Mark Scheme

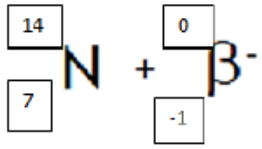
Q1.

Question Number	Answer	Acceptable answers	Mark
	An explanation linking any three from • Radon is radioactive (1) • Radon can escape from rocks and buildings (1) • Radon can be inhaled (1) • Radiation (from radon) can cause cancer (1) • Radon emits alpha (1)	Ignore radiation from rocks themselves Radon enters/gets trapped in buildings/homes / increases background radiation (breathed into) lungs (DNA) mutation / cell damage (Highly) ionising radiation	**(3)**

Q2.

Question Number	Answer	Acceptable answers	Mark
(a)	☒ **D** too many neutrons.		**(1)**

Question Number	Answer	Acceptable answers	Mark
(b)	☒ **A** a β^+ is positively charged and a β^- is negatively charged		**(1)**

Question Number	Answer	Acceptable answers	Mark
(c)	 Any two numbers correct (1) All four numbers correct (2)		**(2)**

Question Number	Answer	Acceptable answers	Mark
(d)	A description to include: Up and down (quarks) / Three (quarks) (1) Correct arrangement (quarks) (1)	 Accept for two marks: uud up, up, down two up quarks and one down quark Ignore charges	**(2)**

Question Number	Answer	Acceptable answers	Mark
(e)	An explanation linking the following: **Either** proton changes to a neutron (1) positron/anti-electron (emitted) (1) OR up quark changes to a down quark (1) positron/anti-electron (emitted) (1) **OR** proton number goes down by one / neutron number goes up by one (1) number of nucleons stays the same (1)	Accept any correct set of statements for two marks $P \rightarrow n + \beta^+$ (1) Ignore positive electron atomic number goes down by one mass number is constant	**(2)**

Q3.

Question number	Answer	Additional guidance	Mark
(i)	use of gradient on graph (1) = 1480 / 97 evaluation (1) 15.3 (counts /s)	look for a triangle / line going up allow 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	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.	**(6)** **exp**

	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	

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

Q5.

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

Q6.

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

Q7.

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)**

Q8.

Question number	Answer	Additional guidance	Mark
	The time taken for the activity of a radioactive nuclide to halve (1)	accept for nuclide: isotope sample	**(1)**

Q9.

	Answer	Additional guidance	Mark
(i)	A description including: roll / release / drop a marble (down the slope) (1) and **one** from record where the marbles go (1) **OR** measure the angle of path (1)	 allow alpha particle for marble allow any method of recording	**(2)** **AO3**

	Answer	Additional guidance	Mark
(ii)	any **one** from marble / weight has no charge (1) the edge of the paper is not far enough away from the weight (1) the marble / weight is too big / small (1) there is only one marble / weight (1) it is 2 dimensional / not 3D (1) all marbles have the same speed (1) marbles (only deflect on) hitting / contact with weight (1)	 not to scale allow marble cannot pass through the weight (1)	**(1)** **A03**

Q10.

Question number	Answer	Additional guidance	Mark
	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**

Q11.

	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**

Q12.

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)**

Q13.

Question number	Answer	Mark
(i)	An answer that combines the following points of application of knowledge and understanding to provide a logical description: • proton number/atomic number decreases by 1 (1) • nucleon number/mass number remains unchanged (as p and n have same mass and mass of electron is (assumed) negligible) (1)	**(2)**

Question number	Answer	Mark
(ii)	C	**(1)**

Q14.

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

Q15.

	Answer	Additional guidance	Mark
(i)	reading from graph (1) (at 5 degrees:) number between 10^6 and 10^7 **AND** (at 100 degrees:) 10^2 evaluation (1) $\frac{\text{number between } 10^6 \text{ and } 10^7}{10^2}$ **OR** between 10^4:1 and 10^5:1 between 10 000:1 and 100 000:1 **OR** between 10^4 and 10^5 between 10 000 and 100 000	(e.g. $10^{6.5}$) (e.g. $10^{4.5}$:1 or 10^7:10^2) allow any correct ratio not in its simplest form (e.g. $10^{4.5}$) award full marks for correct answer without working inverted ratio scores 1 mark maximum	**(2)** **AO2**

	Answer	Additional guidance	Mark
(ii)	an explanation including any **four** from: Observations most (alpha particles) pass (straight) through the foil (with little deflection) (1) some (alpha particles) are {scattered / deflected} through {small angles / less than 90 degrees} (1) (very) few (alpha particles) are {scattered / deflected} through {large angles / greater than 90 degrees} (1) Conclusions atoms are mainly empty space (1) there must be a nucleus / something inside the atom (1) (nucleus / something) must be {small / heavy / dense / concentrated / charged / positive} (1)	Ignore electrons ignore refracted allow repelled allow rebound / reflect / back scattering / bounce back ignore electrons	**(4)** **AO1,AO3**

Q16.

	Answer	Additional guidance	Mark
	substitution (1) number of atoms = $\frac{4.0\times10^{-7}}{0.15\ (\times10^{-9})}$ evaluation (1) 2 700	$\frac{4.0\times10^{-7}}{1.5\ (\times10^{-10})}$ $\frac{0.000\ 000\ 4}{0.000\ 000\ 000\ 15}$ accept any value that rounds to 2 700 award full marks for correct answer without working	**(2)** **AO2**

Q17.

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)**

Q18.

Question number	Answer	Additional guidance	Mark
	An explanation that combines understanding (1 mark) and reasoning (1 mark) linking: • number of neutrons decreases by one (1) • number of protons increases by one.(1)	a neutron becomes a proton plus an electron for (2) marks	**(2)**

Q19.

Question number	Indicative content	Mark
	An explanation that combines identification via a judgment (2 marks) to reach a conclusion via justification/reasoning (1 mark): • some alpha particles go straight through (1) • some alpha particles scattered (1) • idea of all mass / (positive) charge concentrated in centre /nucleus (1) • mainly empty space (in rest of atom) (1)	**(3)**

Q20.

Question Number	Answer	Additional guidance	Mark
	An explanation linking: neutron (decays) to proton (1) beta emitted (1)	 mass number stays the same but atomic number increases by 1 accept answers in terms of quarks (dud becomes uud) beta decay / β seen NOT β^+/beta plus allow (fast) electron emitted allow for 2 marks: n □ p + e OR $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta^{(-)}$	**(2)**

Q21.

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**

Q22.

Question number	Answer	Mark
	one from • same atomic number (1) • same number of protons (1) • same element (1) and one from • different numbers of neutrons (1) • different mass numbers (1)	**(2)**

Q23.

Question Number	Answer	Additional guidance	Mark
	in this order infrared (wave) / IR (1) micro(wave) (1) radio (wave) (1) gamma (ray/wave)(1)	accept μ(wave) accept γ not X	**(4)** AO 1 1

Q24.

Question Number	Answer	Additional guidance	Mark
	a description that combines 4 points from the following: 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

Q25.

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)**

Q26.

Question number	Answer	Additional guidance	Mark
	Determines number of half-lives and rounds (1) 263/87.7 = 3 Determines that 3 half-lives is 1/2 × 1/2 × 1/2 = 1/8 (1) Determines mass of Pu-238 after 3 half-lives (1) 925/8 = 115.625 (g) Determines average energy released per second (1) 115.625 × 0.54 = 62.4 (J)	 allow repeated division by 2 allow ecf from step 2 for 1 mark (mass of Pu-238 after1 half-life 925/2 = 462.5 (g)) allow ecf from 1 half-life or from step 3	 **(4)**

Q27.

Question Number	Answer	Acceptable answers	Mark
(i)	**B 21**		**(1)**

Question Number	Answer	Acceptable answers	Mark
(ii)	**A** $^{39}_{19}K$		**(1)**

Question Number	Answer	Acceptable answers	Mark
(iii)	A description to include any two of • (nucleus/isotope is) unstable (1) • (nucleus/isotope is) radioactive (1) • decay is random (1) • long half life (1)		**(2)**

Q28.

Question Number	Answer	Acceptable answers	Mark
(i)	An explanation linking two of the following:- CT scan lasts much longer / X-ray short exposure (1) CT scan is many X-ray (slices) (1) The intensity of radiation for CT scans is higher than for normal X-rays (1)	 For CT scan X-ray machine moves (slowly) around the body many pictures / series of X-rays/ 3D image	**(2)**

Question Number	Answer	Acceptable answers	Mark
(ii)	Justification including:- appreciation that there would be risks (1) ONE from:- non-invasive/ not painful (1) OR more accurate/better/earlier diagnosis (1) OR life-saving/ provide cure (1)	 the benefits outweigh the risks/drawbacks/concerns/dangers gives more useful information	**(2)**

Q29.

Question Number	Answer	Acceptable answers	Mark
(i)	1250 (million years) (1)	Between 1200 and 1300 (my) inclusive	**(1)**

Question Number	Answer	Acceptable answers	**Mark**
(ii)	2 half lives (1) 2500 (million years) (1)	 Allow ecf from (bi) Give full marks for answer between 2400 and 2600 with no working.	**(2)**

Q30.

Question Number	Answer	Acceptable answers	Mark
(i)	**B** a few hours		**(1)**

Question Number	Answer	Acceptable answers	Mark
(ii)	An explanation including three of the following: MP1 alpha/the radiation is (highly) ionising (1) MP2 the radiation destroys cancers/tumours (1) MP3 alpha particles/ do not penetrate very far in the body/inserted close to the cancer (1) MP4 half-life is long enough for the treatment to take effect (1) MP5 half-life is short enough so that the pellets do not need to be removed (1)	 kills/ destroys/mutates cells mutates DNA alpha particles do not/ get out of the organ being treated/ damage cells in other organ Ignore patients being radioactive Ignore replacement of pellets	**(3)**

Q31.

Question Number	Answer		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