PEARSON EDEXCEL IGCSE PHYSICS · 4PH1

PHYSICS



MARK SCHEME

SECTION 7: RADIOACTIVITY AND PARTICLES (PACK 1)

SCORE	PERCENTAGE
/230	%

STEMUP

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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)	D (the Sun); A is incorrect because a comet is the smallest object B is incorrect because the Earth is smaller than the Sun C is incorrect because the Earth and the Sun are larger than the Moon		1
(b)	A (alpha); B is incorrect because beta is less ionising than alpha C is incorrect because gamma is less ionising than alpha D is incorrect because gamma has a higher frequency than UV so is more ionising		1
(c)	B (ohm); A is incorrect because ampere is the unit for electric current C is incorrect because volt is the unit for voltage D is incorrect because watt is the unit for power		1
(d)	D (x-ray); A is incorrect because infrared has a longer wavelength than ultraviolet and x-ray B is incorrect because microwave has the longest wavelength C is incorrect because ultraviolet has a longer wavelength than x-ray		1
(e)	C (273 K); A is incorrect because this is subtracting 273, rather than adding 273 B is incorrect because this is adding 3, rather than adding 273 D is incorrect because this is adding 373, rather than adding 273		1
		Total for question	= 5 marks

Q3.

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

Q4.

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)	

Q5.

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	

Q6.

Question number	Answer	Notes	Marks
(a)	idea that 15% of **total** energy; is transferred **usefully**;	allow reverse argument e.g. 85% of total energy is wasted	2
(b)	correct efficiency read from graph; substitution into efficiency formula; rearrangement; evaluation; e.g. 90% or 0.9 seen in working 0.9 = 6.0 / total energy input total energy input = useful energy / efficiency (total energy input =) 6.7 (kJ)	 allow ecf from incorrect efficiency allow working in J or kJ allow any correctly rounded value for 4 marks allow 6.6 or 6.6 recurring (kJ) for 3 marks	4
(c) (i)	uranium or plutonium;	allow specifically named fuel e.g. uranium-235, plutonium-239 condone incorrect isotope number	1
(ii)	neutron; unstable; daughter; neutrons; kinetic;		5

Q7.

<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>

Q8.

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	

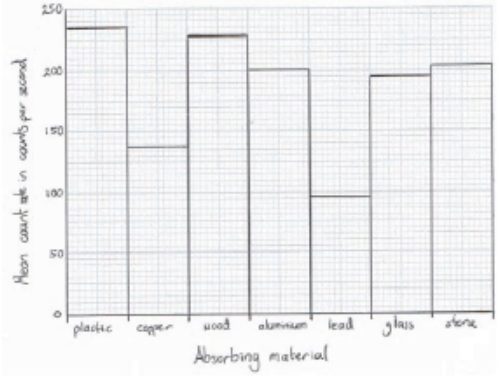
Q9.

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

Q10.

Question number	Answer	Notes	Marks
(a)	A (blue-white); B is incorrect because orange stars are cooler than blue-white stars C is incorrect because red stars are cooler than blue-white stars D is incorrect because yellow stars are cooler than blue-white stars		1
(b)	any two from: gas collapses / gas particles attract each other; temperature (of the gas) increases; fusion **starts**/eq;	 condone 'dust' for 'gas' allow particles increase in KE	2
(c)	two (small) **nuclei**; join together (to produce a large nucleus); releasing energy;	 allow gamma radiation	3
(d) (i)	C (mass); A is incorrect because colour is determined by the surface temperature B is incorrect because distance determines its apparent brightness D is incorrect because temperature determines the spectral class		1
(ii)	any three from: MP1. Rigel will become a red supergiant; MP2. then contracts rapidly; MP3. (explodes as a supernova) leaving a neutron star; MP4. (or) black hole;		3

Q11.

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

Q12.

Question number	Answer	Mark
(a)(i)	4 (1) 0 (1)  	2

Question number	Answer	Additional guidance	Mark
(a)(ii)	(Centre of) stars	allow the Sun	1

Question number	Answer	Mark
(a)(iii)	An explanation that makes reference to the following points: • hydrogen nuclei repel (1) • need a high speed/kinetic energy (1) • to get close enough to fuse together (1)	3

Question number	Answer	Additional guidance	Mark
(b)	An explanation that makes reference to the following points: • when fission occurs a large nucleus splits into smaller nuclei (1) • but when fusion occurs small nuclei fuse together to form a larger nucleus (1)	allow 'heavier', 'lighter' allow specific correct named isotopes	2

(Total for question = 8 marks)

Q13.

Question number	Answer	Notes	Marks
(a) (i)	neutron;		1
(ii)	nucleus/nuclei splitting; releasing (two) daughter nuclei / neutrons / energy;	condone nucleus/nuclei breaking apart ignore daughter cells allow smaller/lighter nuclei for daughter nuclei	2
(iii)	neutrons released (by fission) are absorbed by **other** (uranium) nuclei; causing fission/splitting in **other** (uranium) nuclei;	condone atoms for nuclei condone atoms for nuclei	2
(b)	concrete / lead / (thick) steel;		1
(c)	graphite; slow; boron; absorb;		4
		Total for Question = 10 marks	

Q14.

Question number	Answer	Notes	Marks
(a)	any four from: MP1. neutron absorbed by nucleus; MP2. uranium-235 becomes uranium-236; MP3. nucleus splits; MP4. producing (two) daughter nuclei; MP5. producing neutrons; MP6. releasing/transferring energy;	condone atom for nucleus throughout allow collides for absorbs allow named daughter nuclei e.g. krypton and barium etc. ignore daughter cells condone producing energy, radiation	4
(b) (i)	idea that products of fission/radiation are harmful/dangerous; idea that shielding absorbs radiation / fission products;	allow specific danger e.g. daughter nuclei are radioactive etc. allow idea that radiation cannot penetrate concrete	2
(ii)	particles collide with walls (of pipes); force is exerted on walls; pressure is force on an area;	ignore collisions with other particles allow p=F/A	3
		Total for question = 9 marks	

Q15.

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>(a)</td><td>all three correct ticks = 3 marks;;;
two correct ticks = 2 marks;;
one correct tick = 1 mark;

<table><tr><th>Statement</th><th>Correct (✓)</th></tr><tr><td>uranium-235 loses a proton to become uranium-236</td><td></td></tr><tr><td>uranium-235 absorbs a neutron to become uranium-236</td><td>✓</td></tr><tr><td>daughter cells are produced when uranium-236 splits</td><td></td></tr><tr><td>the nuclear energy store of uranium-236 increases when it splits</td><td></td></tr><tr><td>two or three neutrons are typically released when uranium-236 splits</td><td>✓</td></tr><tr><td>energy is transferred to the kinetic store of the fission products when uranium-236 splits</td><td>✓</td></tr></table></td><td>-1 for 4 ticks
-2 for 5 ticks
0 marks if all ticked</td><td>3</td></tr>
<tr><td>(b)</td><td>neutron / n / neutrons;</td><td></td><td>1</td></tr>
<tr><td>(c)</td><td>B (a helium nucleus);

A is incorrect because this describes gamma radiation
C is incorrect because this describes beta radiation
D is incorrect because this describes neutron radiation</td><td></td><td>1</td></tr>
<tr><td>(d)</td><td>beta (minus);</td><td>accept β, β^-
reject beta plus</td><td>1</td></tr>
</table>

Q16.

Question number	Answer	Notes	Marks
(a)	236 - (97 + 135); x = 4;	answer of 4 scores 2	2
(b)	(fission) releases neutrons; neutrons can be captured by other uranium **nuclei**; (these nuclei) then undergo fission;		3
(c)	evidence of halving of 72 (kBq); evidence of four half-lives required; e.g. count rate after 4 half-lives is 4.5 (kBq) evidence that four half-lives is equivalent to 60 million years;		3
(d)	Any FIVE from: MP1 Idea of strong containers; MP2 idea that containers can't rust; MP3 idea that rust-proof containers expensive/difficult to manufacture; MP4 reference to security of waste site; MP5 reference to dilution in sea water; MP6 reference to leakage into water table;	accept idea of a location that prevents rust accept low earthquake risk	5
		(Total for Question = 13 marks)	

Q17.

Question number	Answer		Notes	Marks
(a)	1 mark for each correct answer in the table;;;;;			5
	Part	**Function**	**Suitable material**	
	control rod	absorbs neutrons / regulates number of neutrons / controls rate of reaction	boron	
	moderator	slows <u>neutrons</u> / absorbs KE of <u>neutrons</u>	graphite	
	shielding	prevents irradiation of workers	concrete / lead / steel / water	
	fuel Rod	idea that it provides material for fission	uranium(-235/238) / plutonium / U / Pu	

(b)	(i)	same number of protons; different number of neutrons;	allow same atomic number, same element allow different nucleon number, different mass number, different atomic mass	2
	(ii)	fission is the **splitting** of a nucleus; fusion is the **joining** of two nuclei;	allow "breaking down" for splitting allow "fusing", "combining" for joining	2
	(iii)	star / fusion reactor / hydrogen bomb / red giant / supernova;	allow any named star or fusion reactor, i.e. Sun, JET, ITER reject protostar, white dwarf	1
	(iv)	any two from: MP1. nuclei move (too) slowly at low temperature; MP2. nuclei interact/collide less often at low pressure; MP3. nuclei repel each other; MP4. nuclei cannot get close enough / don't have chance to undergo fusion;	allow RA in terms of high temperature and high pressure allow nuclei not having enough KE allow atoms/particles for nuclei allow atoms/particles for nuclei	2

Q18.

Question number	Answer	Notes	Marks
(a) (i)	neutron;	accept symbol	1
(ii)	(when a) nucleus splits;		1
(iii)	kinetic energy/KE;	allow thermal	1
(b)	(gamma) radiation is a hazard / harmful shielding will absorb the (gamma) radiation; (concrete needs to be thick as) gamma has the highest penetrating power/can penetrate through many centimetres of lead/absorbed by many centimetres of lead;	ALLOW specific hazard e.g. can cause cancer	3

Q19.

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	

Q20.

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	

Q21.

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

Q22.

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

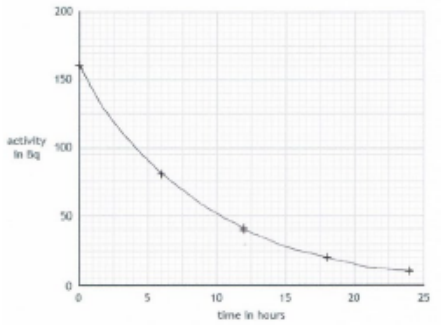
Q23.

Question number	Answer	Notes	Marks
(a)	any four correctly linked stages in star's evolution: MP1. nebula to protostar; MP2. protostar to main sequence; MP3. main sequence to red giant; MP4. red giant to white dwarf; MP5. white dwarf to black dwarf;	limit to 2 marks max. if incorrect stages given e.g. red supergiant, supernova, neutron star, black hole allow cloud of dust/gas for nebula allow main stage for main sequence allow 1 marking point if stage missing e.g. nebula to main sequence gets either MP1 or MP2 since protostar is missing	4
(b)	stars use <u>fusion</u>, reactor uses <u>fission</u>; fusion detail e.g.; • (fusion is the) joining of nuclei • involves light nuclei e.g. hydrogen fission detail e.g.; • (fission is the) splitting of nuclei • involves heavy nuclei e.g. uranium/plutonium	both needed condone atoms for nuclei condone atoms for nuclei	3
		Total for Question = 7 marks	

Q24.

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	

Q25.

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

Q26.

Question number	Answer	Notes	Marks
(a)	(nuclear) fusion;		1
(b)	Sun becomes a red giant; (then) a white dwarf;	allow planetary nebula reject mention of supernova, neutron star or black hole for this mark	2
(c) (i)	(mass =) 5×10^{29} (kg);	allow 5.3×10^{29}, 5.2×10^{29}, 5.25×10^{29} (kg)	1
(ii)	evaluation of time; answer to 1 significant figure; e.g. (time = $5.25 \times 10^{29} / 9 \times 10^{19}$ =) 5.8×10^{9} (years) (time =) 6×10^{9} (years)	allow ecf from (c)(i) allow 5.56×10^{9} (years) allow 6 000 000 000, 6 billion years	2
			Total for question 5 = 6 marks

Q27.

Question number	Answer	Notes	Marks
(a)	planet drawn with approximately circular orbit with Sun at its centre; comet drawn with elliptical orbit with Sun at one of its foci;	planet must be labelled comet must be labelled	2
(b) (i)	nebula / gas cloud;	allow protostar, dust cloud reject planetary nebula	1
(ii)	colour will become red; (because) the (surface of) Sun will cool down;	allow orange allow 'Sun will become a red giant'	2
(c) (i)	any three from: MP1. beta is negatively charged <u>and</u> alpha is positively charged; MP2. beta has lower/less mass; MP3. beta has 1 charge but alpha has 2 charges; MP4. beta is an electron <u>and</u> alpha is 2 protons and 2 neutrons; MP5. beta is less ionising (with distance); MP6. beta has longer range; MP7. beta has higher penetration power;	 allow they are oppositely charged allow RA allow beta has less charge allow alpha is helium nucleus allow RA allow RA allow RA	3
(ii)	any two from: MP1. radioactive source has not been in contact with spacecraft; MP2. idea that spacecraft was not contaminated; MP3. idea that spacecraft has only been irradiated;	 allow spacecraft does not contain any radioactive isotopes allow spacecraft has only been exposed to radiation	2
		Total for question = 10 marks	