Mark Scheme

Q1.

Question number	Answer	Additional guidance	Mark
(a)	An explanation that makes reference to the following linked points: • need to be able to find the mean value of the data (1) • but cannot do these consecutively as the sample will have decayed and hence following readings will be lower/so that you can check the reliability (1)	accept reference to I-131 having a short half life	2

Question number	Answer	Mark
(b)	An explanation that makes reference to two of the following linked points: • short half-life (1) therefore radioactivity will decrease rapidly (1) OR • (beta particles) do not have a long range (in air) (1) therefore do not enter the body (1)	2

Q2.

Question number	Answer	Notes	Marks
(a)	gamma is more penetrating (than alpha); (therefore) idea that gamma can pass through the box / fruit;	ignore refences to ionising ability allow RA allow alpha has shorter range (in air) allow RA allow alpha won't reach the box	2
(b)	any two from: MP1. fruit has no bacteria / (all) bacteria on fruit have been killed; MP2. fruit has not been contaminated; MP3. fruit has not been made radioactive; MP4. radioactive source has not been in contact with the fruit;	 allow fruit does not contain any radioactive isotopes allow fruit does not emit radiation	2

Q3.

Question number	Answer	Notes	Marks
(a)	idea of subtracting the background count rate;		1
(b) (i)	time taken; and either of for (radio)activity to halve; for half of the (radioactive) nuclei / atoms / isotope to decay;	allow "how long it takes" reject "half the time" allow count rate for activity ignore mass, substance	2
(ii)	indication on graph of a half in count rate; 2.6 (minutes);	e.g. line drawn across from 25 until it reaches the curve, then down to the time axis allow 2.5-2.7 (minutes) 2.3 (minutes) = 1 mark	2

Q4.

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>(a)</td><td>B (124);

A is incorrect because this is the number of protons
C is incorrect because this is the number of protons and neutrons
D is incorrect because this is twice the number of protons added to the neutrons</td><td></td><td>1</td></tr>
<tr><td>(b)</td><td>C (a high frequency electromagnetic wave);

A is incorrect because this is the description of alpha radiation
B is incorrect because this is the description of beta radiation
D is incorrect because this is the description of neutron radiation</td><td></td><td>1</td></tr>
<tr><td>(c)</td><td>all 4 rows correct = 3 marks;;;
2-3 rows correct = 2 marks;;
any 1 row correct = 1 mark;

<table>
<tr><th>Variable</th><th>Independent variable</th><th>Dependent variable</th><th>Control variable</th></tr>
<tr><td>count measured using the detector</td><td></td><td>✓</td><td></td></tr>
<tr><td>distance between source and detector</td><td></td><td></td><td>✓</td></tr>
<tr><td>number of lead sheets</td><td>✓</td><td></td><td></td></tr>
<tr><td>time period for measuring the count</td><td></td><td></td><td>✓</td></tr>
</table>

more than one tick in a row negates the mark for that row</td><td></td><td>3</td></tr>
</table>

Q5.

Question number	Answer	Notes	Marks
(a)	C (number of protons in the nucleus); A is incorrect because electrons are not found in the nucleus B is incorrect because this is deduced from the mass number D is incorrect because this is the mass number		1
(b)	D (number of protons and neutrons in the nucleus); A is incorrect because electrons are not found in the nucleus B is incorrect because this is determined from the mass number and is not the mass number itself C is incorrect because this is the atomic number		1
(c)	D (atoms with the same number of protons but a different number of neutrons; A is incorrect because isotopes must have the same number of protons B is incorrect because isotopes have a different number of neutrons to each other C is incorrect because isotopes must have the same number of protons		1
(d)	A (adding an electron); B is incorrect because this will change the element and make it positively charged C is incorrect because this will create a positively charged ion D is incorrect because this will change the element		1
(e)	B (radioactive decay happens at random); A is incorrect because this is a consequence of radioactive decay C is incorrect because it does not explain the random nature of radioactive decay D is incorrect because this explains why radioactive decay happens in the first place		1
(f)	A (becquerel (Bq); B is incorrect because this is the unit for charge C is incorrect because this is the unit for energy D is incorrect because this is the unit for power		1
		Total for Question = 6 marks	

Q6.

Question number	Answer	Notes	Marks
(a)	(number of protons =) 31; (number of neutrons =) 36;		2
(b)	gamma has a high penetrating ability; gamma can be detected outside the body;	allow gamma can pass through / out of the body	2
(c)	gallium-68 has a different number of neutrons; difference in number of neutrons is 1;	allow RA reject if gallium-68 described as having less neutrons "gallium-68 has 1 more neutron"/RA gets both marks	2
			Total for question 1 = 6 marks

Q7.

Question number	Answer	Notes	Marks
(a)	any one from: • handling source with tongs/gloves; • storing source in lead box (when not in use); • minimising time handling source; • maximising distance from source; • taking care with direction of emission from source; • use of lead apron/shielding;	 ignore if mention of other room etc.	1
(b)	B (138); A is incorrect because this is the number of protons C is incorrect because this is the number of nucleons D is incorrect because this is the number of nucleons + protons		1
(c) (i)	photographic film / Geiger-Muller tube;	allow GM tube, GM detector condone Geiger counter allow spark counter	1
(ii)	alpha / α;		1
(d) (i)	time taken; and either of • for (radio)activity to halve; • for half of the (radioactive) nuclei / atoms / isotope to decay;	allow "how long it takes" reject "half the time" allow count rate for activity	2
(ii)	C (1.88×10^{21}); A is incorrect because this is the number of atoms after 3200 years B is incorrect because this is the number of atoms after 1600 years D is incorrect because this is the initial number of atoms		1

Q8.

Question number	Answer	Notes	Marks
(a)	(nuclei with) the same number of protons; (but) different number of neutrons;	allow same atomic number / same element allow different nucleon / mass number /atomic mass	2
(b)	A (82); B is incorrect because this is the number of neutrons C is incorrect because this is the number of nucleons D is incorrect because this is double the proton number + nucleon number		1
(c) (i)	evidence of 3 half-lives; correct evaluation; e.g. $240 \div 2^3 = 30$ $66 \div 3 = 22$ (years)	seen anywhere in working	2
(ii)	correct atomic and mass numbers used for alpha particle; correct evaluation of number of beta particles; e.g. atomic number of alpha = 2, mass number = 4 (therefore) 2 beta decays (to get back to 82) $^{210}_{82}Pb \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}\alpha + 2\,{}^{0}_{-1}\beta$	seen anywhere in working	2
		Total for Question = 7 marks	

Q9.

Question number	Answer	Notes	Marks
(a)	beta;	allow electron(s) reject beta plus	1
(b) (i)	idea of allowing for background radiation;	mention of background radiation is sufficient for the mark	1
(ii)	count rate;	allow count allow corrected count rate	1
(c) (i)	time taken; and either of for (radio)activity to halve; for half of the (radioactive) nuclei / atoms / isotope to decay;	allow "how long it takes" reject "half the time" allow count rate for activity ignore mass, substance	2
(ii)	curve drawn starting at same point as existing curve; curve is consistently drawn below existing curve;		2

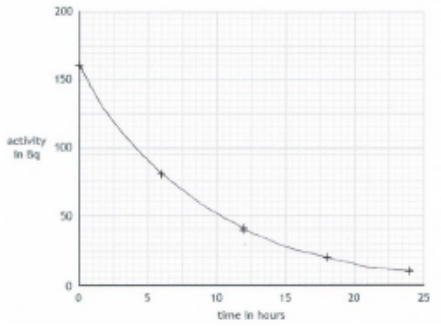
Q10.

Question number	Answer	Notes	Marks
(a)	substitution into $v^2 = u^2 + 2as$; rearrangement; evaluation; e.g. $75^2 = (0^2 +) 2 \times 4.1 \times s$ $s = 5625 / 8.2$ (s =) 690 (m)	allow alternative method of finding the time taken and then using **average** speed = distance/time 1371-1372 = 2 marks allow 686, 685.9756...	3
(b) (i)	any two from: MP1. idea of radiation that is always present / present everywhere; MP2. idea of no 'obvious' source; MP3. any valid source of background radiation given e.g. radon/rocks/cosmic rays/medical or military activity/the Sun etc.;		2
(ii)	any three from: MP1. idea that excessive exposure time can be harmful/increases risk; MP2. idea that dosage is higher (at maximum height); MP3. idea that increased risk of cancer; MP4. idea that there is less atmosphere to absorb cosmic radiation; MP5. cosmic rays/radiation is increased;	allow cell mutation for cancer	3
		(Total for Question = 8 marks)	

Q11.

Question number	Answer	Notes	Marks
(a) (i)	(92 =) number of protons (238 =) number of nucleons / number of protons <u>and</u> neutrons	ignore atomic number allow mass ignore mass number	2
(ii)	(nucleus) loses two protons; (nucleus) loses two neutrons;		2
(b) (i)	evaluation of mass of U-238 in plate; evaluation of number of atoms; e.g. mass = $(1.1 \times 0.045) = 0.0495$ kg $(n = 0.0495 / 4.0 \times 10^{-27} =) 1.2 \times 10^{25}$	accept 49.5 g or 0.0495 kg or correct standard form 1.2375×10^{25}	2
(ii)	any three from idea that food is irradiated / not contaminated; alpha cannot penetrate skin or body / range of alpha insufficient to reach body; contains low percentage of uranium(-238); (long half-life means that) activity will be very low / decays very slowly;	 ignore references to paper Accept 'mass' for 'percentage'	3

Q12.

Question number	Answer	Notes	Marks
(a)	activity shown to decrease over time; descending curve getting shallower starting at (0,160); line passes through two other valid points; • (6,80) • (12,40) • (18,20) • (24,10)  		3
(b) (i)	idea that it decays very quickly / activity will be zero by the time it is injected / there will be no technetium-99m left;	ignore 'it has a short half-life'	1
(ii)	any **one** from: • idea that gamma can penetrate out of the body; • idea that gamma can be detected outside the body; any **one** from: • idea that half-life is long enough to complete the procedure; • idea that activity will fall to safe level in a day / quickly;	marks must be from separate lists allow idea that technetium will not be in body for very long	2

(c)	harmful effect of gamma radiation given; idea that patient will have procedure very rarely / only when necessary (so risk is low); idea that doctor will administer procedure regularly (so risk is higher) / doctor limits time exposure to patient (to reduce risk);	e.g. • cancer • cell damage • cell mutation allow suggestion that risk to patients is higher as they receive greater dose allow idea that doctor increases distance from patient (to reduce risk)	3

Q13.

Question number	Answer	Notes	Marks
(a)	any suitable natural source; e.g. (the) Sun, cosmic rays, rocks, (named) food, radon etc.	reject if contradicted by a list allow named radioactive isotopes e.g. carbon-14, uranium-235, uranium-238 ignore "space", cosmic microwave background radiation (CMBR)	1
(b) (i)	any two **described** differences from: MP1. alpha has more mass; MP2. alpha has more charge; MP3. alpha is positive and beta is negative; MP4. alpha has shorter range (in air); MP5. alpha is slower; MP6. alpha is less penetrating; MP7. alpha is more ionising; MP8. alpha is a helium nucleus but beta is an electron;	allow RA throughout allow alpha is heavier allow oppositely charged allow alpha stopped by air/paper and beta stopped by aluminium/thin metal allow alpha is 2 protons and 2 neutrons but beta is an electron	2
(ii)	evidence of trying to balance nuclear equation; correct number of alphas; correct number of betas; e.g. $90 = 86 + 2\alpha$ number of alpha = 3 number of beta = 2	e.g. 232 - 220 = 12 also gains first mark also gains first mark this balances atomic number despite mass number not balancing (if no beta was present)	3
(c)	any three from: MP1. (alpha) can cause cell mutation / cancer; MP2. idea that alpha is only dangerous when inside body; MP3. alpha is blocked by skin / few cm of air; MP4. thorium can only cause irradiation (since it remains in work surface); MP5. radon / gas can cause (both) contamination (and irradiation) (since it can go inside body / food); MP6. radon / gas can be inhaled / enter body; MP7. thorium cannot enter body;	allow both (thorium and radon) can cause irradiation	3
		Total for Question = 9 marks	

Q14.

Question number	Answer	Notes	Marks
(a) (i)	different number of neutrons; technetium-99 has 1 more neutron;	reject if number of protons is given as different DOP condone technetium-99 has 99 neutrons and technetium-98 has 98 neutrons	2
(ii)	43; -1;		2
(b)	any four max. from: MP1. use of GM tube + counter/GM tube/photographic film; MP2. measure count (rate) without source / find background count; MP3. measure count (rate) with source; MP4. (subtraction to) find corrected count (rate); MP5. repeat readings to obtain mean; MP6. idea that paper / aluminium does not affect count / reading; MP7. idea that lead reduces count rate **significantly**; PLUS any safety precaution from: MP8. idea of keeping distance from source; MP9. minimise exposure time; MP10. use of shielding;	allow 'reading' for count rate allow Geiger counter; allow lead blocks (all) radiation e.g. tongs/moving away from source e.g. keeping source in lead-lined box, use of lead apron / gloves, working in a different room from source	5
(c)	use of one data point; evaluation of distance^2 × count rate; second data point and second evaluation of distance^2 × count rate; conclusion reached consistent with the two evaluations; e.g. (1,100) gives $1^2 \times 100 = 100$ (4,6) gives $16 \times 6 = 96$ 96 is approximately equal to 100 so relationship is verified	reject idea that evaluations are inconsistent unless there is a significant difference between them e.g. due to ECF (1,100) gives constant = 100 (2,25) gives constant = 100 (3,11) gives constant = 99 (4,6) gives constant = 96 (5,4) gives constant = 100	4
		Total for Question = 13 marks	

Q15.

Question number	Answer	Notes	Marks
(a) (i)	any ONE from: wear gloves; use tongs; do not point source at anyone; keep source at arm's length; keep source in lead-lined box; keep exposure time short; wear goggles; lead **apron**;	 accept use of remote control i.e. a robot i.e. only have the source out for as long as is necessary	1
(ii)	Geiger-Muller tube (and counter);	allow GM tube/counter/detector condone 'photographic film'	1
(b)	;;; Material Type of radiation | 10 mm of air | 2 cm of aluminium | 10 cm of lead alpha | X | X | X beta | | X | X gamma | | | X	each correct row scores 1 mark	3
(c) (i)	recall of KE = ½ m v^2; substitution; correct evaluation; correct answer: 1.5×10^{-12} (J) e.g. KE = ½ m v^2 KE = ½ × $(6.6 \times 10^{-27}) \times (2.1 \times 10^{7})^2$ KE = 1.4553×10^{-12} (J)	 −1 POT error	3
(ii)	candidate's answer for (i) e.g. 1.5×10^{-12} (J)		1
(iii)	thermal;		1
		Total for Question = 10 marks	

Q16.

Question number	Answer	Notes	Marks
(a) (i)	4; 2;		2
(ii)	removal of electron(s) (from an atom);	allow gaining electron(s)	1
(iii)	alpha particles are **absorbed** by/cannot **penetrate/ stopped** by a few cm **in air**; so alphas do not reach the workers;	allow do not penetrate **casing** (of deionser) condone 'do not penetrate skin/clothes'	2
(b) (i)	time taken; for (radio)activity/mass/number of (remaining) nuclei to half;	accept any synonym e.g. period/amount of time/	2
(ii)	evidence of halving of 70; 420 days means 3 half-lives; evaluation of 8.75 (kBq);	 accept however presented i.e. 70→35→17.5→8.75 allow 9 (kBq)	3
		Total for Question = 10 marks	

Q17.

Question number	Answer	Notes	Marks
(a)	any two from: MP1. alphas do not penetrate as far; MP2. alphas are more ionizing; MP3. alphas are more likely to collide (with material); MP4. alphas have more mass / move slower;	 allow RA allow RA allow RA allow RA	2
(b) (i)	(nuclei with) same numbers of protons; (nuclei with) different numbers of neutrons;	allow (nuclei with) same atomic number allow (nuclei with) different mass number	2
(ii)	one mark for each correct number;; $^{235}_{92}U \rightarrow {}^{231}_{\boxed{90}}Th + \boxed{4}_{2}\alpha$		2
(iii)	any indication that 2100 million years is 3 half-lives; evaluation of number of uranium nuclei after 1 half-life; (after 2100 million years) there are 800 million uranium nuclei; (after 2100 million years) there are 5600 million thorium nuclei; 5600 (million) / 800 (million) = 7;	 3200 (million) uranium nuclei after one half-life scores first three marks allow total number of nuclei is constant allow $7 \times 800 = 5600$	5
		Total for Question = 11 marks	

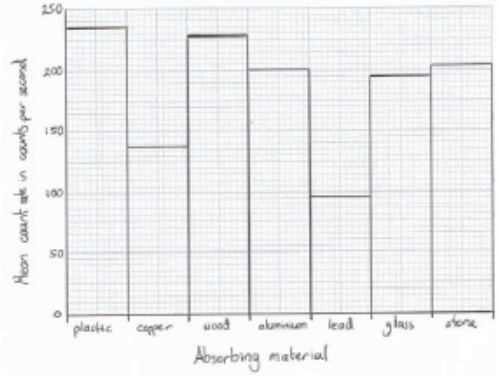
Q18.

Question number	Answer	Notes	Marks
(a)	idea of radiation from sources in the environment; idea that background is ever present/all around;	allow idea of 'no other sources present'	2
(b) (i)	time taken; and either of for the (radio)activity to halve; for half of the (radioactive) nuclei / atoms/ isotope /mass to decay;	allow "how long it takes" reject "half the time" allow count rate for activity ignore substance	2
(ii)	evidence of graph used correctly; 3.8 (days);	i.e. line drawn across from 600 to curve and down to time axis allow full marks for 3.8-3.85	2
(c)	4 (for alpha nucleon number); 2 (for alpha proton number); 86 (for Rn proton number);	 ECF for incorrect alpha proton number then multiplied by 3	3
(d)	any TWO from: MP1. idea of irradiation of internal organs; MP2. alphas are {highly/very/most} ionizing; MP3. causes mutations/cancer;	 allow idea that there is no 'dead skin' layer for alphas to penetrate allow 'damages tissue' or 'damages cells/DNA'	2
		(Total for Question = 11 marks)	

Q19.

Question number	Answer	Notes	Marks
(a)	A helium **nucleus** / 2 protons and 2 neutrons/ 4 nucleons, 2 protons;	Ignore chemical symbol	1
(b) (i)	Arrow labelled Y, through X away from nucleus; Line of action of force would pass through centre of nucleus by eye;		2
(ii)	Arrow labelled Z, opposite direction to their answer from b) (i) by eye; Same size as their answer from b) (i) by eye;	If no arrow Y, condone correct direction for arrow Z, i.e. force arrow pointing away from point X.	2
(iii)	MP1 Force on alpha is repulsive; MP2 Alpha and nucleus must be same (type of) charge; MP3 Alpha is positive **therefore** nucleus is positive;	Allow 'like charges repel' for MP1 and MP2	3
(c)	Selection of F = ma; Substitution or re-arrangement; Evaluation; e.g. a = 3.6 / 6.6 x 10^{-27} = 5.5 x 10^{26} m/s^2	Can be implied from working -1 for PoT error Allow 5.45 x 10^{26}, 5.454 x 10^{26}, 5.4545... x 10^{26} etc Condone 5.4 x 10^{26}	3

Q20.

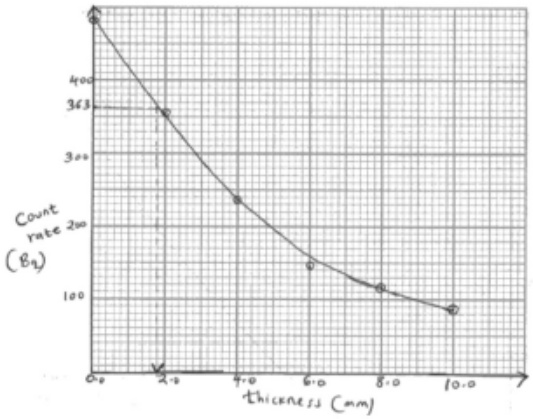
Question number	Answer	Notes	Marks
(a)	Geiger-Muller tube / GM tube;	allow Geiger counter, Geiger meter, GM detector	1
(b)	(absorbing) material;	allow absorber	1
(c)	any two from: MP1. idea that thickness also affects the count/results; MP2. idea that thickness is a control variable; MP3. idea of making experiment valid;	 allow fair test for valid	2
(d)	measure count over longer time / take more repeats / measure background count;	allow quoted time longer than 3 seconds	1
(e) (i)	suitable linear scale chosen (>50% of grid used); axes labelled with quantities and unit; all bar plotting correct to nearest half square;  	ignore orientation do not accept multiples of 30 for scale **Absorbing material** / **Mean** plastic 235 copper 137 wood 227 aluminium 202 lead 97 glass 195 stone 203	3
(ii)	B (absorbing material is not a continuous variable); A is incorrect because absorbing material is not a continuous variable C is incorrect because line graphs are drawn for continuous variables D is incorrect because count rate is a continuous variable		1
(iii)	idea that the lower the count, the better the absorber; lead is the best absorber;	ignore student is right/wrong allow RA allow that plastic is the worst absorber	2

Q21.

Question number	Answer	Notes	Marks
(a)	becquerel(s) / Bq;	allow recognisable spellings allow if written in table	1
(b) (i)	vertical axis labelled "activity" AND horizontal axis labelled "time in years";	ignore unit on vertical axis	1
(ii)	smooth curve of best fit drawn;	curve should pass within 1 small square of each data point condone curve starting at second point	1
(iii)	evidence of working on graph or in working space; half-life = 5.6 (years);	e.g. lines shown on graph or evidence of halving 8000 etc. allow range of 5.4-5.8	2
(iv)	3 half-lives; (3 × 5.6 =) 16.8 (years);	allow 16.2-17.4 (years) allow ecf from (iii)	2
(c)	both have same number of protons; cobalt-60 has one more neutron;	allow RA ignore references to atomic/mass numbers	2
(d)	nucleus loses a neutron; nucleus gains a proton;	"neutron becomes a proton" scores both marks condone plurals e.g. neutrons, protons	2

(e)	any four from: **Hazards (max. 2 marks)** MP1. radiation from them can cause cancer / cell damage / damage to organisms / people; MP2. radiation is highly penetrating; MP3. risk of theft / eq; MP4. remain radioactive for some time; MP5. risk of contamination of land/water; **Precautions (max. 2 marks)** MP6. need for shielding; MP7. use of machines to remove from reactor; MP8. need for security (to prevent public access/protect from hijacking/eq); MP9. need to be suitably protected against damage; MP10. special facilities required, not landfill; MP11. relatively short half-life means that very long-term storage is not necessary;	 e.g. lead, concrete etc. e.g. from earthquakes, overheating etc. e.g. stored underground/underwater, measures to avoid leakage	4
		Total for Question = 15 marks	

Q22.

Question number	Answer	Notes	Marks
(a) (i)	(the) Sun / cosmic rays / rocks / radon (in the air) / weapons testing / food / (named) nuclear disasters / medical equipment;	reject CMBR allow soil	1
(ii)	use of GM tube (and counter, timer); idea of removing source (from room); idea of measuring background count several times and calculating mean; subtract background count from readings;	allow radiation detector, Geiger counter for GM tube e.g. measuring count with source and without source	4
(b) (i)	correctly calculated mean; correctly rounded to 0 decimal places; e.g. (mean =) 147.666... (mean =) 148	 answer of 147 gains 1 mark	2
(ii)	suitable linear scale chosen (>50% of grid used); axes labelled with quantities and unit; plotting correct to nearest half square;	ignore orientation allow ecf from (i) reject if non-linear scale used	3
(iii)	acceptable curve of best fit drawn;  	i.e. smooth curve with points distributed equally either side allow ecf from (ii) ignore curve outside given data range	1
(iv)	calculated value of 75% of initial count rate; correct read-off from candidate's graph; e.g. (count rate =) 363 (Bq) (lead thickness =) 1.8 (mm)	 allow 1 mark max. for correctly reading from 25% of initial count rate allow 1.7 - 1.9 (mm)	2

(c)	gamma; idea that all beta/alpha would be absorbed by lead / only gamma can penetrate through (thin) lead;		2
		Total for Question = 15 marks	