Question number	Answer	Notes	Marks
1 (a) (i)	number of protons = 1; number of neutrons = 2;		2
(ii)	any three of the following **comparisons**: MP1. beta particle is negatively charged <u>and</u> alpha is positively charged; MP2. beta particle has lower/less mass ORA; MP3. beta particle has 1 charge but alpha has 2 charges; MP4. beta particle is an electron but alpha is 2p + 2n /eq; MP5. beta is less ionising; MP6. beta has higher speed; MP7. beta particles have larger range; MP8. beta has higher penetrating ability;	ignore descriptions of applications of types of radiation allow 'beta is lighter' ORA allow beta can pass through paper but alpha will be stopped	3
(iii)	any sensible suggestion; e.g. • alpha is 4 nucleons, tritium has (only) 3 / eq • tritium has only 1p, 2p are in alpha • tritium has not got enough mass / mass number too low • tritium has not got enough nucleons • tritium has not got enough p / atomic number too low • tritium has not got enough p+n	ignore tritium is too small	1
(b)	any two from: MP1. energy explanation; e.g. beta particles have given up all their KE on impact MP2. absorption explanation; e.g. beta particles have hit (and been absorbed by) phosphor MP3. penetration explanation; e.g. beta cannot penetrate (thick) glass / tube MP4. range explanation; e.g. signs are further away than the range of beta	ignore: • beta particles have low ionisation /OWTTE • no gas can escape	2

Question number	Answer	Notes	Marks
1 (c) (i)	time taken; and either of • for (radio)activity to **halve**; • for **half** of (radioactive) nuclei / atoms / isotope to decay;	allow how long it takes reject 'half the time' allow count rate for activity reject: • particles • molecules • substance • 'break down' • 'reactivity' • a nucleus / an atom • halve in mass • to completely/fully decay	2
(ii)	working seen/appropriate line(s) on graph seen; 13.5 years;	 tolerance ± 0.5 years	2
(d)	MP1. correct judgment re claim; MP2. (because) EITHER correct statement re time (at which the activity is 400); OR activity (at 20 years); e.g. the manufacturer is correct because the time would be 21.5 years (to reach an activity of 400) OR the manufacturer is correct because the activity is 420 (counts per minute) (at 20 years)	 allow range of 21-22 years allow range of 410 to 440 total marks = 14	2

Question number	Answer	Notes	Marks
2 (a)	A - fission		1
(b)	A - absorbing some of the neutrons		1

Total 2 marks

Question number	Answer	Notes	Marks
3 (a) (i)	A – electromagnetic waves		1
(ii)	time; for amount of (radioactive) isotope to halve; OR for (radio)activity to halve;	accept how long it takes do not accept 'half of the time' accept for 'amount' (number of un-decayed) nuclei / atoms / molecules / (un-decayed) mass of isotope	2
(b)	Any two of - MP1. (α or β) would have insufficient **range**; MP2. (α or β) would be absorbed by patient/air; MP3. (α or β) are more ionising (than gamma rays);	specific concepts and terminology are needed if the source is external max mark is ONE allow ORA **penetration** ORA stopped by skin / bone Allow (α or β) would be (more) likely to cause cancer/ damages cells (than gamma rays), ORA	2
(c) (i)	Any two of - MP1. Idea that activity is due to **nucleus** decaying; MP2. (after some time) fewer radioactive nuclei /atoms left; MP3. Number (of nuclei) decaying per second decreases;	specific concepts and terminology are needed do not credit repeat of stem Reject for 1 mark. (it/nucleus) breaks down allow • nucleus is unstable • nucleus emits gamma • nucleus changes into new isotope fewer atoms of the same isotope left decay rate decreases	2

(ii)	one halving calculated; Idea of four half-lives / halvings; Evaluation; e. (420/2=) 210 for 1 mark 24 ÷ 6 = 4 (half-lives) 26 MBq (26.25)	• 4 repeated halving seen • fraction remaining is 1/16 of activity Allow • four divisions by 2 seen for 2nd mark • remaining fraction = 1/16 = 0.0625 Correct answer without working scores full marks	3

Total 10 marks

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>4 (a) (i)</td><td>
<table>
<tr><th>safety precaution</th><th>needed</th><th>not needed</th></tr>
<tr><td>not touch the source with bare hands</td><td>(✓)</td><td></td></tr>
<tr><td>use tongs</td><td>✓</td><td></td></tr>
<tr><td>wear gloves</td><td></td><td>(✓)</td></tr>
<tr><td>wear goggles</td><td></td><td>✓</td></tr>
<tr><td>students sit at least two metres away</td><td>✓</td><td></td></tr>
<tr><td>wear a lead apron</td><td></td><td>✓</td></tr>
<tr><td>store source in a lead box</td><td>✓</td><td></td></tr>
</table>
3 ticks correct in first column;

2 ticks correct in second column;
</td><td>Ignore incorrect ticks in first column (award 1 mark as long as the three correct boxes are ticked)</td><td>2</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>(b) (i)</td><td>(because distance is a) controlled variable;</td><td>allow idea of fair test/affecting results

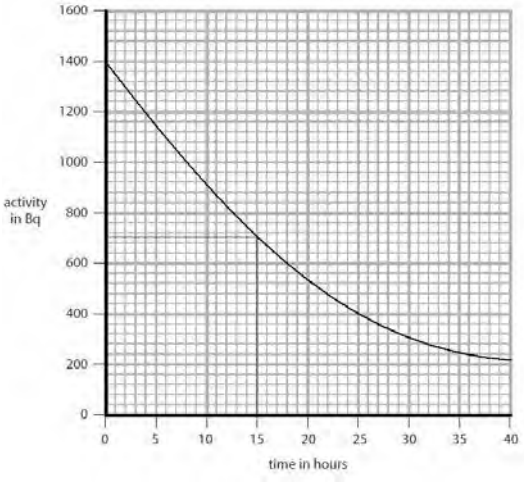
ignore comments relating to accuracy, reliability</td><td>1</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>(ii)</td><td>MP1. idea of background radiation;

MP2. any ONE sensible source;
e.g.
cosmic rays
rocks/Earth/buildings
some foodstuffs (coffee)
radon</td><td>allow ‘sources of radiation all around us’
allow nuclear weapons testing/disasters</td><td>2</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

(iii)	MP1. lead; MP2. idea of best absorber giving lowest count rate; MP3. for Ba-133/can't evaluate using Sr-90 data;	 dependent on MP1 dependent on MP1	3
(iv)	any 3 of: MP1. stone absorbs better than {plastic / wood / paper} for Sr-90/beta; MP2. stone worst absorber for Ba-133/gamma; MP3. use of data to justify MP1 or MP2; MP4. may not be worse absorber than paper as paper much thinner/not tested for Ba-133;	no mark for 'I agree with this conclusion /OWTTE' allow stone best absorber for Sr-90 e.g. the count rate for plastic is about half that of stone for Ba-133	3
(v)	MP1. beta; MP2. it's not alpha *because* {alpha would not reach the detector at this distance/ alpha would not go through paper}; MP3. it's not gamma *because* gamma is not stopped by metals ;	allow 'beta and gamma' allow 'it goes through paper' allow 'it doesn't go through metals' MP2 and MP3 dependent on MP1	3
(vi)	reading would be too high/eq;		1
(vii)	idea that count rate needs to be constant during the investigation/ORA;	allow either idea that would not need to replace the source often/ORA; or idea that shorter half-life has higher activity and therefore is more hazardous;	1

Total 16 marks

Question number	Answer	Notes	Marks
5 a	(Atoms / nuclei with the) same number of protons; Different numbers of neutrons;	ALLOW relevant correct alternatives e.g. • atomic number, proton number • nucleon number, atomic mass ignore comments about electrons	1 1
b i	Electron;	ignore comments about properties of electrons e.g. speed ALLOW • e^- or e^+ • positron	1
ii	any suitable detector e.g. Geiger(-Muller) tube/detector/counter; photographic film; zinc sulfide; gold leaf electroscope;	ALLOW • phonetic/incorrect spelling	1
iii	beta penetrates paper; beta absorbed/stopped by lead +/or aluminium ;	IGNORE • all details of experimental setup • beta goes through aluminium/eq DO NOT ALLOW • bounced back for absorbed • contradictions in answers e.g. re aluminium	1 1

	MP1. line goes through 0,1400 and (first half-life plotted at) 15, 700; MP2. line goes through/second half-life plotted at 30, 350; MP3. a correctly **curved line** between 15 and 30 hours AND the line extends beyond 35 hours; i.e.  	ALLOW for MP2 an ecf from incorrect first half-life to 'correct' second half-life e.g. 800---400 IGNORE • a *slight* upcurve at 35 to 40 hours • Bar charts • **Since this is a sketch then allow tolerance of +/- 1 square on the points**	1 1 1

Question number	Answer	Notes	Marks
d i	any FOUR from: MP1. there is a known proportion / composition / activity when rocks formed; MP2. measure/determine the proportion of uranium or the activity now; MP3. compare activity now to original activity/eq; MP4. (hence) determine the time / number of half-lives elapsed; MP5. (hence) calculate age from reference to half-life;	allow as a numerical example ignore work out the proportion when rocks were formed ALLOW • Bq for activity • radioactivity for activity • amount for proportion IGNORE • measure half-life of uranium • they know its activity ALLOW colloquial expressions such as 'see how long it took to decay this much'	1 1 1 1

ii	MP1. idea that it/half-life is **too** short OR idea that decay occurs **too** quickly/rapidly; PLUS MP2. (hence) **U / isotope** would (all) have decayed (long ago) OR **U activity** would be too small (to distinguish from background / to measure);	comparative of some sort needed for MP1 allow not enough time care that you do not award both alternatives for MP2 IGNORE granite decays it decays	1 1

(Total for Question 5 = 15 marks)