

01. 0625\_s23\_ms\_41 Q: 9

Question	Answer	Marks
(a)	(number of neutrons =) 7	B1
	any one from: <ul style="list-style-type: none"> <li>number of electrons = number of protons</li> <li>white dots are protons / there are 5 protons</li> <li>grey dots are neutrons</li> <li>(number of neutrons) = 12 – 5</li> </ul>	B1
(b)(i)	(X2 has) one more proton more and one fewer neutron (than X1) OR (X2 has) 6 protons and 6 neutrons	A2
	(X2 has) one neutron fewer / one more proton (than X1) OR (X2 has) 6 protons / 6 neutrons	C1
(b)(ii)	(X2) has fewer (excess) neutrons (in its nucleus) OR A	B1
(c)(i)	time (taken)	M1
	for number of (radioactive) nuclei / atoms (in a sample of X1) to halve OR for rate of decay to halve	A1
(c)(ii)	large number of particles produced in short time OR high / large decay rate OR high dose (of radiation) in short time	B1

02. 0625\_s23\_ms\_42 Q: 9

Question	Answer	Marks
(a)	$\alpha$ – no. of neutrons 2	B1
	$\beta$ – no. of protons 0 and charge $-1.6 \times 10^{-19}$	B1
	$\gamma$ – no. of neutrons 0 and charge 0 and (very) thick concrete / thick lead	B1
(b)	(the nucleus has) one less neutron and one more proton	B1
(c)	95 (counts / min)	A4
	initial count rate due to source = 550 – 30 (counts / min) OR 520 seen	C1
	(75 min =) 3 half-lives OR (count rate =) 1/8 (of initial count rate)	C1
	final count rate due to source = (520 / 8 =) 65	C1
(d)	any two from: <ul style="list-style-type: none"> <li>limit time of exposure</li> <li>store sources in lead boxes</li> <li>keep distance from sources</li> <li>avoid contact OR use tongs OR wear gloves</li> </ul>	B2

03. 0625\_s23\_ms\_43 Q: 8

Question	Answer	Marks
(a)(i)	(neutron) becomes proton and electron OR (neutron) becomes proton and $\beta$ particle	B1
(a)(ii)	charge on neutron = 0 OR total charge on products = 0	B1
	charge on proton = +1 AND charge on electron = –1	B1
(b)	$({}_{86}^{212}\text{Rn} \rightarrow) {}_{84}^{208}\text{Po} + 4{}_2^4\alpha$	A3
	any two from: <ul style="list-style-type: none"> <li>proton numbers balance</li> <li>nucleon numbers balance</li> <li><math>{}_2^4\alpha</math> OR <math>{}_2^4\text{He}</math> seen</li> </ul>	C2

04. 0625\_w23\_ms\_41 Q: 9

Question	Answer	Marks
(a)(i)	(americium-241 has) one neutron fewer (in the nucleus)	<b>B1</b>
(a)(ii)	(different) number of protons (in nucleus)	<b>B1</b>
	(different) number of neutrons (in nucleus)	<b>B1</b>
(b)(i)	${}_{95}^{241}\text{Am} \rightarrow {}_{93}^{237}\text{Np} + {}_2^4\text{a}$	<b>A3</b>
	any two from: ${}_{95}^{241}\text{Am}$ ${}_{93}^{237}\text{Np}$ ${}_2^4\text{a}$	<b>C2</b>
(b)(ii)	( $\alpha$ -particles have) more kinetic energy (than $\beta$ -particles)	<b>B1</b>
	( $\alpha$ -particles have) more charge (than $\beta$ -particles)	<b>B1</b>
(b)(iii)	Low(er) (initial) activity OR Few emissions per unit time	<b>M1</b>
	so smoke detectors are not hazardous to humans <b>OR</b> so disposal of old detectors is cheap / easy	<b>A1</b>

05. 0625\_w23\_ms\_43 Q: 9

Question	Answer	Marks
(a)(i)	alpha	<b>B1</b>
	highly ionising <b>OR</b> not (very) penetrating	<b>B1</b>
	any value between 10–500 years	<b>B1</b>
(a)(ii)	beta	<b>B1</b>
	absorption depends on thickness (of aluminium)	<b>B1</b>
	any number of years	<b>B1</b>
(b)	too many neutrons	<b>B1</b>
	decay reduces number of neutrons	<b>B1</b>
(c)	any two from: <ul style="list-style-type: none"> <li>• radon gas (in the air)</li> <li>• rocks <b>OR</b> buildings</li> <li>• food <b>OR</b> drink</li> <li>• cosmic rays</li> </ul>	<b>B2</b>

06. 0625\_m22\_ms\_42 Q: 10

Question	Answer	Marks
(a)	${}_{95}^{241}\text{Am} \rightarrow {}_{93}^{237}\text{Np} + {}_2^4\alpha$	
	${}_{93}^{237}\text{Np}$ nucleon number correct for Np	B1
	${}_{93}\text{Np}$ proton number correct for Np	B1
	$+ {}_2^4\alpha$ alpha notation correct	B1
(b)(i)	alpha (particles emitted from americium)	B1
	move close to / hit molecules in the air (between the metal plates)	B1
	removing electrons (out of the molecules)	B1

Question	Answer	Marks
(b)(ii)	<p>Any two from:</p> <ul style="list-style-type: none"> <li>alpha not penetrating / short range AND alpha (particles) stopped by smoke particles</li> <li>alpha (particles) more highly ionising (than gamma) AND ionise air more easily</li> <li>range of alpha particles is short / alpha is not penetrating AND alpha less harmful (to humans)</li> </ul>	B2

07. 0625\_s22\_ms\_43 Q: 10

Question	Answer	Marks
(a)	background radiation (present in values in Table 10.1)	B1
	(background radiation) is removed (before plotting) OR (background radiation) not present in the graph values	B1
(b)	$70 \leq \text{half-life} \leq 76$ (s)	A2
	evidence of at least one pair of values for count rate halving taken from graph	C1
(c)	${}_{91}^{234}\text{Pa} \rightarrow {}_{92}^{234}\text{U} + {}_{-1}^0\beta$	
	${}_{92}\text{U}$ on RHS	B1
	${}_{234}\text{U}$	B1
	$+ {}_{-1}^0\beta$ on RHS	B1

08. 0625\_w22\_ms\_41 Q: 9

Question	Answer	Marks
(a)	they all have the same number of neutrons / nucleons <b>or</b> they are all identical	<b>B1</b>
(b)(i)		<b>B2</b>
	(number of protons =) 80	B1
	(number of neutrons =) 118	B1
(b)(ii)	19 counts / minute $\leq$ count rate $\leq$ 21 counts / minute	<b>B1</b>
(b)(iii)	2.4 days $\leq$ $\tau$ $\leq$ 2.9 days	<b>A4</b>
	count rate from line – background count e.g. 390 – 20	C1
	answer from first C1 mark divided by 2 e.g. 370 / 2 <b>or</b> 185	C1
	background count + answer from second C1 mark e.g. 20 + 370 / 2 <b>or</b> 20 + 185 <b>or</b> 205	C1

09. 0625\_w22\_ms\_42 Q: 10

Question	Answer	Marks
(a)(i)	(proton number) 2	<b>B1</b>
	(nucleon number) 4	<b>B1</b>
(a)(ii)	$3.2 \times 10^{-18}$ (C)	<b>B1</b>
(b)	${}^{230}_{88}\text{Ra} \rightarrow {}^{230}_{89}\text{Ac} + {}^0_{-1}\beta$	<b>A3</b>
	<i>any two from:</i> <ul style="list-style-type: none"> <li>nucleon numbers 230 on left <b>AND</b> 230 on right</li> <li>Ra and proton number 88 on left <b>AND</b> Ac and proton number 89 on right</li> <li><math>{}^0_{-1}\beta</math>.</li> </ul>	C2
(c)	(mass =) $1.2 \times 10^{-12}$ g	<b>A2</b>
	3 half-lives <b>OR</b> $9.6 \times 10^{-12} / 8$ <b>OR</b> $9.6 \times 10^{-12} / 2^3$	C1

10. 0625\_w22\_ms\_43 Q: 10

Question	Answer	Marks
(a)	$\alpha$ -particles are short and thick / $\beta$ -particles are long and thin	B1
	any <b>two</b> from: <ul style="list-style-type: none"> <li><math>\alpha</math>-particles are more ionising / <math>\beta</math>-particles are less ionising</li> <li><math>\alpha</math>-particles are less penetrating or have shorter range / <math>\beta</math>-particles are more penetrating or have longer range</li> <li><math>\alpha</math>-particles have more energy / <math>\beta</math>-particles have less energy</li> </ul>	B2
(b)(i)	(element with) same number of protons	B1
	(element with) different number of neutrons	B1
(b)(ii)	${}_{11}^{24}\text{Na} \rightarrow {}_{12}^{24}\text{Mg} + {}_{-1}^0\beta$	
	Na on left with correct proton and nucleon number	B1
	$\beta$ on right with correct proton and nucleon number	B1
	Mg on right with correct proton and nucleon number	B1
(b)(iii)	half life (of Na 24) long enough (to allow detection of leaks)	B1
	negligible amount (of Na 24) remains in liquid after a few days (so) less hazardous (to human health)  <b>OR</b> decays to something stable/magnesium (is stable) <b>AND</b> (so) less hazardous (to human health)	B1

11. 0625\_m21\_ms\_42 Q: 10

	Answer	Marks
(a)	2	B1
	4	B1
	+2	B1
(b)	${}_{38}^{90}\text{Sr} \rightarrow {}_{39}^{90}\text{Y} + {}_{-1}^0\beta$	
	nucleon numbers 90 on both sides of equation	B1
	Sr and proton number 38 on left AND Y and proton number 39 on right	B1
	${}_{-1}^0\beta$ (to right of arrow)	B1
(c)	(original mass = $4 / 9.2 =$ ) 37 mg	A2
	2 half-lives	C1

12. 0625\_s21\_ms\_42 Q: 11

	Answer	Mark
(a)(i)	(initial CR adjusted for background = $220 - 20 =$ ) 200	C1
	(after 1 half-life CR adjusted for background =) 100 OR (detected CR) = 120	C1
	2.4 min	A1
(a)(ii)	12 or 13	C1
	$(12 + 20 =)$ 32 OR $(13 + 20 =)$ 33	A1
(b)	incorrect	B1
	container / (2 mm) plastic does not absorb / stop / block / is penetrated by $\gamma$	B1
	good extra detail e.g. any one of: <ul style="list-style-type: none"> <li>• container / (2 mm) plastic absorbs / stops <math>\alpha</math></li> <li>• partially correct as statement</li> <li>• need lead to stop <math>\gamma</math></li> <li>• <math>\gamma</math> is dangerous / harmful owtte</li> </ul>	B1

13. 0625\_s21\_ms\_43 Q: 10

	Answer	Mark
(a)(i)	curve bending downwards while in magnetic field (and labelled $\alpha$ )	B1
(a)(ii)	curve bending in opposite direction from $\alpha$ while in magnetic field OR up the page if no curve shown for $\alpha$ in (a)(i) (and labelled $\beta$ )	B1
	greater curvature for $\beta$ than for $\alpha$	B1
(a)(iii)	line passing straight through magnetic field (and labelled $\gamma$ )	B1
(b)	any two from: <ul style="list-style-type: none"> <li>• stand behind shielding provided / wall / as far away as possible</li> <li>• store in lead-lined boxes</li> <li>• limit exposure time / (monitoring exposure) with film badge</li> <li>• do not allow pregnant staff to work</li> </ul>	B2
(c)(i)	${}_{53}^{131}\text{I}$	B1
(c)(ii)	any two from: <ul style="list-style-type: none"> <li>• <math>\gamma</math> can be detected outside body</li> <li>• needs long enough half-life to be detected / reach part of the body required</li> <li>• needs short enough half-life to soon have very little activity</li> <li>• gamma weakly ionising or pass out of body without harm</li> </ul>	B2

14. 0625\_w21\_ms\_41 Q: 9

Question	Answer	Marks
(a)	(very small) nucleus and surrounded by electrons (in orbit / shells)	B1
	92 protons or 92 electrons or number of protons = number of electrons	B1
	protons and neutrons in nucleus	B1
	143 neutrons	B1
(b)	(uranium-238 has) three more neutrons (in nucleus)	B1
(c)	${}_{38}^{94}\text{E}$	B1
	${}_{38}^{94}\text{E}$	B1
(d)(i)	55	B1
(d)(ii)	140	B1

15. 0625\_w21\_ms\_43 Q: 11

Question	Answer	Marks
(a)(i)	background radiation OR any reasonable specific source of background radiation e.g. cosmic rays, the sun, space, building materials, earth, rocks, radon gas, student etc.	B1
(a)(ii)	(radioactive decay is a) random (process)	B1
(b)		B3
	U: proton no 92 and nucleon number 238	B1
	Th: proton number 90 and nucleon number 234	B1
	$\alpha$ : proton number 2 and nucleon number 4	B1
(c)	11	A2
	three half lives or evidence of multiplying half-life by 3	C1

16. 0625\_m20\_ms\_42 Q: 11

(a)	neutrons 12	B1
	electrons 22	B1
	mass 34 OR 2 more 3 more	B1
(b)	$\beta$	B1
	$\beta$ – (would be) stopped by 5 mm / thick Al	B1
	$\alpha$ – (would be) stopped by 0.1 mm Al / Al foil AND $\gamma$ – (would) not (be) stopped by 5 mm / thick Al	B1

17. 0625\_s20\_ms\_41 Q: 10

(a)	equal number of electrons OR equal number of protons	<b>B1</b>
(b)(i)	${}^{13}_5\text{X}$	<b>C1</b>
	${}^0_{-1}\beta$	<b>C1</b>
	${}^{13}_6\text{Y}$	<b>A1</b>
(b)(ii)	any <b>three</b> from: <ul style="list-style-type: none"> <li>• <math>\beta</math>-particles have charge of smaller size</li> <li>• <math>\beta</math>-particles have smaller mass</li> <li>• <math>\beta</math>-particles have less energy</li> <li>• <math>\beta</math>-particles travel faster / less time near to air molecule</li> <li>• effect / force on electrons in air molecules less</li> </ul>	<b>B3</b>

18. 0625\_s20\_ms\_42 Q: 10

(a)	(beam) narrow OR straight OR in one direction OR	<b>B1</b>
	radiation in other directions absorbed	<b>B1</b>
(b)(i)	out of page / towards viewer	<b>B1</b>
	equiv. to current in direction of beam	<b>B1</b>
(b)(ii)	opposite to (i)	<b>B1</b>
	equiv. to current in opposite direction to beam OR LH rule mentioned or described	<b>B1</b>
(b)(iii)	none	<b>B1</b>
	( $\gamma$ ) uncharged OR not equivalent to current	<b>B1</b>

19. 0625\_s20\_ms\_43 Q: 10

(a)	${}^0\text{X}$	<b>B1</b>
	${}^{-1}\text{X}$	<b>B1</b>
	$\beta$ OR beta (particle)	<b>B1</b>
(b)(i)	background radiation	<b>B1</b>
	rocks / ground / buildings / food / space / weapons testing / nuclear accidents or waste / sun / air / radon / argon	<b>B1</b>
(b)(ii)	subtracts 10 from 80	<b>B1</b>
	evidence of recognising two half-lives OR compares 70 and 10	<b>B1</b>
	(final reading =) $70/4 + 10 = 27$ OR $(70/10 = 7)$ age > 2 half-lives OR age nearly 3 half-lives	<b>B1</b>
	age > 11 400	<b>B1</b>

20. 0625\_w20\_ms\_41 Q: 10

Question	Answer	Marks
(a)	radiation that is always present or due to environment or in everyday life	B1
	soil / rocks / earth / cosmic rays / space / Sun / weapons testing / radon / nuclear waste	B1
(b)(i)	alpha-emission (only)	B1
	alpha-particles do not penetrate (two sheets of) paper or $\beta$ -particles and $\gamma$ -rays pass through (two sheets of) paper	B1
(b)(ii)	${}^{208}_{84}\text{Po} \rightarrow {}^4_2\alpha + {}^{204}_{82}\text{Pb}$	B1
	${}^{204}\text{Pb} \dots$ or ${}_{82}\text{Pb}$	C1
	${}^{204}_{82}\text{Pb}$	A1

21. 0625\_w20\_ms\_42 Q: 11

Question	Answer	Marks
(a)	nuclear fission – nucleus / atom splits (into two) <b>AND</b> nuclear fusion – two nuclei / atoms join together	B1
	One from <ul style="list-style-type: none"> <li>{nuclear fission – large(r) mass (number) OR heavy nuclei / atoms involved OR neutrons involved / emitted}</li> </ul> <b>AND</b> nuclear fusion – small(er) mass (number) OR light nuclei / atoms involved OR no neutrons <ul style="list-style-type: none"> <li>fission in a nuclear reactor AND fusion in Sun / stars</li> <li>fission produces very radioactive / long lasting waste</li> <li>fission makes lighter new elements AND fusion makes heavier new elements</li> <li>fission at normal p / T AND fusion at high p / T</li> <li>fusion produces more energy (than fission)</li> </ul>	B1
(b)(i)	longer half-life – radioactive substance active in body for a long time	B1
	shorter half-life – might be insufficient time for investigation OR it takes time / hours for the tracer to spread round the body	B1
(b)(ii)	proton numbers balance for equation expected answer: ${}_{42}\text{Mo} \rightarrow {}_{43}\text{Tc} + {}_{-1}\beta$	B1
	all nucleon numbers correct	B1
	correct proton and nucleon number for $\beta$ -particle	B1
(b)(iii)	any suitable use, e.g. sterilisation of equipment, treatment of cancer, gamma for diagnosis, radiotherapy NOT any link to X-rays	B1

22. 0625\_m19\_ms\_42 Q: 11

(a)(i)	Nucleon number for Pt: 194	B1
	Proton number for Pt: 78	B1
	Symbol for beta particle: ${}^0_{-1}\beta$	B1
(a)(ii)	After 1 half-life / 19 hrs, count rate = $1100 / 2 = 550$ counts / min	C1
	After 2 half-lives / 38 hrs, count rate = $550 / 2 = 275$ counts / min	A1
	OR 38 hrs = 2 half-lives	(C1)
	After 38 hrs / 2 half-lives, count rate = $1100 / 4 = 275$ counts / min	(A1)

(b)	Two of:			<b>B2</b>
		<u><math>\gamma</math>-emission</u> electromagnetic radiation / travels at the speed of light uncharged no mass long range in air stopped by many cm of lead / very penetrating low ionisation (of air) leaves proton number unchanged not deflected in electric / magnetic field	<u><math>\beta</math>-emission</u> particles / electrons (negatively) charged has mass shorter range in air stopped by a few mm of aluminium higher ionisation (of air) proton number changes deflected in electric / magnetic field	


23. 0625\_s19\_ms\_42 Q: 11

(a)	$^{222}_{86}\text{Rn}$ on L side of equation	<b>B1</b>
	$^{218}_{84}\text{Po}$ on R side of equation	<b>B1</b>
	$^4_2\alpha$ on R side of equation	<b>B1</b>
(b)	mention of 2 half-lives OR mention or use of two halvings of 100% NOT $5700 \div 2$ OR $14 \div 2$	<b>C1</b>
	11 000 (years)	<b>A1</b>

24. 0625\_s19\_ms\_43 Q: 11

(a)	$^{241}_{95}\text{Am} \rightarrow ^4_2\alpha + ^{237}_{93}\text{Np}$	
	Am on L with correct proton no	<b>B1</b>
	Am on L with correct nucleon no	<b>B1</b>
	alpha symbol on R with correct proton and nucleon no	<b>B1</b>
	Np on R with correct proton and nucleon no.	<b>B1</b>
(b)(i)	current decreases / is stopped AND alpha particles absorbed (by smoke) owtte	<b>B1</b>
(b)(ii)	Any <b>two</b> from: alpha particles highly ionizing / more ionising than beta particles or gamma rays alpha particles short range (in air) safer to use alpha because they do not travel out of smoke detector	<b>B2</b>

25. 0625\_w19\_ms\_41 Q: 9

(a)(i)	${}^8_3\text{Li}$	<b>B1</b>
(a)(ii)	 $4 \times \ominus$ $4 \times \oplus$ electron	<b>B1</b> <b>B1</b> <b>B1</b>
(b)(i)	radioactive emission / (background) radiation / decay is random	<b>B1</b>
(b)(ii)	any one of: rocks, buildings, soil, Earth, space, cosmic rays, Sun, radon, nuclear waste, weapons testing	<b>B1</b>
(b)(iii)	440 – 24 or 416 or 52 or 55 or 79 or 3 (half-lives) or 45/15 or $1/2^3$ or $1/8$ $1/2^3$ or $1/8$ or 52 or 55 or 79 76 (counts)	<b>C1</b> <b>C1</b> <b>A1</b>

26. 0625\_w19\_ms\_42 Q: 10

(a)	neutron charge = 0 $\gamma$ -ray mass = 0 AND charge = 0 He nucleus mass = 4 m He nucleus charge = 2 e	<b>B1</b> <b>B1</b> <b>B1</b> <b>B1</b>
(b)	any 3 different valid points, e.g. <ul style="list-style-type: none"> <li>• detail of handling source appropriately for, e.g. use of tongs</li> <li>• protective clothing</li> <li>• minimise exposure by time OR distance OR activity</li> <li>• detail of shielded storage</li> <li>• detail of secure storage</li> <li>• monitoring exposure</li> <li>• must be disposed of securely</li> <li>• limitation of access to approved personnel</li> <li>• procedure in place in case of accident / criminal act to protect people and / or environment</li> </ul>	<b>3 ×</b> <b>B1</b>

27. 0625\_w19\_ms\_43 Q: 11

(a)	top: any path to the left within 45 degrees to the horizontal	<b>B1</b>
	middle: path to the right and deflected up (ending in a straight line)	<b>B1</b>
	bottom: path to the right and deflected down (ending in a straight line)	<b>B1</b>
(b)	192	<b>B1</b>
	use or clear indication of 4 half-lives	<b>C1</b>
	$(192 / 16 =) 12$	<b>A1</b>
	28	<b>B1</b>
(c)	any 3 different valid points e.g. <ul style="list-style-type: none"> <li>• must be stored with shielding</li> <li>• must be stored securely / safely</li> <li>• must be transported with shielding</li> <li>• must be transported securely</li> <li>• expensive to store</li> <li>• expensive to transport</li> <li>• in case of accident / terrorism could escape to environment / danger to people</li> <li>• site of storage uninhabitable for thousands of years</li> </ul>	<b>3 × B1</b>

28. 0625\_m18\_ms\_42 Q: 11

(a)(i)	In box / cupboard with lead walls	<b>B1</b>
(a)(ii)	(Handle) with (long) tongs OR remote-controlled device OR wearing lead gloves OR wearing lead suit	<b>B1</b>
(b)	Col 1: gamma / $\gamma$ (rays) alpha / $\alpha$ (particles) beta / $\beta$ (particles)	<b>B1</b>
	Col 3: – a few cm or up to 10 cm a few m or up to 10 m	<b>B1</b>
	Col 4: thick lead or 30 cm lead or very thick concrete or 3 m concrete – thin aluminium or 2 mm aluminium	<b>B1</b>
(c)(i)	alpha / $\alpha$ (particles or rays)	<b>B1</b>
(c)(ii)	beta / $\beta$ (particles or rays)	<b>B1</b>

29. 0625\_s18\_ms\_41 Q: 11

(a)	Number of protons = 86 and number of electrons = 86	<b>1</b>
	Number of neutrons = 136	<b>1</b>
(b)	${}_{84}^{218}\text{Po}$	<b>1</b>
	$+ {}_2^4\alpha$	<b>1</b>
(c)	7.6 days = 2 half-lives or evidence of two halvings	<b>1</b>
	(number of Rn atoms left = $6.4 \times 10^6 \div 4 = 1.6 \times 10^6$ )	<b>1</b>
	number of $\alpha$ -particles emitted = $(6.4 \times 10^6 - 1.6 \times 10^6) = 4.8 \times 10^6$	<b>1</b>

30. 0625\_s18\_ms\_42 Q: 11

(a)	${}^{231}\text{Th}$	<b>1</b>
	${}_{90}\text{Th}$	<b>1</b>
(b)(i)	splitting of a nucleus into (2) parts/light(er)nucleus	<b>1</b>
(b)(ii)	(fission involves production of) ionising radiation OR radiation dangerous/harmful (to humans)	<b>1</b>
	(thick concrete walls) absorb/stop the radiation (and so protect workers)	<b>1</b>
(b)(iii)	no $\text{CO}_2/\text{SO}_2$ /greenhouse gases/acid rain	<b>1</b>
	nuclear waste (disposal) OR leaks of radioactive material OR risk of radiation in case of accident	<b>1</b>
(c)	(52 hours =) 2 half-lives OR evidence of 2 halvings	<b>1</b>
	(after 52 hours number of thorium atoms left = $4.8 \times 10^9 \div 4 = 1.2 \times 10^9$ OR (number of thorium atoms decayed =) $\frac{3}{4} \times 4.8 \times 10^9$ )	<b>1</b>
	(number of atoms decayed = $4.8 \times 10^9 - 1.2 \times 10^9 = 3.6 \times 10^9$ )	<b>1</b>

31. 0625\_s18\_ms\_43 Q: 11

(a)(i)	$\beta$ (-particles)	<b>B1</b>
(a)(ii)	$\alpha$ (-particles)	<b>B1</b>
(a)(iii)	$\gamma$ (-rays)	<b>B1</b>
(b)(i)	downward <u>curve</u>	<b>B1</b>
(b)(ii)	3 (half-lives identified) <b>OR</b> $168 \div 56$	<b>C1</b>
	$1 \div 8$ <b>OR</b> $9.0 \times 10^5$ (Rn) atoms remain	<b>C1</b>
	$(7.2 \times 06 - 9.0 \times 105 =) 6.3 \times 10^6$ ( $\alpha$ -particles emitted)	<b>A1</b>

32. 0625\_w18\_ms\_41 Q: 11

(a)	$\begin{matrix} 14 \\ 6 \end{matrix}$ C on left-hand side	<b>B1</b>
	$\begin{matrix} 14 \\ 7 \end{matrix}$ on right-hand side (ignoring letter after or before $\begin{matrix} 14 \\ 7 \end{matrix}$ )	<b>B1</b>
	N after $\begin{matrix} 14 \\ 7 \end{matrix}$ on right-hand side	<b>B1</b>
	$+ \begin{matrix} 0 \\ -1 \end{matrix}$ e on right-hand side <b>OR</b> $- \begin{matrix} 0 \\ -1 \end{matrix}$ e on left-hand side	<b>B1</b>
(b)	Not $\alpha$ because count-rate with paper increase	<b>B1</b>
	Not $\beta$ because count-rate with aluminium increase	<b>B1</b>
	is $\gamma$ because count rate reduces with lead only OR does not reduce with paper or aluminium	<b>B1</b>

33. 0625\_w18\_ms\_42 Q: 10

(a)(i)	any <b>two</b> from <ul style="list-style-type: none"> <li>• soil / rocks / buildings / the Earth</li> <li>• cosmic rays / space</li> <li>• the Sun</li> <li>• medical sources</li> <li>• food or drink</li> <li>• air / radon</li> </ul>	<b>B2</b>
(a)(ii)	random (variation of background radiation / radioactivity)	<b>B1</b>
(b)	160 and 10 (counts/min)	<b>C1</b>
	$(160 / 10 =) 16$	<b>C1</b>
	4 half-lives	<b>A1</b>
	$(24 / 4 =) 6$ days	<b>B1</b>
(c)	2 correct lines	<b>B1</b>
	4 correct lines	<b>B1</b>
	6 correct lines	<b>B1</b>

34. 0625\_w18\_ms\_43 Q: 10

(a)	${}^{234}_{91}\text{(Pa)}$	<b>B1</b>
	${}^0_{-1}(\beta)$	<b>B1</b>
(b)	72 / 24 or 3.0 (half-lives)	<b>C1</b>
	$2^3$ or 1/8 or 2480/8	<b>C1</b>
	310 counts/second	<b>A1</b>
(c)	count rate larger (than 310 counts/second)	<b>B1</b>
	protactinium is also emitting ( $\beta$ -)particles / (nuclear) radiation	<b>B1</b>
	count rate (approximately) double or product of protactinium decay also radioactive or amount of protactinium small or protactinium is <u>highly</u> radioactive or half-life of protactinium much shorter (than half-life of thorium) / very short	<b>B1</b>

35. 0625\_m17\_ms\_42 Q: 11

(a)	$\alpha$ -particles and $\beta$ -particles are both present, stated or implied	<b>B1</b>
	$\alpha$ -particles: stopped by / absorbed by paper	<b>B1</b>
	$\beta$ -particles: deflected by (magnetic) field	<b>B1</b>
	$\gamma$ -rays: absent	<b>B1</b>
	with paper and magnetic field count falls to background / 20 counts/s.	<b>B1</b>
(b)	$\alpha$ -particles: (150 – 60 =) 90 counts/s $\beta$ -particles: (60 – 20 =) 40 counts/s $\gamma$ -rays: zero All 3 correct = 2 marks; 1 or 2 correct = 1 mark.	<b>B2</b>
<b>Total:</b>		<b>7</b>

36. 0625\_s17\_ms\_41 Q: 11

(a)	Background count rate stated as in range 17 – 21 counts/s	<b>B1</b>
	Background used on at least 2 of first 3 readings	<b>C1</b>
	Any halving of corrected or uncorrected reading	<b>C1</b>
	(half-life =) $\frac{1}{2}$ hour	<b>A1</b>
(b)	${}^3_1\text{H}$ on LHS of an equation	<b>B1</b>
	${}^0_{-1}\beta$ on RHS of equation	<b>B1</b>
	Equation all correct: ${}^3_1\text{H} = {}^0_{-1}\beta + {}^3_2\text{X}$	<b>B1</b>
(c)	Top: any path to the left within $45^\circ$ horizontal	<b>B1</b>
	Middle: path to the right and deflected down (ending in a straight line)	<b>B1</b>
	Bottom: path not deflected OR path to the right and deflected up <u>much</u> less than middle path	<b>B1</b>
<b>Total:</b>		<b>10</b>

37. 0625\_s17\_ms\_42 Q: 11

(a)	(some) $\beta$ /beta/radiation would penetrate gloves/reach other body parts (so insufficient protection)	<b>B1</b>
	middle: any path to the left within $45^\circ$ of horizontal	<b>B1</b>
	bottom: path to the right and deflected down ending in a straight line	<b>B1</b>
(b)	radiation from background/rock/air/outer space/cosmic rays	<b>B1</b>
	random variation owtte.	<b>B1</b>
(c)	thick gloves would stop $\alpha$ /alpha (so helpful)	<b>B1</b>
	(some) $\beta$ /beta/radiation would penetrate gloves/reach other body parts (so insufficient protection)	<b>B1</b>
<b>Total:</b>		<b>7</b>

38. 0625\_s17\_ms\_43 Q: 11

(a)(i)	produces a narrow beam of $\gamma$ -rays OR absorb $\gamma$ -rays that are not on path shown	<b>B1</b>
(a)(ii)	no change	<b>B1</b>
	$\gamma$ -rays not deflected	<b>B1</b>
	$\gamma$ -rays are electromagnetic radiation/uncharged OR not deflected by magnetic field	<b>B1</b>
(b)	<b>(ionising effect of) <math>\alpha</math>-particles greater than <math>\beta</math>-particles and <math>\beta</math>-particles greater than <math>\gamma</math>-rays</b>	<b>B1</b>
	any two from: mass $\alpha > \text{mass } \beta > \text{mass } \gamma$ charge $\alpha > \text{charge } \beta > \text{charge } \gamma$ speed $\gamma > \text{speed } \beta > \text{speed } \alpha$	<b>B2</b>
<b>Total:</b>		<b>7</b>

39. 0625\_w17\_ms\_41 Q: 11

(a)(i)	An electron	<b>M1</b>
	In / from / by the nucleus	<b>A1</b>
(a)(ii)	Proton numbers balance on left and right sides of equation	<b>B1</b>
	Nucleons numbers balance on left and right sides of equation	<b>B1</b>
	${}^0_{-1}\beta$	<b>B1</b>
(b)	Time for activity / count rate / number of nuclei / number of atoms to halve	<b>B1</b>
(c)(i)	$\alpha$ -particles would be stopped / absorbed by <u>the plastic / bottle</u>	<b>B1</b>
(c)(ii)	$\gamma$ -rays would not be absorbed by the liquid / bottle OR reading not reduced (in passing through liquid / bottle) OR very penetrative so no change in detector reading	<b>B1</b>

40. 0625\_w17\_ms\_42 Q: 11

(a)	nucleon numbers balance each side of equation	<b>B1</b>
	proton numbers balance each side of equation	<b>B1</b>
	${}^0_{-1}\beta$	<b>B1</b>
(b)(i)	background radiation OR radiation from the environment	<b>B1</b>
	rocks / ground / buildings / food / space / weapons testing / nuclear accidents or waste / sun / air / radon / argon	<b>B1</b>
(b)(ii)	random (variation)	<b>B1</b>
(b)(iii)	clear evidence of subtracting 23 from (original) count	<b>C1</b>
	clear evidence of dividing original / corrected count by 4	<b>A1</b>
	clear evidence of adding <u>23</u> correctly to result after division	<b>A1</b>

41. 0625\_w17\_ms\_43 Q: 10

(a)	electromagnetic (waves/rays/radiation)	<b>M1</b>
	high frequency/energy or short wavelength	<b>A1</b>
(b)(i)	no change or (stays at) 43	<b>B1</b>
(b)(ii)	no change or (stays at) 99	<b>B1</b>
(c)(i)	(radiation) always present/ due to environment/ in absence of radioactive sample/ natural (radiation)	<b>B1</b>
(c)(ii)	112 – 16 or 96 or 112/28 or $\frac{1}{4}$ or 18/2	<b>C1</b>
	28 – 16 or 12 or 1/8 or 18/3 or 9.0 (hours)	<b>C1</b>
	6.0 hours	<b>A1</b>
(d)	any <b>two</b> of: <ul style="list-style-type: none"> <li>• (distance): tongs/ manipulator/ centre of cardboard box</li> <li>• (absorption): lead gloves/ suit/ lead glass screen/ goggles/ glasses</li> <li>• (time): limit exposure time/ keep in box until needed/ film badge</li> </ul>	<b>B2</b>