	
			Total	5	

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Question			Answer/Indicative content	Marks	Guidance
10			**Level 3: (5 – 6 marks)** **The three types of radiation (alpha, beta and gamma) are correctly identified from at least three of the sources with valid explanations.** Quality of written communication does not impede communication of the science at this level. **Level 2: (3 – 4 marks)** **Two types of radiation (from alpha, beta or gamma) are correctly identified with reasons given.** Quality of written communication partly impedes communication of the science at this level. **Level 1: (1 – 2 marks)** **One type of radiation (from alpha or beta or gamma) with a simple reason is correctly identified OR two types of radiation are correctly identified.** Quality of written communication impedes communication of the science at this level. **Level 0: (0 marks)** Insufficient or irrelevant science. Answer not worthy of credit.	6	**Indicative scientific points may include:** **Sources** • **A** is gamma – affected only by lead • **B** is alpha – stopped by paper / stopped by all barriers • **C** is alpha and beta – alpha as reduction with paper and beta as reduction with aluminium • **D** is alpha and gamma – alpha as reduction with paper, no reduction with aluminium, but gamma as reduction with lead. Ignore any source if all 3 types given (ie. simple guessing) **Use the L1, L2, L3 annotations when useful. Do not use ticks.** **Examiner's Comments** This was a level of response 6-mark data handling question on absorbing radiation. It was generally well understood and gave a range of marks from 0 to 6. Just over half of candidates scored 5 or 6 marks here. Candidates could generally identify the nature of the sources. Usually they could justify them too. Beta was the one most likely to be incorrect. Also some candidates failed to recognise that some sources had two types of radiation but this was still not essential to gain full marks.
			Total	**6**	

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Question			Answer/Indicative content	Marks	Guidance
11			alpha cannot get through the body (to reach the detector) [1] alpha is absorbed by the body / skin / tissue / flesh [1]	1	**allow** only beta **and** gamma can penetrate the skin / get through the body (to the reach the detector) [1] **allow** alpha does not penetrate (tissue / body / skin) [1] **ignore** references to alpha and paper **ignore** references to damage Examiner's Comments This question asked why alpha was not used as a tracer. Some answers referred to high ionising power but failed to develop that and say they the alpha was absorbed by the body. Others stated that alpha is stopped by paper but failed to develop that further. Weaker answers did not refer to penetration but to the damage caused by alpha.
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
12	a	i	(can cause) cancer / mutations [1] can damage or ionise cells / DNA / tissues / (named) organs [1]	1	**allow** can kill for idea of damage **eg** kills cells [1] **not** merely 'damage' **Examiner's Comments** This was quite well answered with more candidates mentioning damage or ionisation of **cells** than in previous years. Damage to tissues or organs was often seen and worthy of the mark.
		ii	half-life [1]	1	**allow** correct descriptions of half-life **allow** rate of (radioactive) decay ignore speed of decay / mass or amount of sample **ignore** because it decays quickly **Examiner's Comments** Over 60% of candidates answered correctly with 'half-life.' 'Rate of decay' was occasionally seen too [1]. Weaker answers included 'its radioactivity' or 'how old it is'.

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Question			Answer/Indicative content	Marks	Guidance
	b		**any two from** so (all) gamma is (only) concentrated / focussed on the **tumour / cancer cells** AW [1] so that healthy / normal / other / non-cancerous cells receive less gamma / AW [1] otherwise (if patient moves) gamma may damage / affect (more) healthy / normal cells or tissue / ora [1]	2	Eg. idea that tumour has maximum exposure / cancer cells get a lethal dose [1] cancer cells rather than healthy cells get a lethal dose [2] **allow** (clamp is needed to hold the patients head still) to avoid damage to other tissue [1] **Examiner's Comments** Many referred rather vaguely to gamma hitting the 'right place' or the 'wrong place'. Better answers explained that gamma is meant to be focussed on the tumour [1] but (if the head moved) it may damage (surrounding) healthy cells [1].
			Total	4	
13			beta [1] gamma [1]	2	**either order** **Examiner's Comments** This question was focussed on the use of radiation in hospitals. Around half knew that beta and gamma could penetrate skin. It was surprising that many identified ultrasound as a form of radiation.
			Total	2	

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Question			Answer/Indicative content	Marks	Guidance
14			**Level 3: (5 – 6 marks)** **Reference to the three types of radiation AND two safety precautions.** Quality of written communication does not impede communication of the science at this level. **Level 2: (3 – 4 marks)** **Reference to two types of radiation AND a simple safety precaution.** Quality of written communication partly impedes communication of the science at this level. **Level 1: (1 – 2 marks)** **Simple reference to two types of radiation OR a simple safety precaution.** Quality of written communication impedes communication of the science at this level. **Level 0: (0 marks)** Insufficient or irrelevant science. Answer not worthy of credit.	6	This question is targeted up to grade E Indicative scientific points may include: **radiations** • alpha • beta • gamma **safety precautions** • use tongs • keep a safe distance • do not point at people or body part • protective clothing • short exposure time • shielded storage • labelled storage Use the L1, L2, L3 annotations in Scoris; do not use ticks. **Examiner's Comments** About 10% of candidates did not attempt the question. There were some excellent responses to this question. The majority of candidates correctly identified the three types of radiation. In terms of safety precautions the most common was protective clothing. Candidates wrote at length about gloves, goggles, aprons etc., but this was only one point. Other precautions were safe handling and safe storage.
			Total	**6**	

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Question			Answer/Indicative content	Marks	Guidance
15	a	i	decreases [1] **but** decreases by half / by 30 (decays per second) [2]	2	 **allow** from 60 to 30 [2] **eg 60 and 30 indicated on graph scores [2]** if **NO** marks awarded **allow** by one half life [1] **Examiner's Comments** Most knew the activity had reduced [1] and many went on to say or describe in numbers that it had halved [2].
		ii	line starting at 120 and always to the right and above right element A [1]	1	any line curving upwards (at any part) scores [0] graphs must not cross each other **Examiner's Comments** Many gained [1] for sketching the graph with a longer half life. The most commonerror was the graphs crossing usually around 6 to 8 days. It was encouraging to rarely see graphs with a shorter half life [0].
	b	i	(idea that nuclear radiation) can increase risk of cancer or cell damage [1]	1	**allow** (idea that) the radioactivity is not in the body for a long time (to cause damage) [1] **Examiner's Comments** This discriminated very well. Better candidates understood the dangers of using medical tracers with a longer half life and often made a good link to cell damage.

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Question			Answer/Indicative content	Marks	Guidance
		ii	beta and gamma [1]	1	more than one scores 0 marks if answer line blank allow correct answer indicated in list **Examiner's Comments** In general most knew that beta and gamma radiation can penetrate skin. The most common error was to identify that gamma only can penetrate skin.
			Total	5	
16		i	(idea that it) varies [1]	1	**allow** named examples ie it is higher in Finland / Spain [1] **allow** named examples ie it is lower in UK / Austria [1] **Examiner's Comments** Most candidates interpreted the information in the bar chart very well
		ii	**any one from** (more) radioactive rocks / uranium in rocks [1] (more) granite [1] (more) radon gas [1]	1	 **allow** (more) cosmic rays [1] **allow** higher level answers in terms of northern lights / near the northern lights [1] **but not** just Finland is further north / near the north pole **Examiner's Comments** There were very few correct responses in suggesting why a country has a higher natural background count rate. Most answers referred to artificial contributions to background radiation.
			Total	2	

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Question			Answer/Indicative content	Marks	Guidance
17	a		a **fast moving** electron (1)	1	if answer line blank allow correct answer circled or underlined more than one answer = 0 marks Examiner's Comments This objective question produced a range of answers with 'electron' or 'fast moving protons' being commonly seen wrong answers.
	b		mass number is unchanged ✓ nucleus has one more neutron nucleus has one more proton ✓ atomic number decreases by one	1	both ticks required more than two ticks = 0 marks Examiner's Comments Despite being instructed to tick two boxes, a large number only indicated one choice. About a quarter of candidates, however, got this correct.
	c	i	→ $^{237}_{93}Np$ + $^{4}_{2}He$ (2)	2	any two or three numbers correct = 1 mark Examiner's Comments This was about alpha decay and was better answered than in previous years with just over half of candidates gaining full marks.

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Question			Answer/Indicative content	Marks	Guidance
		ii	**any two from** alpha particles cause the air inside the smoke detector to ionise (1) idea that smoke particles absorb / stop (some alpha) radiation (1) less ionisation (of air) **with smoke** [1] current is reduced (causing alarm to sound) (1)	2	**Ignore** references to alpha detector **Ignore** merely particles 'hit' But alpha particles absorbed or stopped by smoke particles so less ionisation of air particles (2) Examiner's Comments The question on the smoke detector separated the grades clearly. Most candidates scored the 'smoke blocking alpha' mark but only the better answers referred to the ionisation of the air. References to current were usually not clear enough to be creditworthy.
			Total	6	

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Question			Answer/Indicative content	Marks	Guidance
18			**any two from** (idea that for **absolute dating**) absolute dating gives a more exact date / ora (1) (Idea about **absolute dating**) not enough Carbon-14 in old rocks (for absolute dating) or absolute dating only works when there is enough carbon in the sample (1) (idea that **relative dating**) can get the age of (very) old plants / wider age range of plants / ORA [1] (idea that for **relative dating**) need comparative data eg. requires knowledge of the ages of surrounding rocks (1) Idea that using **both methods** together gives a more **reliable** / valid / complete answer or both results support each other [1]	2	**Allow carbon dating for absolute dating** **Eg.** more accurate / precise **Ignore** 'better result' **allow** relative dating can get the age of (very) old rocks [1] **Eg. both methods** give more certain answer [1] **Eg. both methods** give more confidence in the result [1] **Allow both methods** give a more accurate answer [1] **Accuracy mark can only be given once.** Examiner's Comments Candidates usually gained one of the two marks available for the use of relative and absolute dating.
			Total	**2**	

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Question			Answer/Indicative content	Marks	Guidance
19	a		decrease (1) as time increases (1)	2	**allow** decrease with time (2) **allow** decrease faster initially / AW (2) **allow** higher level answers e.g. decrease exponentially (2) Examiner's Comments Nearly all could describe the trend in the data table correctly.
	b		the numbers half the fastest or the numbers half in less time / AW (1)	1	**allow** higher level answers e.g. the half-life is 50 ± 5 minutes or in each 100 minutes the numbers quartered (1) Examiner's Comments This question on comparing the half life of samples from the decay over time was one of the most challenging on the paper. Very few could correctly use the data to explain which sample had the shortest half life- most candidates simply focussing on the lowest activity at the end of the time interval. This discriminated very well. Better candidates understood the dangers of using medical tracers with a longer half-life and often made a good link to cell damage.
	c		nucleus (1)	1	if answer line blank allow correct answer circled or underlined more than one answer = 0 marks Examiner's Comments Around a third of candidates selected that radiation came from the nucleus. The most common wrong answer was selecting that it came from 'electrons orbiting the nucleus'.
			Total	4	

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Question			Answer/Indicative content	Marks	Guidance
20			**any two from** (idea that for **absolute dating**) absolute dating gives a more exact date / ora (1) (Idea about **absolute dating**) not enough Carbon-14 in old rocks (for absolute dating) or absolute dating only works when there is enough carbon in the sample (1) (idea that **relative dating**) can get the age of (very) old plants / wider age range of plants / ORA [1] (idea that for **relative dating**) need comparative data eg. requires knowledge of the ages of surrounding rocks (1) Idea that using **both methods** together gives a more **reliable** / valid / complete answer or both results support each other / [1]	2	**allow** Carbon dating for absolute dating **Eg** more accurate / precise / **Ignore** 'better result' **allow** relative dating can get the age of (very) old rocks [1] **Eg both methods** give more certain answer [1] **Eg, both methods** give more confidence in the result [1] Allow **both methods** give a more accurate answer [1] **Accuracy mark can only be given once.** Examiner's Comments Only higher ability candidates coped well with interpreting and applying the information provided to explain why both absolute and relative methods are used together.
			Total	2	

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Question			Answer/Indicative content	Marks	Guidance
21			Level 3: (5–6 marks) Correctly identifies three sources with an explanation AND explains the usefulness of all three sources in terms of penetration. Quality of written communication does not impede communication of the science at this level. Level 2: (3–4 marks) Correctly identifies three sources OR explains the usefulness of all three sources in terms of penetration. Quality of written communication partly impedes communication of the science at this level. Level 1: (1–2 marks) Describes two basic trends in the data OR identifies one source correctly. Quality of written communication impedes communication of the science at this level. Level 0: (0 marks) Insufficient or irrelevant science. Answer not worthy of credit.	6	This question is targeted up to grade A Indicative scientific points may include: Level 3: • X is gamma, Y is alpha, Z is beta • gamma – no differential, alpha stopped too easily, beta shows differential with paper (thickness) Level 2: • X is gamma, Y is alpha, Z is beta • gamma – no differential, alpha stopped too easily, beta shows differential with paper (thickness) Level 1: • X / gamma unaffected • Y / alpha stopped by paper • Z / beta reduced with thickness • one source identified Answers which incorrectly identify X, Y or Z are limited to level 2 (4 marks) Use the L1, L2, L3 annotations in Scoris; do not use ticks. <u>Examiner's Comments</u> This six-mark level of response question on a radioactivity experiment was well answered and accessed by the great majority. Most answers were lengthy and often detailed. About a third of answers did not identify the sources correctly often getting gamma (X) and beta (Z) the wrong way round. Some became confused over the raw numbers – 'highest counts per minute means gamma', for example. The answers however discriminated well and gave a wide range of marks. About a third of candidates gave good answers and used the data logically to clearly explain their choice and get full marks.

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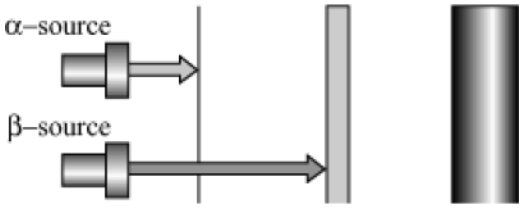
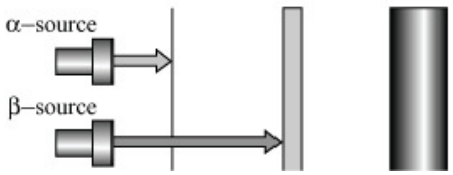
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Question			Answer/Indicative content	Marks	Guidance
			Total	6	
22			half-life of **Y** is (approximately) 1 hour / h / hr (1) half-life of substance **X** is (approximately) 4 hour / h / hr (1) **if no marks scored above:** the idea that substance **Y** has a shorter half-life (than substance **X**) / ora for X scores (1)	2	**allow** range 0.75 - 1 hour correct units required for this marking point **allow** range 3.5 - 4 hours correct units required for this marking point **ignore** 'between 3 to 4 hours' **but** half-life of **X** is 4 x that of **Y** (2) **Ignore** incorrect units if stated for this marking point **ignore** substance X remains radioactive longer as targeting A* for 1 of the marks **Examiner's Comments** Most candidates had at least an appreciation of half life and identified X as having the longer of the two [1]. Better answers quantified this with X being 4 years and Y being 1 year [2]. There was a certain amount of confusion between half life and activity.
			Total	2	

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Question			Answer/Indicative content	Marks	Guidance
23			arrow or line from alpha to front / rear face of paper and arrow or line from beta to front / rear of aluminium (1)	1	**allow** alpha line slightly penetrating paper and beta line slightly penetrating aluminium but not passing all the way through  Do **not allow** mark if radiation emerges from barrier **Examiner's Comments** This question was well attempted with many candidates gaining full marks. Occasionally alpha and beta were the wrong way round. Occasionally also some candidates failed to attempt the question at all indicating that they had not read the paper with sufficient care. There were some careless diagrams with the arrows just stopping short of the barriers or just going beyond the barriers.
			Total	1	
24			arrow or line from alpha to front / rear face of paper and arrow or line from beta to front / rear of aluminium (1)	1	**allow** alpha line slightly penetrating paper and beta line slightly penetrating aluminium but not passing all the way through  **Do not allow** if radiation emerges from the barrier **Examiner's Comments** Most candidates were able to complete the diagram showing the penetrating power of alpha and beta radiation.
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
25			Level 3 (5–6 marks) Answers must refer clearly to the use of lead to absorb gamma and that paper and aluminium will not stop gamma. The count only being reduced with a lead absorber or stopped by lead must be included. Safety should be addressed. If only one safety point addressed or there is one error with absorption award 5 marks. Quality of written communication does not impede communication of science at this level. Level 2 (3–4 marks) Answers refer to the idea of using absorbers and relative penetrating power. If absorption of alpha, beta and gamma are not all included award 3 marks. Quality of written communication partly impedes communication of science at this level. Level 1 (1–2 marks) Answers are limited to stopping one type of radiation or one safety features or the set-up. Errors in what absorbs a radiation will result in 1 mark being awarded. Quality of written communication impedes communication of science at this level. Level 0 (0 marks) Insufficient or irrelevant science. Answer not worthy of credit.	6	This question is targeted at grades up to C Relevant points about absorption include: • alpha stopped by paper or aluminium / (thin) metal • beta stopped by aluminium / (thin) metal • count does not reduce with paper and / or aluminium • gamma passes through paper / (thin) metal • gamma stopped by lead or concrete. Relevant safety points include: • protective clothing • tongs / keep a safe distance • short exposure time • keep class a safe distance • direction of source points away from teacher. Relevant points about set-up include: • GM tube detects radiation • source, absorber then GM tube. Some answers may be wholly or partly expressed in diagrams so mark them accordingly e.g: • experimental set up • relative absorptions • identification of source as gamma emitter Use the L1, L2, L3 annotations in scoris. Do not use ticks. Examiner's Comments This question was targeted at grades up to C and candidates often struggled to include sufficient detail about the absorption and penetrating power of alpha particles, beta particles and, in particular, gamma radiation. Often the penetrating powers were muddled, the appropriate

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Question			Answer/Indicative content	Marks	Guidance
					absorber often being for another nuclear radiation. Most candidates totally neglected **safety**, despite the emboldening of the word in the question. When diagrams were offered as part of the answer, they were often unclear as to what penetrated or was stopped by what.
			Total	6	
26		i	**ONE** from: • Either (percentage of ^{14}C decreases because) it is radioactive / decays **Or** • no ^{14}C taken in after death (1) **ONE** from: (percentage of ^{12}C stays the same because) • ^{12}C is not radioactive / does not decay / is stable (1)	2	**Allow** references to half-life **Eg.** undergoes half-lives **Eg.** 'it halves every 5730 years' (1) **Allow** unstable (isotope) (1)
		ii	22 920 (years)	1	
			Total	3	
27			3 (1) 3 (1) 1 (1)	3	each correct number scores 1 mark $^{1}_{1}H + {}^{2}_{1}H \rightarrow {}^{\mathbf{3}}_{2}He$ (1) $^{2}_{1}H + {}^{\mathbf{3}}_{1}H \rightarrow {}^{4}_{2}He + {}^{\mathbf{1}}_{0}n$ (1)
			Total	3	

Question			Answer/Indicative content	Marks	Guidance
28		i	A and C (1) and any two from because gamma radiation passes through skin (1) because it is harmful to healthy cells (1) because it is used to treat cancer (1)	3	
		ii	any one from limit exposure time (1) use a screen (1) keep a safe distance (1) wear protective clothing (1) use appropriate handling technique (1)	1	 **allow** any named example of a limit to exposure time e.g. wear radiation badges (1) **allow** any named example of a screen e.g. stand behind a glass wall (1) **allow** any named example of a safe distance e.g. keep away from the patient when treating them (1) **allow** named appropriate protective clothing e.g. lead apron (1) **allow** use tongs (1)
			Total	4	
29			source A: Beta (1) source B: Gamma (1)	2	**allow** β **allow** γ
			Total	2	

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Question			Answer/Indicative content	Marks	Guidance
30			C ✓	1 (AO2.1)	Examiner's Comments Many candidates chose distractor B as they had the misconception that beta radiation will not pass through aluminium foil. While an aluminium plate will stop beta radiation, thin aluminium foil will not be an effective screen for all the beta radiation.
			Total	1	
31			B ✓	1 (AO1.2)	Examiner's Comments This question required candidates to use their knowledge of half-life to interpret the graph. The majority of candidates were able to work out the half-life of the source using the graph.
			Total	1	
32			B ✓	1 (AO1.1)	Examiner's Comments Most candidates successfully applied their knowledge of ionisation to identify what happens to the atom for it to become a positive ion.
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
33	a	i	(Radioactive nuclei) are unstable ✓	1 (AO1.1)	ALLOW (nuclei have) too many neutrons Examiner's Comments Just over half of the candidates correctly explained that some isotopes are radioactive because the nuclei are unstable or have too many neutrons. Common incorrect responses referred to 'more neutrons' or ideas about numbers of electrons or protons.
		ii	Different numbers of neutrons ✓	1 (AO1.1)	Examiner's Comments The majority of candidates successfully stated that there are a different number of neutrons in carbon-12 and carbon-14.
	b	i	226 ✓ Th 90 ✓	2 (AO2.2) (AO2.2)	
		ii	0 ✓ β –1 ✓	2 (AO2.2) (AO2.2)	
		iii	$^{235}_{92}U \rightarrow \gamma = {}^{U}$ ✓	2 (AO2.2) (AO2.2)	Examiner's Comments Almost all candidates were able to complete all three decay equations. Of the small number who could not complete the equation the most common error was stating the atomic number of beta as +1 rather than -1.
			Total	8	
34			D ✓	1 (AO 1.1)	Examiner's Comments Most candidates answered this question although a common misconception was that the nucleus was uncharged (option D).
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
35			C ✓	1 (AO 2.2)	Examiner's Comments 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	

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Question			Answer/Indicative content	Marks	Guidance
36	a		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.
	b	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.

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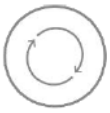
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Question			Answer/Indicative content	Marks	Guidance
		ii	(Source) **B** ✓ (Source) **B** because count rate is reduced by paper ✓	2 (AO 3.2a) (AO 2.1)	Examiner's Comments Candidates were expected to the interpret information from the table. The first 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.
	c		**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.

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Question			Answer/Indicative content	Marks	Guidance
	d		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 <u>Examiner's Comments</u> 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.
			Total	12	

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Question			Answer/Indicative content	Marks	Guidance
37			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 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.*	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 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

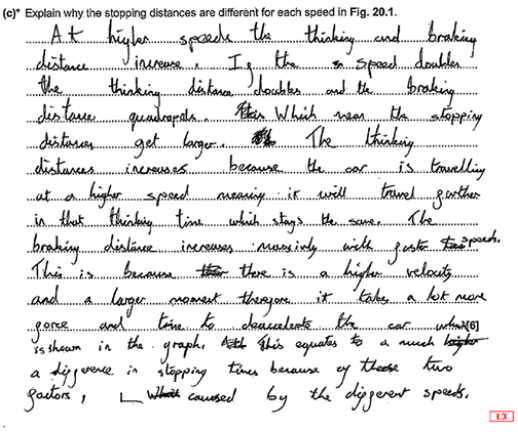
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Question	Answer/Indicative content	Marks	Guidance
			the thinking distance and braking distance before stating that the stopping distances increased with speed. Often candidates demonstrated the change in stopping distance using the data from the table. 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, ~~then~~ 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

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Question			Answer/Indicative content	Marks	Guidance
					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. I.e. the a speed doubles the thinking distance doubles and the breaking distance quadrupals. 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 breaking distance increases massively with greater the speed. 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 when[6] is shown in the graph. this equates to a much larger a difference in stopping times because of these two factors, which caused by the different speeds. L3 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	

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Question			Answer/Indicative content	Marks	Guidance
38			B ✓	1 (AO 1.1)	<u>Examiner's Comments</u> This question required candidates to apply their scientific knowledge and analyse the information in the table about nuclear radiation in order to choose the best isotope to use as medical tracer.  **Misconception** Many candidates could identify that gamma was the best radiation to use but had the misconception that a half-life of 6 minutes was long enough. Therefore, they incorrectly chose option C. Teaching often emphasises the need for a short half-life to reduce patient exposure to radiation, but this time cannot be shorter than the time required to carry out the procedure.
			Total	1	
39			B ✓	1 (AO 1.1)	
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
40	a		FIRST CHECK THE ANSWER ON ANSWER LINE **If answer = 20 (minutes) then award 2 marks** Evidence on graph or elsewhere of half of activity indicated ✓ (Half life =) 20 (minutes) ✓	1 (AO 2×2.2)	**ALLOW** 19-21 (minutes) ✓✓ Examiner's Comments Most candidates were able to successfully work out the half-life of isotope A from the graph, although there was evidence that some candidates had not read the initial activity from the scale on the y axis correctly.
	b		FIRST CHECK THE ANSWER ON ANSWER LINE **If answer = 128 (counts per minute) award 2 marks** Evidence of halving /doubling using data ✓ (Activity =) 128 (counts per minute) ✓✓	1 (AO 2×2.2)	e.g. time to go from 64 to 32 (cpm) is 30 (mins) / initial activity = 64 × 2 If answer is 105 to 127 or 129 to 136 then award a maximum of 1 mark ✓ Examiner's Comments Candidates found this question challenging. Most candidates' answers were in the range allowed for 1 or 2 marks but many made the common error of trying to find the differences between values in the table rather than spotting where the activity had halved.
	c		Conclusion 1 (incorrect) **Any one from:** Idea that activity is a random/unpredictable occurrence / AW ✓ Idea that low numbers of counts amplify relative variations / AW ✓ Conclusion 2 (incorrect) **Any one from:** (All radioactive isotopes) have a half-life / AW ✓ changes in activity will be small if half-life is long ✓	1 (AO 2×3.1b)	**ALLOW** correct answers referring to background radiation/readings Examiner's Comments This Assessment Objective 3 question tested candidates' ability to analyse the information from the graph and draw conclusions about the activity and the half-life. Many candidates agreed with both conclusions and tried to justify their answers. Candidates were most likely to evaluate conclusion 2 correctly and state that all (radioactive) isotopes have a half-life. It was rare to see conclusion 1 evaluated correctly as candidates did not link the graph to the random nature of radioactive decay.
			Total	**6**	

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Question			Answer/Indicative content	Marks	Guidance
41			D ✓	1 (AO1.2)	Examiner's Comments The majority of the candidates realised that the masses and charges needed to balance.
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
42	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 Examiner's Comments 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)	Examiner's Comments 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**	

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Question			Answer/Indicative content	Marks	Guidance
43	a		25(g) ✓	1 (AO 1.2)	Examiner's Comments 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).
	b	i	C ✓	1 (AO 2.2)	**ALLOW** answer from diagram if clear Examiner's Comments 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)	Examiner's Comments 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**

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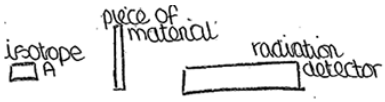
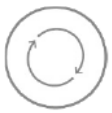
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Question			Answer/Indicative content	Marks	Guidance
					Scientist 1 The fact that A has a higher activity than B is correct as it also has a longer half life. A is more hazardous due to its high activity rate Scientist 2 A has got a longer half life 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 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 ✓	4 (AO 2×2.2) (AO 2×1.2)	May be described or drawn in a diagram **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

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Question			Answer/Indicative content	Marks	Guidance
					which absorber would stop which type of radiation. Exemplar 5  The scientist should detect how much radiation the isotope has on its own and then place each material (one at a time) between the isotope ~~as~~ and the detector. Gamma radiation is the strongest, therefore should pass through everything except aluminium. Alpha is the weakest, so it should be stopped by cardboard. Beta should be stopped by lead. [4] 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	10	

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Question			Answer/Indicative content	Marks	Guidance
44			B ✓	1 (AO1.1)	
			Total	**1**	
45	a	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
	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	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)	
			Total	**11**	
46			A ✓	1 (AO1.1)	
			Total	**1**	

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Question			Answer/Indicative content	Marks	Guidance
47	a		(The nucleus contains) 95 protons ✓ (and) 146 neutrons ✓	2 (AO2 × 1.1)	IGNORE references to electrons ALLOW the nucleus has a charge of (+) 95
	b		237 ✓ 93 ✓ He / α ✓	3 (AO2 × 2.2) (AO1 × 1.1)	
	c	i	The time it takes the number of (undecayed/radioactive) nuclei to halve ✓	2 (AO1.1)	ALLOW count-rate or activity for number of undecayed nuclei ALLOW the time it takes for half of the (radioactive) nuclei to decay ALLOW atoms for nuclei
		ii	It is long enough so the activity does not change significantly / source will not need to be replaced ✓	1 (AO2.1)	ALLOW it will last a long time
		iii	Thorium (is greatest risk to begin with) / ORA ✓ As thorium will have a higher activity/count-rate (at the beginning) / ORA ✓	2 (AO2 × 3.2a)	ALLOW thorium decays faster / ORA

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Question			Answer/Indicative content	Marks	Guidance
	d		**Any two from:** (Agree) Smoke alarms use small amounts of americium-241 ✓ Mainly emits alpha particles which are stopped by skin/soil ✓ Americium-241 is contained within the foil / AW ✓ Americium-241 cannot move out of materials in detector / be inhaled ✓ Soil emits more radiation ✓ **Or** **Any two from:** (Disagree) Smoke alarm contains an isotope with a long half-life ✓ The smoke alarm/foil could be damaged ✓ Americium-241 may contaminate objects (in the waste) ✓ Americium-241 also emits gamma rays (which are more penetrating that alpha particles) ✓ Soil may not absorb all radiation ✓	2 (AO2 × 3.2a)	**IGNORE** vague answers such as 'bad for the environment' **ALLOW** gamma is not stopped by the foil
			Total	11	

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