The Nucleus, Radioactive Decay and Using Radiation

Questions

Q1.

A teacher sets up an experiment to show some students how far beta particles travel in air.

Figure 10 shows some of the equipment she uses.

(Source: *www.einstein.yu.edu*)

Figure 10

(i) State the scientific name for the radioactivity detector shown in Figure 10.

(1)

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The teacher also has:

- a radioactive source that emits only beta particles
- a metre rule.

(ii) State two precautions the teacher must take to protect herself from the effects of radioactivity.

(2)

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2 .....

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(iii) Describe how the teacher could show how far beta particles travel in air.

(4)

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(Total for question = 7 marks)

Q2.

The mass of a proton is 1.6726 × 10–27 kg.
The mass of an electron is 9.1094 × 10–31 kg.
Calculate how many times the mass of a proton is greater than the mass of an electron.

Give your answer to two significant figures.

(3)

..... times

(Total for question = 3 marks)

Q3.

A G-M tube is connected to a counter.
A teacher places the G-M tube near to a radioactive source.
A student starts the counter and clock at the same time and writes down the readings shown on the counter every 15 s.

The student plots the readings with a line of best fit, as shown in Figure 10.

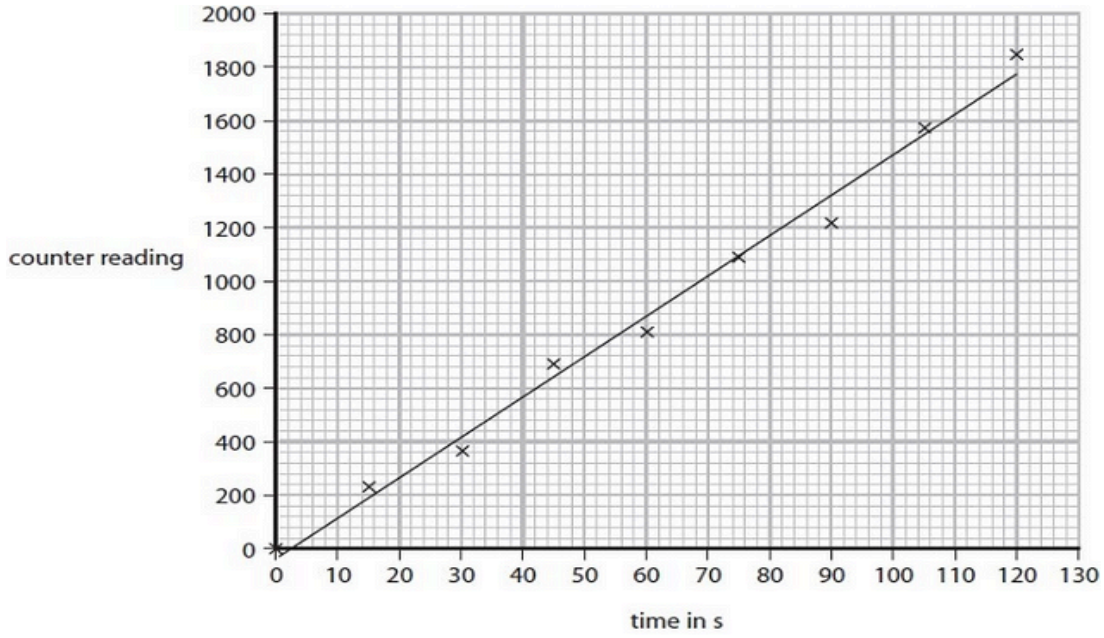

Figure 10

(i) Calculate the average count rate, in counts / s, from the graph.

Show your working on the graph.

(2)

average count rate = ... counts / s

(ii) The student says that the experiment must have been done carelessly because the data seemed quite scattered
away from the best fit line.

The teacher claims such results should be expected in radioactivity experiments.
Justify the teacher's claim.

(2)

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(Total for question = 4 marks)

Q4.

This question is about radioactivity.

Radium-223 is a radioactive substance.

Radium-223 is an alpha emitter.

The half-life of radium-223 is 11 days.

A radioactive source contains 1.7 × 1023 nuclei of radium-223.

Calculate the number of radium-223 nuclei remaining in the source after a time of 33 days.

(2)

number of radium-223 nuclei remaining = ...

(Total for question = 2 marks)

Q5.

Radio waves and gamma radiation are at opposite ends of the electromagnetic spectrum.

Compare how these two electromagnetic radiations are produced.

(6)

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(Total for question = 6 marks)

Q6.

This question is about radioactivity.

Fluorine-19 is a stable isotope of the element fluorine.

The element fluorine also has several radioactive isotopes.

Describe one similarity and one difference between the numbers of particles in one nucleus of fluorine-19 and one nucleus of a radioactive isotope of fluorine.

(2)

similarity

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.....

difference

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.....

(Total for question = 2 marks)

Q7.

* Gamma radiation is produced by radioactive decay.

Alpha radiation and beta radiation are also produced by radioactive decay.

Compare the processes of alpha decay and beta decay.

Your answer should include what each radiation is and what effect each decay has on the original nucleus.

(6)

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(Total for question = 6 marks)

Q8.

The half-life of strontium-90 is 29 years.

The table in Figure 9 gives some information about how the mass of a sample of strontium-90 changes with time.

mass of strontium-90 in g	time in years
1600	0
.....	29
400	.....

Figure 9

Complete the table in Figure 9.

(Total for question = 2 marks)

Q9.

Carbon-13 and carbon-14 are isotopes of carbon.

Nuclei of carbon-13 and carbon-14 can be represented by these symbols

$$^{13}_{6}C \quad \text{and} \quad ^{14}_{6}C$$

Complete the table for an atom of carbon-13 and an atom of carbon-14.

(2)

	number of neutrons in the nucleus	number of electrons in orbit around the nucleus
carbon-13		
carbon-14		

(Total for question = 2 marks)

Q10.

This question is about radioactivity.

* Exposing people to radioactive sources can be dangerous.

Describe the dangers of exposure to radioactive sources and what can be done to protect hospital staff when they are working with radioactive sources.

(6)

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(Total for question = 6 marks)

Q11.

This question is about radioactivity.

Alpha (α), beta (β) and gamma (γ) are three types of radioactive emissions. Which statement describes all of these radioactive emissions?

(1)

☒ A ionising and emitted by stable nuclei

☒ B ionising and emitted by unstable nuclei

☒ C neutral and emitted by stable nuclei

☒ D neutral and emitted by unstable nuclei

(Total for question = 1 mark)

Q12.

Sometimes food can become contaminated with radioactive substances.

Describe the harmful effects of eating food contaminated with radioactive substances.

(2)

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(Total for question = 2 marks)

Q13.

Carbon-14 is radioactive and has a half-life of 5 700 years.

The number of radioactive carbon-14 atoms in a very old piece of wood is found to have decreased from 1 000 000 to 125 000.
Determine the age of the piece of wood.

(2)

age of wood = ... years

(Total for question = 2 marks)

Q14.

(i) X-rays can be used in diagnosis and treatment from outside the body. Some x-rays are absorbed by bone as they travel through the body.

Figure 4 shows how the intensity of the x-ray beam gets less as the x-rays travel further through the bone.

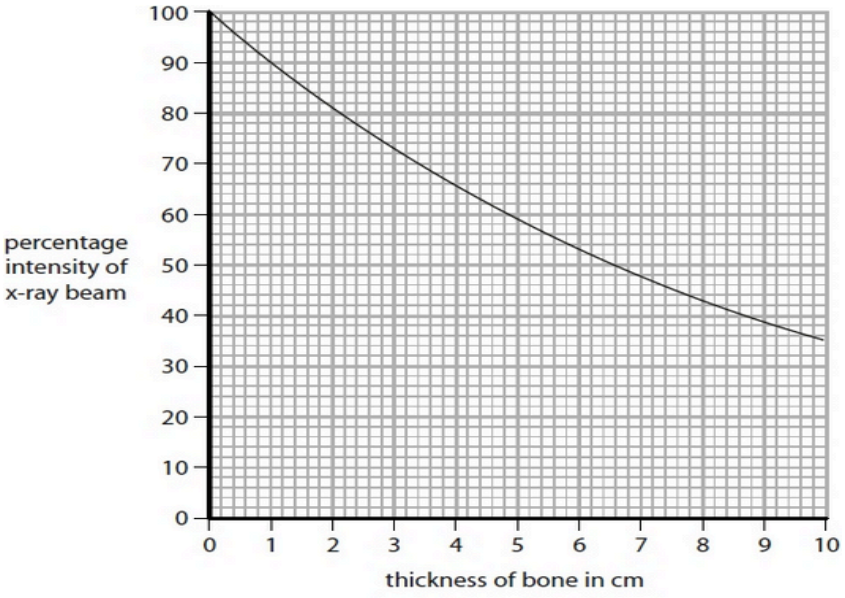

Figure 4

Use the graph to determine the thickness of bone that will reduce the percentage intensity of the x-ray beam by half.

(2)

thickness = ... cm

(ii) Radioactive isotopes may be placed inside the body for treatment.
The energy absorbed by tissue in the body needs to be known.

The number of joules of energy absorbed by each kilogram of tissue is measured in one of the units shown.

This unit is

(1)

☒ A kg/W

☒ B J/kg

☒ C kg/J

☒ D W/kg

(Total for question = 3 marks)

Q15.

Figure 4 shows a Geiger-Müller (GM) tube used for measuring radioactivity.

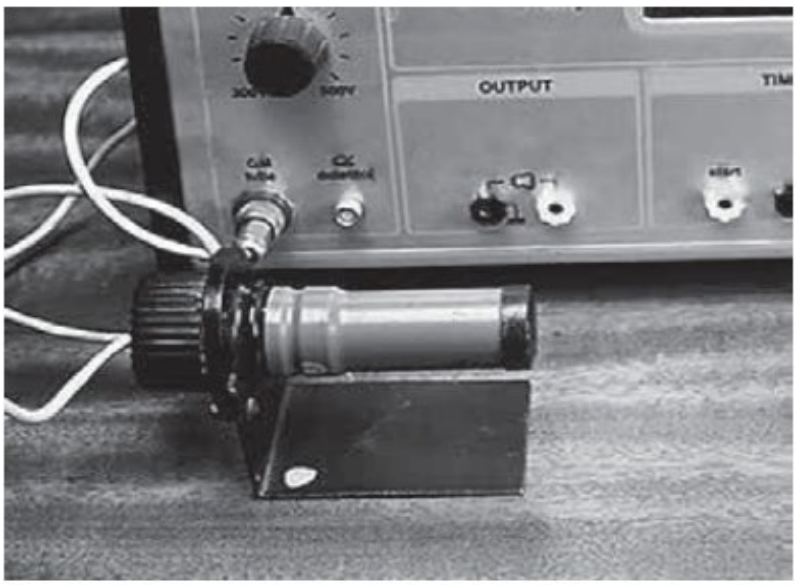

Figure 4

One radioactive source used in hospitals is technetium (Tc).

Technetium is produced from the radioactive decay of molybdenum (Mo).

Complete the following nuclear equation.

(1)

$$^{99}_{42}\text{Mo} \rightarrow \text{\_\_\_\_} + {}^{0}_{-1}\beta$$

(Total for question = 1 mark)

Q16.

The half-life of cobalt-60 is 5 years.

A school cobalt source had an activity of 38.5 kBq in the year 2000.

Estimate the activity of this source in the year 2020.

(3)

activity = ... kBq

(Total for question = 3 marks)

Q17.
A radioactive rock is placed near to the front of a Geiger-Müller (GM) tube.

A radioactivity count-rate is first made in air.

The count-rate is measured again with each of three different absorbers between the rock and the GM tube.
Figure 19 shows the count-rates measured.

absorber	count-rate in counts per minute
3 cm of air	1272
thin sheet of paper	931
3 mm thick sheet of aluminium	328
2 cm thick sheet of lead	21

Figure 19

A scientist has an idea that the rock emits three different types of radiation.

Explain how the data in this table supports the scientist's idea.

(6)

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(Total for question = 6 marks)

Q18.

This question is about radioactivity.

Figure 14 shows a Geiger-Muller (G-M) tube attached to a counter.
The G-M tube is used to measure the activity of a source of beta (β) radiation.
There is an aluminium sheet between the beta source and the G-M tube.
The counter is switched on and after 1 minute shows a count of 268.

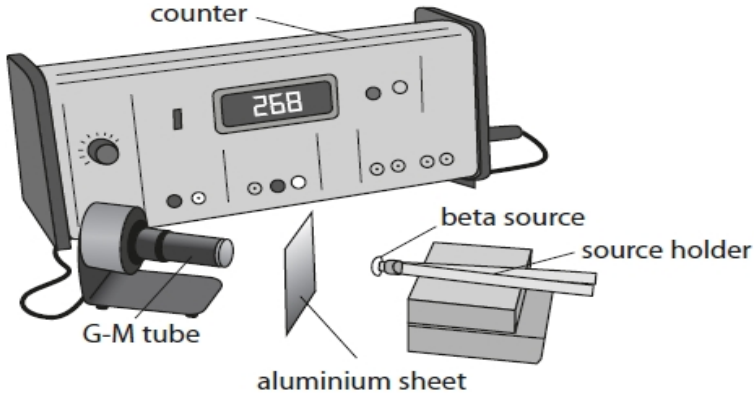

Figure 14

(i) The aluminium sheet is taken away.
The counter is reset to zero and then switched on again.
A new count is taken for 1 minute.

Explain why the new count is greater than 268.

(2)

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(ii) The beta source is then also taken away.
The counter is reset to zero and switched on again.
A new count is taken for 1 minute.

Give a reason why there would now be a reading on the counter.

(1)

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.....

(iii) State the SI unit for the activity of a radioactive source.

(1)

.....

(Total for question = 4 marks)

Q19.

The typical size of an atom is

(1)

- ☒ A 10–5 m
- ☒ B 10–10 m
- ☒ C 10–15 m
- ☒ D 10–20 m

(Total for question = 1 mark)

Q20.

Figure 9 represents a decay that can happen inside the nucleus of an atom.

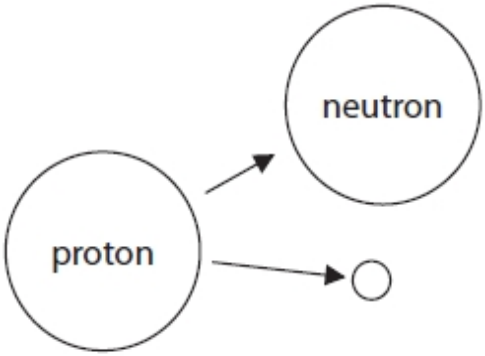

Figure 9

Which decay is represented in Figure 9?

(1)

- ☒ A alpha
- ☒ B beta minus
- ☒ C beta plus
- ☒ D gamma

(Total for question = 1 mark)

Q21.

Describe how a teacher should use a Geiger-Müller (GM) tube to compare the count-rates from two different radioactive rocks.

(4)

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(Total for question = 4 marks)

Q22.

(i) State the name of an instrument that can be used to measure radioactivity.

(1)

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(ii) State two sources of background radiation.

(2)

1 .....

2 .....

(Total for question = 3 marks)

Q23.
Figure 8 shows a helium nucleus.

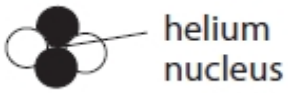

Figure 8

Two of the particles in the helium nucleus are neutrons.

State the name of the other two particles in the helium nucleus.

(1)

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(Total for question = 1 mark)

Q24.
A hospital uses a radioactive isotope with a half-life of 6 hours.

A technician measures a count rate of 80 counts per minute (cpm) from this isotope.

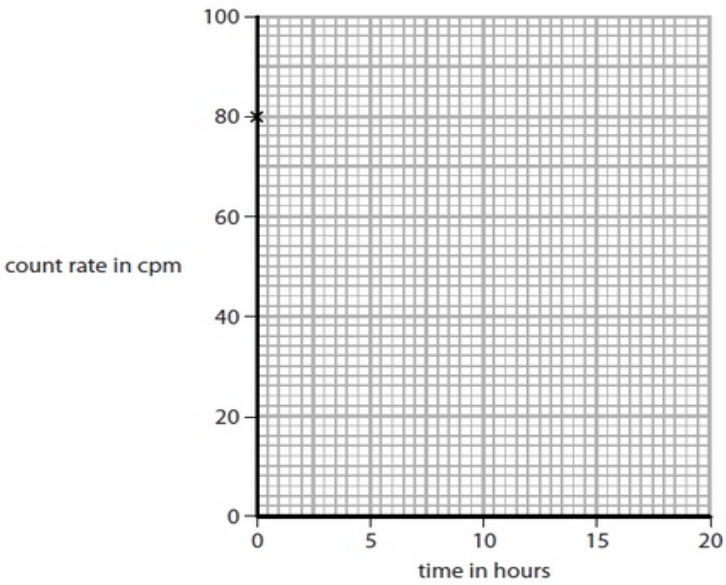

Figure 18

Complete the graph on Figure 18, as accurately as possible, to show how the count-rate from this isotope will change from the time of the first measurement.
The first point is already drawn in Figure 18.

(3)

(Total for question = 3 marks)

Q25.

Radioactive substances are used in the generation of electricity.

State two other uses of radioactive substances.

(2)

1 .....

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2 .....

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(Total for question = 2 marks)

Q26.

Energy from the nuclei of atoms can be used in medical diagnosis and treatment.

(i) Fluorine-18 is a radioactive isotope used in PET scanners for medical diagnosis.

Explain why fluorine-18 must be produced close to the hospital where it is used.

(2)

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(ii) Some tumours inside the body can be treated by using either alpha radiation or gamma radiation.

Explain why the source of alpha radiation is usually inside the body but the source of gamma radiation can be outside the body.

(4)

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(Total for question = 6 marks)

Q27.

(i) Use words from the box to complete the sentences below about ions.

absorbing	gaining	inner	losing	outer

(2)

Atoms may form positive ions by ..... electrons.

The electrons involved in forming positive ions are the ..... electrons.

(ii) Which of these radiations is both electromagnetic and ionising?

(1)

☒ A alpha

☒ B beta minus

☒ C gamma

☒ D neutron

(iii) Which type of radiation will travel the shortest distance in air?

(1)

☒ A alpha

☒ B beta minus

☒ C beta plus

☒ D gamma

(Total for question = 4 marks)

Mark Scheme – The Nucleus, Radioactive Decay and Using Radiation

Q1.

Question number	Answer	Additional guidance	Mark
(i)	Geiger-Müller tube	accept Geiger (counter) geiger (counter) GM (tube) gm(tube) accept any recognisable (phonetic) spelling	(1)

Question number	Answer	Additional guidance	Mark
(ii)	any **two** from: keep a safe distance (1) point the source away from people (1) handle the source with tongs/at a distance (1) limit exposure time/return source to store (asap) (1) use shielding (1) use of gloves (1) use of mask (1) protective clothing (1) wear a film badge/monitor (1)	 use of screen Do not credit goggles	(2)

Question number	Answer	Additional guidance	Mark
(iii)	a description to include four from: take measurement without source (1) place source in front of/near/close to detector (1) increase the distance (between source and detector) (1) measure distance (from source to detector) (1) take reading from the screen/counter (1) until reading gets to background value /constant value (1) use same time for each count (1) repeat / check when down to low values (1)	 measure/account for background (count) DO NOT allow 'inside' allow reverse argument by starting with detector long way away from source allow zero as constant value mention of (count) <u>rate</u>	(4)

Q2.

Question Number	Answer	Additional guidance	Mark
	substitution (1) <u>1.6726 (x 10^{-27})</u> 9.1094 (x 10^{-31}) evaluation (1) 1836 evaluation to 2 sf (1) 1800	 Allow 1 mark for answers that round to 1.836 to any power of ten for this mark 1.836 x 10^3 OR 1.80 x 10^3 accept 1840 or any rounding of 1836.125 1.8 x 10^3 **any number** shown to 2 sf gets this mark award full marks for the correct answer without working	(3)

Q3.

Question number	Answer	Additional guidance	Mark
(i)	use of gradient on graph (1) = $\frac{1480}{97}$ evaluation (1) 15.3 (counts /s)	look for a triangle / line going up allow $\frac{1480}{100}$ accept other data from the graph allow numbers between 12.0 and 16.0 award full marks for answers in the correct range without working	(2)

Question number	Answer	Additional guidance	Mark
(ii)	explanation the process (of radioactive decay) is unpredictable / (occurs) random(ly) (1) so the count rate would not be constant / there will be variations with each reading (1)	 do not allow 'difficult to predict' ignore background results (expected to) scatter	(2)

Q4.

Question number	Answer	Additional guidance	Mark
CS2	33 days is 3 half-lives (1) $2.1(25) \times 10^{22}$ (1)	$\frac{1.7 \times 10^{23}}{2\ (\times 2 \times 2)}$ 2.1(25) to any other power of ten scores mp1 only award full marks for correct answer without working.	(2) AO2

Q5.

Question Number	Answer	Mark
	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **AO1 strand 1 (6 marks)** • radio waves are (often) produced intentionally (by humans) • gamma rays are (often) produced spontaneously / randomly • radio waves are produced by (free) electrons • radio waves are produced by oscillating (free) electrons / alternating current (ac) • radio waves are produced in electrical circuits / aerials • gamma rays may result from radioactive decay • gamma rays produced in the nucleus • gamma rays produced by energy changes / rearrangement in the nucleus • gamma rays produced to stabilise the nucleus • gamma rays produced in annihilations (PET scanning etc) • gamma rays may be produced as a result of (nuclear) fission or fusion	**(6)**

Level	Mark	Descriptor
	0	• No rewardable material.
Level 1	1-2	• Demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) • Presents an explanation with some structure and coherence. (AO1)
Level 2	3-4	• Demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) • Presents an explanation that has a structure which is mostly clear, coherent and logical. (AO1)
Level 3	5-6	• Demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) • Presents an explanation that has a well-developed structure which is clear, coherent and logical. (AO1)

Summary for guidance			
Level	**Mark**	**Additional Guidance**	**General additional guidance – the decision within levels** e.g. - At each level, as well as content, the scientific coherency of what is stated will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	Additional guidance isolated fact(s) about one radiation	Possible candidate responses gamma rays are (often) produced spontaneously / randomly
Level 2	3–4	Additional guidance Some understanding shown i.e. a limited comparison made including some facts about the production of each radiation OR more detailed facts given about the production of one of them	Possible candidate responses radio waves produced in wires and gamma produced in nucleus radio waves produced by AC in wires
Level 3	5–6	Additional guidance Understanding is detailed and fully developed. detailed comparison made with linked facts about the production of each (one radiation may have significantly more detail than the other but both should feature for level 3)	Possible candidate responses radio waves produced by electrons oscillating in wires; gamma produced by annihilation of electrons interacting with positrons

Q6.

Question number	Answer	Additional guidance	Mark
	same number of protons (1) different number of neutrons (1)	same atomic number different mass number	(2) AO2

Q7.

Question number	Indicative content	Mark
*	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive, and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. AO1 1 **(6 marks)** **alpha** • a particle (not a wave) • made up of 4 particles • helium nucleus • has a positive charge • when emitted by a nucleus, atomic number goes down by 2 • mass number goes down by 4 **beta** • a particle (not a wave) • made up of 1 particle • electron (or positron) • has a negative charge • when emitted, atomic number goes up by 1 • mass number does not change Ignore references to range, penetration, ionisation.	(6) AO1

Level	Mark	Descriptor
	0	• No rewardable material.
Level 1	1-2	• Demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) • Presents an explanation with some structure and coherence. (AO1)
Level 2	3-4	• Demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) • Presents an explanation that has a structure which is mostly clear, coherent and logical. (AO1)
Level 3	5-6	• Demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) • Presents an explanation that has a well-developed structure which is clear, coherent and logical. (AO1)

Level	Mark	Additional Guidance	General additional guidance – the decision within levels e.g. - At each level, as well as content, the scientific coherency of what is stated will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	Additional guidance isolated facts	Possible candidate responses A beta particle is an electron. An alpha particle is a helium nucleus
Level 2	3–4	Additional guidance effect of alpha and beta decay or nature and effect of alpha or beta	Possible candidate responses A beta particle is an electron. When emitted the mass number doesn't change but atomic number goes up by one
Level 3	5–6	Additional guidance detailed comparison that includes nature of alpha and nature of beta and effect of either alpha or beta OR effect of alpha and beta and nature of either alpha or beta	Possible candidate responses Alpha particle is a helium nucleus AND A beta particle is an electron. When emitted the mass number doesn't change but atomic number goes up by one

Q8.

Question number	Answer	Additional guidance	Mark
	mass in g / time in days 1600 / 0 800 (1) / 29 400 / 58 (1)	numbers in correct boxes	(2)

Q9.

Question Number:	Answer	Additional guidance	Mark
	<table><tr><td></td><td></td><td></td></tr><tr><td></td><td>7</td><td>6</td></tr><tr><td></td><td>8</td><td>6</td></tr></table> (1) (1)	one mark for each column must have both numbers in a column correct to get the mark	(2)

Q10.

Question number	Indicative content	Mark
*	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **Dangers of exposing people to radioactive sources/radiation.** • it is ionising • may cause cancer • may destroy /kill cells • can mutate DNA • can burn the skin **Protection of hospital staff using radioactive sources/radiation.** • use tongs to carry radioactive sources • use lead containers to store sources • stay at a distance from radioactive sources • use sources for as short a time as possible • wear (lead lined) protective clothing (PPE) • give treatments from behind a shield /wall • wear a radiation badge (dosimeter)	**(6)** **AO1**

Level	Mark	Descriptor
	0	No rewardable material.
Level 1	1–2	Demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific, enquiry, techniques and procedures lacks detail. (AO1) Presents a description which is not logically ordered and with significant gaps. (AO1)
Level 2	3–4	Demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas, enquiry, techniques and procedures is not fully detailed and/or developed. (AO1) Presents a description of the procedure that has a structure which is mostly clear, coherent and logical with minor steps missing. (AO1)
Level 3	5–6	Demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas, enquiry, techniques and procedures is detailed and fully developed. (AO1) Presents a description that has a well-developed structure which is clear, coherent and logical. (AO1)

Level	Mark	Additional Guidance	General additional guidance – the decision within levels e.g. - At each level, as well as content, the scientific coherency of what is stated will help place the answer at the top, or the bottom, of that level.
	0	No rewardable material.	
Level 1	1–2	Additional guidance At least one isolated fact about the dangers of radiation and/or protection from radiation	Possible candidate responses it's ionising causes cancer burns you kills cells mutates DNA wear a radiation badge use tongs work from behind a shield use protective clothing
Level 2	3–4	Additional guidance simple explanation of the dangers of radiation and a fact about protection or reverse OR detailed explanation of the dangers of radiation or protection from radiation	Possible candidate responses radiation is ionising and can kill cells so wear a radiation badge **or** use tongs and stay at a distance from radiation source as it can cause cancer **or** use tongs to stay at a distance from radiation sources and wear a radiation badge
Level 3	5–6	Additional guidance detailed explanation of the dangers of radiation and protection from radiation	Possible candidate responses radiation is ionising and can kill cells **and** use tongs and stay at a distance from the radiation source

Q11.

Question number	Answer	Mark
	B ionising and emitted by unstable nuclei A is incorrect stable nuclei do not give radioactive emissions C is incorrect not all radioactive emissions are neutral D is incorrect not all radioactive emissions are neutral	**(1)** **AO1**

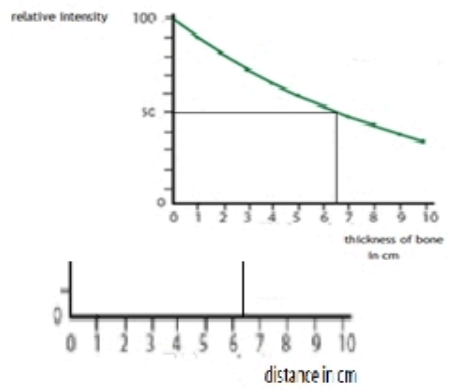
Q12.

	Answer	Additional guidance	Mark
	A description to include **two** from: (radioactive material/substances) inside the food/body (1) emit radiation from inside the body (1) damage body cells (1)	 trapped in the body exposed to radioactivity cause cancer	**(2)** **AO1**

Q13.

Question Number	Answer	Additional guidance	Mark
	processing (1) $\frac{125\ 000}{1\ 000\ 000}$ OR $\frac{1}{8}$ OR 3 half-lives or 3 x 5700 evaluation (1) 17 100	 accept an appropriate attempt using more than one halving 17 000 award full marks for the correct answer without working	**(2)**

Q14.

Question Number	Answer	Additional guidance	Mark
(i)	Constructs a line across at an intensity of 50 (with a vertical to the thickness axis) (1) e.g.  (thickness =) 6.5 - 6.7 (cm) (1)	award full marks for the correct answer without working	(2)

Question Number	Answer	Mark
(ii)	**The only correct answer is B J/kg** None of the other options have units which are the same as J/kg	(1)

Q15.

Question Number	Answer	Mark
	an answer containing both of the following numbers in the correct places (1) $^{99}_{43}Tc$	**(1)** AO 2 1

Q16.

Question number	Answer	Additional guidance	Mark
	recognition of there being **4 half lives** involved (1) so fraction of **1/16** involved (1) evaluation (1) 2.4 (kBq)	 allow 2 marks for 4.8 (kBq) (used three instead of 4 half lives) allow 1 mark for any other $(1/2)^n$ being involved i.e. for answers that round to 19.3 (kBq), 9.63 (kBq), 1.2(kBq) award full marks for the correct answer without working	**(3)**

Q17.

Question Number	Answer	Mark
	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive, and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **AO3 Strand 2a and 2b (6 marks)** • shows some idea that the data can support arguments about alpha, beta and gamma radiation being present • argues that there is some evidence that alpha might be emitted (count rate going down with paper interposed) • argues that there is a lot of evidence that beta particles are emitted (count rate goes down a lot when the aluminium is inserted) • argues that there might be some gamma getting through (lead stopping everything apart from gamma) OR that with the lead present the count rate has gone down to a level consistent with background, so no gamma was present a level 3 answer will use data effectively	**(6)** AO 1 1

Level	Mark	Descriptor
	0	• No rewardable material.
Level 1	1-2	• Deconstructs scientific information but understanding and connections are flawed. An unbalanced or incomplete argument that provides limited synthesis of understanding. • Judgements are supported by limited evidence. (AO3)
Level 2	3-4	• Deconstructs scientific information and provides some logical connections between scientific concepts. An imbalanced argument that synthesises mostly relevant understanding, but not entirely coherently. • Judgements are supported by evidence occasionally. (AO3)
Level 3	5-6	• Deconstructs scientific information and provide logical connections between scientific concepts throughout. A balanced, well-developed argument that synthesises relevant understanding coherently. • Judgements are supported by evidence throughout. (AO3)

Q18.

Question number	Answer	Additional guidance	Mark
(i)	An explanation to include; there is no aluminium to absorb β particles (1) (therefore) more β particles reach the G-M tube (1)	aluminium absorbs/stops/blocks beta particles accept reverse arguments accept radiation for beta particles	(2) AO2

Question number	Answer	Additional guidance	Mark
(ii)	(idea of) background radiation	a named source of background radiation	(1) AO3

Question number	Answer	Additional guidance	Mark
(iii)	becquerel	accept Bq accept close spelling	(1) AO1

Q19.

Question Number	Answer	Mark
	B 10^{-10} m	**(1)**

Q20.

Question number	Answer	Mark
	☒ **C** beta plus Options A, B and D are not represented by Figure 9.	**(1)**

Q21.

Question Number	Answer	Additional guidance	Mark
	a description to include: 1. put rock(s) in front of/near tube (1) 2. measure (count rate) separately for the two different rocks (1) 3. measure each count for the same time period (1) 4. keep source-detector distance the same for both rocks (1) 5. take (into account)/measure background count (1) 6. repeat readings and take average(s) (1)	not 'in' tube keep rocks apart	**(4)** AO 2 2

Q22.

Question Number	Answer	Additional guidance	Mark
(i)	Geiger (Müller counter) (1)	GM {tube/meter} or other appropriate detector e.g. dosimeter, film badge, scintillation counter accept incorrect spellings such as "giga" ignore radioactive counter	**(1)**

Question Number	Answer	Additional guidance	Mark
(ii)	any **two** acceptable sources from : **cosmic** (rays) (1) Sun (1) rocks / ground (1) {nuclear / atomic} tests / nuclear waste (1) (nuclear) power stations (1) plant (sources) (1) buildings (1) food (1) water (1) medical (1) radon (1)	 cosmic microwave background radiation (CMBR) accept nuclear accidents (Chernobyl, Fukushima etc) accept named foods accept X-rays, radiotherapy ignore alpha, beta, gamma	**(2)**

Q23.

Question Number	Answer	Mark
	proton(s)	**(1)** AO 1 1

Q24.

Question Number	Answer	Additional guidance	Mark
	• point after first half-life - 6, 40 (1) • point after second half-life - 12, 20 (1) • point after third half-life - 18, 10 (1)	within 1 small square by eye smooth curve starting at 80, with a decreasing gradient passing through one correct half-life point scores 2 marks smooth curve starting at 80, with a decreasing gradient passing through two correct half-life points scores 3 marks **if no other mark scored** smooth curve showing decreasing gradient but not going through any correct points scores 1 mark	**(3)** AO 3 1a

Q25.

Question number	Answer	Additional guidance	Mark
	Any two from smoke alarm (1) food irradiation (1) sterilising (1) detecting leaks/cracks (1) gauging thicknesses (1) in medicine diagnostic (1) in medicine therapeutic (1) dating (archaeological samples) (1)	 named named	**(2)**

Q26.

Question Number	Answer	Additional guidance	Mark
(i)	an explanation including: (fluorine-18 has) a short half-life (1) (so) it must be **used** as soon as possible after making (1)	 decays too quickly related to transport / proximity ignore arguments about harm to person / the environment	**(2)**

Question Number	Answer	Additional guidance	Mark
(ii)	an explanation including: **alpha** short range/low penetration (1) (so) needs to be close to the tumour (1) **gamma** long range/high penetration (1) (so) can get into the body from outside (1)	 accept highly ionising accept weakly ionising pass through the skin 'alpha more ionising than gamma' 1 mark by itself	**(4)**

Q27.

Question Number	Answer	Additional guidance	Mark
(i)	Atoms may form positive ions by **losing** electrons. (1) The electrons involved are the **outer** electrons (1)	accept any clear indication that correct word is in gap	(2)

Question Number	Answer	Mark
(ii)	The only correct answer is **C gamma** A is not correct because alpha radiation is not electromagnetic B is not correct because beta minus radiation is not electromagnetic D is not correct because neutron radiation is not electromagnetic	(1)

Question Number	Answer	Mark
(iii)	The only correct answer is **A alpha** B is not correct because beta minus travels further in air than alpha C is not correct because beta plus travels further in air alpha D is not correct because gamma travels further in air than than alpha and beta	(1)