5. Nuclear physics

5.2 Radioactivity

Paper 3 and 4

Answer Key

Paper 3

Q1.

Question	Answer	Marks
(a)(i)	α / alpha β / beta γ / gamma	B2
(a)(ii)	α / alpha	B1
(a)(iii)	γ / gamma	B1
(b)(i)	1 / 8 OR 0.125	A2
	idea of 3 half-lives e.g. 6 + 6 + 6	(C1)
(b)(ii)	type of particle: electron 43; neutron 56; proton 43	B2

type of particle	number
electron	43
neutron	56
proton	43

Q2.

(b)	(beta-particles are fast-moving / negatively charged) electrons	B1
(c)	(29×3 =) 87 years	A2
	idea of 3 <u>half-lives</u> **OR** $16 \div 2^3$ (= 2)	(C1)

Q3.

Question	Answer	Mark
(a)(i)	both have 92 (protons) **OR** same (number of protons)	B1
(a)(ii)	U-235 has (3) fewer neutrons **OR** U-238 has (3) more neutrons **OR** U-235 has 143 and U-238 has 146 neutrons	B1
(b)	(2×24 =) 48 (minutes)	A3
	(change in mass takes place over / decay takes) 2 half-lives	(C2)
	$16 \rightarrow 8(.0) \rightarrow 4(.0)$ **OR** $16 \times \frac{1}{2} \times \frac{1}{2}$ (= 4(.0))	(C1)

Q4.

(b)	point at (20, 2.0) plotted correctly	**B1**
	point at (30, 1.0) plotted correctly	**B1**
	points joined by a (smooth) curve to about 30 days	**B1**

Q5.

(b)(i)	A and B and D	**B1**
(b)(ii)	A	**B1**
(c)	2 (h)	**A2**
	3 half lives	(C1)

Q6.

Question	Answer	Marks
(a)	see table below; 1 mark for each correct column	**B4**
(b)	(2 × 5700 =) 11 400 (years)	**A3**
	(change in mass takes place over / decay takes) 2 half-lives	(C2)
	8(.00) → 4(.00) → 2.(00) **OR** 8(.00) × ½ × ½ = 2.(00)	(C1)

name of particle	number of particles	position of particle	relative charge of particle
electron	**6**	**orbiting / outside (nucleus)**	**–1 OR minus one**
neutron	**8**	in the nucleus	**0 OR zero OR none OR neutral**
proton	6	**(in the) nucleus**	+1 (plus one)

1 mark for each correct column

Q7.

(b)	(negatively charged) electron	**B1**
	electromagnetic (wave / ray)	**B1**
(c)	0.2(0) (mg)	**A3**
	1.6 × ½ × ½ × ½ **OR** 1.6 ÷ 8 **OR** 1.6, 0.8, 0.4	(C2)
	24(.0) ÷ 8(.0) **OR** idea of 3 half-lives	(C1)

Q8.

Question	Answer	Marks
(a)	**4 correct ticks for 3 marks** **2 or 3 correct ticks for 2 marks** **1 correct tick for 1 mark**	**B3**

characteristic	type of radiation		
	α (alpha)-particles	β (beta)-particles	γ (gamma)-rays
electromagnetic wave			(✓)
least ionising			✓
least penetrating	✓		
a helium nucleus	✓		
negatively charged		✓	

Question	Answer	Marks
(b)	241	**B1**
	(Pu)	
	94	**B1**
(c)	$2(.0) \times 10^{12}$ (atoms)	**A3**
	$8(.0)\ (\times 10^{12})/4$ **OR** $8(.0)\ (\times 10^{12}) \times \frac{1}{2} \times \frac{1}{2}$	C2
	28 years = 2 half-lives **OR** 28 years / 14 = 2 (half-lives)	C1

Q9.

(b)	electron	**B1**
(c)	17 400	**A2**
	16000 – 8000 – 4000 – 2000 OR 3 half lives	(C1)

Q10.

Question	Answer	Marks
(a)	alpha (particles) not emitted	**M1**
	any **one** from idea that count rate for paper is similar to count rate for air OR if alpha emitted count rate for paper would decrease/be less (than 480)	**A1**
(b)	gamma (rays) emitted	**M1**
	any **one** from idea that count rate for (10 mm) lead is less (than count rate for (2 mm) aluminium/air/paper owtte) OR (most/some of) gamma (rays) are absorbed by lead	**A1**

Q11.

Question	Answer	Marks
(a)	$^{241}_{95}$(Am)	B1
		B1
(b)	430 (years)	A2
	(decrease in activity from) 16 000 (counts/min) to 8000 (counts/min)	(C1)

Q12.

Question	Answer	Marks
(a)	see table below	B3
(b)	idea of 3 half-lives OR 45 ÷ 15	C1
	80 ÷ 8 OR 80 × ½ × ½ × ½	C1
	10 (mg)	A1

property	type of radiation		
	α-particles	β-particles	γ-rays
largest mass	✓		
most ionising	✓		
most penetrating			✓
negatively charged		✓	
greatest speed			✓

Q13.

Question	Answer	Marks
(a)(i)	gamma OR	B1
(a)(ii)	alpha OR	B1
(b)	same atomic number / Z / number of protons	B1
	different nucleon number / A / number of neutrons	B1
(c)	idea of 2 half-lives	C1
	1 / 4	A1

Q14.

Question	Answer	Marks
(a)(i)	uranium-235 AND uranium-238	B1
(a)(ii)	plutonium(-238) AND uranium-238	B1
(a)(iii)	plutonium(-238)	B1
(b)	idea of 3 half-lives OR 72 ÷ 24	B1
	40 ÷ 8	C1
	5(.0) (mg)	A1

Q15.

(b)(i)	(from June 2004 to June 2014 =) 10 (years)	B1
	(decrease in activity from) 80 000 (Bq) to 20 000 (Bq) takes 2 half-lives	B1
	10 ÷ 2 = (5 years)	B1
(b)(ii)	(decrease in activity from) 20 000 (Bq) to 10 000 (Bq) is one half-life	C1
	so half the time difference = 5 years OR 2019	A1

Q16.

Question	Answer	Marks
(b)	(four days is) 2 half-lives	C1
	activity is 2400 ÷ 4	C1
	600 (counts / minute)	A1

Q17.

Question	Answer	Marks
(a)	rocks, buildings, (natural) radon, air, cosmic rays, sun, food, drink	B1
(b)(i)	evidence of using graph	C1
	TWO pairs of coordinates seen	C1
	7.5 (min)	A1
(b)(ii)	Use a lead(-lined) box / container	B1

Q18.

Question	Answer	Marks
(a)	beta / β AND gamma / γ	B1
(b)	(137 – 56 =) 81	B1
(c)	idea of three half-lives	C1
	36 ÷ 8	C1
	4.5 (mg)	A1

Q19.

(b)	changes to a different element / gains a proton	B1
(c)(i)	lead	B1
(c)(ii)	any **one** from: minimise time for handling maximise distance from source use of shielding prevent contamination	B1

Q20.

Question	Answer	Marks
(a)	2.5 (minutes)	B1
(b)	any answer above 1246 (counts/s), e.g. 1247	B1
(c)	1. helium nucleus OR 2 protons **AND** 2 neutrons	B1
	2. strongly (ionising)	B1
	3. weakly (penetrating)	B1

Q21.

Question	Answer	Marks
(a)(i)	nucleon number OR mass number	B1
(a)(ii)	proton number OR atomic number	B1
(b)(i)	selected count rate halved	B1
	two pairs of co-ordinates clearly indicated	B1
	(half-life =) 4 (minutes)	B1
(b)(ii)	shallower curve drawn	B1

Q22.

Question	Answer	Marks
(a)(i)	unpredictable owtte	B1
(b)	From top to bottom of table alpha: HIGH LOW	B1
	beta: MEDIUM MEDIUM	B1
	gamma: LOW HIGH	B1
(c)	protons	B1
	neutrons	B1
	2 of each drawn/labelled AND no electrons	B1

Q23.

(b)	**Any three from:** (nucleus has) same number protons or same atomic / proton number same charge different mass different nucleon number different number of neutrons	B3
(c)	idea of 3 half-lives Or 8.0 → 4.0 → 2.0 → 1.0	C1
	5700 × 3	C1
	17 100 (years)	A1

Q24.

(b)(i)	**any 2 from:** different forms of same element same number of protons different number of neutrons / nucleons	B2
(b)(ii)	value from graph selected e.g. 16 000	C1
	half the original value selected or stated e.g. 8000	C1
	12.3 or 12.4 (years)	A1

Q25.

Question	Answer	Marks
(a)(i)	α or alpha	**1**
(a)(ii)	α or alpha	**1**
(b)(i)	beta or β	**1**
	beta emission would be affected by the thickness of the metal owtte	**1**
(b)(ii)	(counter) reading higher	**1**
(b)(iii)	rollers move apart/provide less force/pressure owtte	**1**
(b)(iv)	38	**1**

Q26.

(b)(i)	18 / 6 or 3 half lives seen or implied	**1**
	1 / 8 or division by 8	**1**
	1.5 (mg)	**1**
(b)(ii)	any **two** from: high energy/fast-moving electron/negatively charged particle about 2000 times smaller than a proton/neutron	**2**
(b)(iii)	any **one** from: new element formed neutron becomes/turns into a proton Z/proton number increases by one neutron number decreases by one	**1**

Paper 4

Q27.

(c)(i)	electron	**B1**
(c)(ii)	a neutron changes into a proton (and electron)	**B1**
(d)	17 000 years	**A3**
	$1.2 \times 10^{11} / 9.6 \times 10^{11}$ **OR** 1 / 8 **OR** one halving seen e.g. $9.6 \times 10^{11} \div 2$	C1
	3 (half-lives) **OR** $1/8 \times 9.6 \times 10^{11} = 1.2 \times 10^{11}$	C1

Q28.

Question	Answer	Marks
(a)	(nucleus of carbon-14 contains) more neutrons **OR** (nucleus of) carbon-12 has fewer neutrons	**B1**
	*any **one** from:* • (atom / nucleus of carbon-14) is heavier • (atom / nucleus of carbon-14 is) not stable • (nucleus of carbon-14 contains) two more neutrons	**B1**
(b)(i)	Every 5700 years the (remaining) carbon-14 decreases by half **OR** amount of C-14 halved every half life	**A2**
	amount of carbon-14 halves in 5700 years **OR** amount of carbon-14 decreases at a decreasing rate (with time)	C1
(b)(ii)	11 000 (years ago)	**A3**
	$2 \times$ half-life have elapsed	C1
	25% of C-14 at time of death is still present in tree OR 75% of C-14 has decayed.	C1
(c)	medical tracers **OR** medical imaging **OR** medical diagnosis	**B1**
	*any **one** from:* • keep dose low • doesn't stay in body too long • less damage (to body) OR less harmful (to humans)	**B1**

Q29.

Question	Answer	Marks
(a)(i)	${}^{0}_{-1}\beta$	**B1**
	${}^{208}_{\dots}Pb$	**B1**
	${}^{\dots}_{82}Pb$	**B1**
(a)(ii)	γ-emission / it consists of waves / rays **OR** γ-emission has no mass / charge	**B1**
(a)(iii)	(it contains) too many / excess of neutrons **OR** (nucleus is) <u>too</u> heavy	**B1**
(b)	smooth curve (through magnetic field) **AND** labelled β	**B1**
	path towards bottom of page **AND** no upward component **AND** labelled β	**B1**
	(continuation of beam along) horizontal line through magnetic field **AND** labelled γ	**B1**

Q30.

Question	Answer	Marks
(a)(i)	any **two** from: • reduce exposure time **AND** low(er) amount of radiation absorbed • increase distance between source and hospital staff **AND** lower amount of radiation reaches staff • use of shielding (e.g. walls, lead etc.) **AND** radiation absorbed by shielding / cannot penetrate through shielding • use isotopes with short half-life **AND** lower amount of radiation emitted from patient / radiation (above background) emitted for a shorter period of time • use of film badge / dosimeter **AND** manage individuals exposure owtte • restrict pregnant staff / patient in hospital **AND** radiation may harm foetus owtte	**B2**
(a)(ii)	high ionisation (within body)	**B1**
	radiation would not reach detector (outside body)	**B1**
(b)	${}^{24}_{11}Na \rightarrow {}^{24}_{12}Mg + {}^{0}_{-1}\beta$	
	${}^{24}_{11}Na$ on LHS	**B1**
	${}^{0}_{-1}\beta$ on RHS	**B1**
	${}^{24}_{12}Mg$ on RHS	**B1**

Q31.

Question	Answer	Marks
(a)(i)	(americium-241 has) one neutron fewer (in the nucleus)	**B1**
(a)(ii)	(different) number of protons (in nucleus)	**B1**
	(different) number of neutrons (in nucleus)	**B1**
(b)(i)	$^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\text{a}$	**A3**
	any two from: $_{95}\text{Am}$ ^{237}Np $^{4}_{2}\text{a}$	C2
(b)(ii)	(α-particles have) more kinetic energy (than β-particles)	**B1**
	(α-particles have) more charge (than β-particles)	**B1**
(b)(iii)	Low(er) (initial) activity OR Few emissions per unit time	**M1**
	so smoke detectors are not hazardous to humans **OR** so disposal of old detectors is cheap / easy	**A1**

Q32.

Question	Answer	Marks
(a)	(number of neutrons =) 7	**B1**
	any **one** from: • number of electrons = number of protons • white dots are protons / there are 5 protons • grey dots are neutrons • (number of neutrons) = 12 – 5	**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) ORA	**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**

Q33.

Question	Answer	Marks
(a)	α – no. of neutrons 2	**B1**
	β – no. of protons 0 **and** charge -1.6×10^{-19}	**B1**
	γ – 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: • limit time of exposure • store sources in lead boxes • keep distance from sources • avoid contact **OR** use tongs **OR** wear gloves	**B2**

Q34.

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

Q35.

Question	Answer	Marks
(a)(i)	(proton number) 2	B1
	(nucleon number) 4	B1
(a)(ii)	3.2×10^{-19} (C)	B1
(b)	${}^{230}_{88}\text{Ra} \rightarrow {}^{230}_{89}\text{Ac} + {}^{0}_{-1}\beta$	A3
	any two from: • nucleon numbers 230 on left **AND** 230 on right • Ra and proton number 88 on left **AND** Ac and proton number 89 on right • ${}^{0}_{-1}\beta$.	C2
(c)	(mass =) 1.2×10^{-12} g	A2
	3 half-lives **OR** $9.6 \times 10^{-12} / 8$ **OR** $9.6 \times 10^{-12} / 2^3$	C1

Q36.

Question	Answer	Marks
(a)(i)	top: travels to left	B1
	middle: deflected down AND still travels to right	B1
	bottom: straight on	B1
(a)(ii)	plus OR positive OR +	B1
(b)	79 (electrons)	B1
	119 (neutrons)	B1
	79 (protons)	B1

Q37.

(b)	${}^{135}_{55}$ on left	B1
	Cs on left	B1
	${}^{135}_{56}\text{Ba}$ on right	B1
	$+\beta$ on right OR $-\beta$ on left	B1

Q38.

Question	Answer	Marks
(a)(i)	α in Box 4 / towards bottom of page	B1
	γ in Box 3 / no deflection	B1
(a)(ii)	α in Box 1 / into page	B1
	γ in Box 3 / no deflection	B1

Q39.

Question	Answer	Marks
(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 γ	B1
	good extra detail e.g. any **one** of: • container / (2 mm) plastic absorbs / stops α • partially correct as statement • need lead to stop γ • γ is dangerous / harmful owtte	B1

Q40.

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** β-particles **and** γ-rays pass through (two sheets of) paper	B1
(b)(ii)	${}^{208}_{84}Po \rightarrow {}^{4}_{2}\alpha$ / ${}^{4}_{2}He$	B1
	${}^{204}Pb$... **or** ${}_{82}Pb$	C1
	${}^{204}_{82}Pb$	A1

Q41.

(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 : $_{42}Mo \rightarrow {}_{43}Tc + {}_{-1}\beta$	**B1**
	all nucleon numbers correct	**B1**
	correct proton and nucleon number for β-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**

Q42.

Question	Answer	Marks
(a)(i)	any **two** from • soil / rocks / buildings / the Earth • cosmic rays / space • the Sun • medical sources • food or drink • air / radon	**B2**
(a)(ii)	random (variation of background radiation / radioactivity)	**B1**
(b)	160 and 10 (counts/min)	**C1**
	(160 / 10=) 16	**C1**
	4 half-lives	**A1**
	(24 / 4 =) 6 days	**B1**
(c)	2 correct lines	**B1**
	4 correct lines	**B1**
	6 correct lines	**B1**