Q1.

6	(a)	(i)	curve is not smooth, fluctuations, etc	B1	
		(ii)	curve is same shape or same half-life, not affected by temperature, etc.....	B1	[2]
	(b)	(i)	134.....	B1	[1]
		(ii)	α-particle shown as $^4_2\mathrm{He}$ or as $^4_2\alpha$	B1	
			nucleon number of Po shown as 216	B1	
			proton number of Po shown as 84.....	B1	
					[3]

Q2.

8	(a)	position shown as $A = 227$, $Z = 91$	B1	**[1]**
	(b)	Pu shown as $A = 243$, $Z = 94$	B1	
		D shown with $A = A_{Pu}$ and with $Z = (Z_{Pu} + 1)$	B1	**[2]**

Q3.

8	(a)	nucleus emits	M1	
		α- or β- particles and/or γ-rays	A1	**[2]**
	(b)	decay unaffected by environmental changes	M1	
		such as temperature, pressure etc. *(one e.g. is sufficient)*	A1	**[2]**
	(c)	constant probability of decay (per unit time) of a nucleus	B1	
		cannot predict which particular nucleus will decay next	B1	**[2]**

Q4.

7	(a)	β(-decay)	B1	[1]
	(b)	γ(-decay)	B1	
		either any two of *Z*, *N* and *A* do not change		
		or it is loss of energy only		
		or it is an electromagnetic wave	B1	[2]
		Allow 'α(-decay) as change of 4 in the nucleon number cannot be shown on the diagram'	(B2)	
		Do not give credit for a 'bald' α(-decay)		

Q5.

7 **(a)** α-particle: *either* helium nucleus *or* contains 2 protons + 2 neutrons
or $^{4}_{2}He$ B1

β-particle: *either* electron *or* $^{0}_{-1}e$ B1

α speed < β speed (1)
α discrete values of speed/energy, β continuous spectrum (1)
either α ionising power >> β ionising power
or α range << β range (1)
α positive, β negative *(only if first two B marks not scored)* (1)
α mass > β mass *(only if first two B marks not scored)* (1)
(any two sensible pairs of statements relevant to differences,
– do not allow statements relevant to only α or β, 1 each, max 2) B2 [4]

(b) **(i)** $^{236}_{92}U \rightarrow {}^{232}_{90}Th$ M1
$+ {}^{4}_{2}He$ A1 [2]

(ii) **1.** correct position for U at $Z = 92$, $N = 145$ B1
2. correct position for Np relative to U i.e. $Z + 1$ and $N - 1$ B1 [2]

Q6.

8 **(a)** rate of decay / activity / decay (of nucleus) is not affected by external factors / environment / surroundings ..... B2 [2]
(If states specific factor(s), rather than giving general statement above, then give 2 marks for two stated factors, but 1 mark only if one factor stated)

(b) **(i)** gamma / γ ..... B1 [1]

(ii) alpha / α ..... B1 [1]

(iii) gamma / γ ..... B1 [1]

(iv) beta / β ..... B1 [1]

Q7.

7 (a) nuclei/atoms with same proton number/atomic number B1
nuclei/atoms contain different numbers of neutrons/different atomic mass ..... B1 [2]

(b) (i) 92 ..... A1 [1]

(ii) 146 ..... A1 [1]

(c) (i) mass = $238 \times 1.66 \times 10^{-27}$ C1
$= 3.95 \times 10^{-25}$ kg ..... A1 [2]

(ii) volume = $\frac{4}{3}\pi \times (8.9 \times 10^{-15})^3$ $(= 2.95 \times 10^{-42})$ C1
density = $(3.95 \times 10^{-25})/(2.95 \times 10^{-42})$
$= 1.3 \times 10^{17}$ kg m^{-3} ..... A1 [2]

(d) nucleus contains most of mass of atom B1
either nuclear diameter/volume very much less than that of atom
or atom is mostly (empty) space ..... B1 [2]

Q8.

7 (a) (i) *either* helium nucleus
or contains 2 protons and 2 neutrons ..... B1 [1]

(ii) e.g. range is a few cm in air/sheet of thin paper
speed up to 0.1 *c*
causes dense ionisation in air
positively charged or deflected in magnetic or electric fields
(*any two, 1 each to max 2*) ..... B2 [2]

(b) (i) $^4_2\alpha$ B1
either $^1_1$p *or* $^1_1$H ..... B1 [2]

(ii) 1 initially, α-particle must have some kinetic energy ..... B1 [1]

(ii) 2 1.1 MeV = $1.1 \times 1.6 \times 10^{-13} = 1.76 \times 10^{-13}$ J C1
$E_K = \frac{1}{2}mv^2$ C1
$1.76 \times 10^{-13} = \frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2$ C1
$v = 7.3 \times 10^6$ m s^{-1} ..... A1 [4]
use of 1.67×10^{-27} kg for mass is a maximum of 3/4

Q9.

7	(a)	(i)	*either* helium nucleus *or* particle containing two protons and two neutrons	B1	[1]
		(ii)	allow any value between 1 cm and 10 cm	B1	[1]
	(b)	(i)	energy = $(8.5 \times 10^{-13})/(1.6 \times 10^{-13})$	M1	
			= 5.3 MeV	A0	[1]
		(ii)	number = $(5.3 \times 10^{6})/31$	C1	
			= 1.7×10^{5} (*allow 2 s.f. only*)	A1	[2]
		(iii)	number per unit length = (1.7×10^{5}) / **(a)(ii)**		
			correct numerical value	A1	
			correct unit	B1	[2]

Q10.

7	(a)	(i)	2 protons and 2 neutrons	B1	[1]
		(ii)	e.g. positively charged 2*e* mass 4u constant energy absorbed by thin paper *or* few cm of air (3 cm → 8 cm) (*not low penetration*) highly ionizing deflected in electric/magnetic fields (*One mark for each property, max 2)*	B2	[2]
	(b)		mass-energy is conserved	B1	
			difference in mass 'changed' into a form of energy	B1	
			energy in the form of kinetic energy of the products / γ-radiation photons / e.m. radiation	B1	[3]

Q11.

7	(a)		W = 1 and X = 0	A1	[1]
			Y = 2	A1	[1]
			Z = 55	A1	[1]
	(b)		explanation in terms of mass – energy conservation	B1	
			energy released as gamma or photons or kinetic energy of products or em radiation	B1	[2]

Q12.

7	(a)	thin paper reduces count rate hence α	B1	
		addition of 1 cm of aluminium causes little more count rate reduction hence only other radiation is γ	B1	[2]
	(b)	magnetic field perpendicular to direction of radiation	B1	
		look for a count rate in expected direction / area if there were negatively charged radiation present. If no count rate recorded then β not present.	B1	[2]

Q13.

7	(a)	the majority/most went straight through or were deviated by small angles	B1	
		a very small proportion/a few were deviated by large angles	B1	
		small angles described as < 10° and large angles described as >90°	B1	[3]
	(b)	most of the atom is empty space/nucleus very small compared with atom	B1	
		mass and charge concentrated in (very small) nucleus	B1	
		correct links made with statements in **(a)**	B1	[3]

Q14.

7	(a)	(i)	$W = 206$ and $X = 82$	A1	
			$Y = 4$ and $Z = 2$	A1	[2]
		(ii)	mass-energy is conserved	B1	
			mass on rhs is less because energy is released	B1	[2]
	(b)		not affected by external conditions/factors/environment or two examples temperature and pressure	B1	[1]

Q15.

7	(a)	(i)	nucleus contains 92 protons	B1	
			nucleus contains 143 neutrons (missing 'nucleus' 1/2)	B1	
			outside / around nucleus 92 electrons	(B1)	
			most of atom is empty space / mass concentrated in nucleus	(B1)	
			total charge is zero	(B1)	
			diameter of atom ~ 10^{-10} m or size of nucleus ~ 10^{-15} m	(B1)	
			any two of (B1) marks		[4]
		(ii)	nucleus has same number / 92 protons	B1	
			nuclei have 143 and 146 neutrons (missing 'nucleus' 1/2)	B1	[2]
	(b)	(i)	$Y = 35$	A1	
			$Z = 85$	A1	[2]
		(ii)	mass-energy is conserved in the reaction	B1	
			mass on rhs of reaction is less so energy is released explained in terms of $E = mc^2$	B1	[2]

Q16.

8	(a)	shows nucleon number as 220	B1	
		shows proton number as 87	B1	[2]
	(b)	shows products as $^{4}_{2}$He OR $^{4}_{2}\alpha$	B1	
		and $^{216}_{85}$At ....(allow e.c.f. from (a))	B1	[2]

Q17.

6	(a)	(i)	26 protons.....	B1	
		(ii)	30 neutrons.....	B1	[2]
	(b)	(i)	mass = $56 \times 1.66 \times 10^{-27}$	C1	
			(allow $\times 1.67 \times 10^{-27}$ but 0/2 for use of 26 or 30)		
			$= 9.3 \times 10^{-26}$ kg.....	A1	
		(ii)	density = mass/volume where volume = $4/3 \times \pi \times r^3$.....	C1	
			$= (9.3 \times 10^{-26})/(4/3 \times \pi \times \{5.7 \times 10^{-15}\}^3)$		
			$= 1.2 \times 10^{17}$ kg m^{-3}	A1	[4]
	(c)		nucleus occupies only very small fraction of <u>volume of atom</u>		
			or 'lot of empty space inside atom'.....	B1	
			(do not allow spacing between atoms)		
			any further good physics e.g. nuclear material is very dense	B1	[2]

Q18.

7	**(a)**	**(i)**	nucleus is small	**M1**	
			in comparison to size of atom	**A1**	**[2]**
		(ii)	nucleus is massive/heavy/dense	**B1**	
			and charged (allow to be scored in **(i)** or **(ii)**)	**B1**	**[2]**
	(b)	**(i)**	symmetrical path and deviation correct w.r.t. position of nucleus	**B1**	
			deviation less than in path AB	**B1**	
		(ii)	deviation > 90° and in correct direction	**B1**	**[3]**

Q19.

7	**(a)**		most α-particles deviated through small angles (*accept 'undeviated'*) few α-particles deviated through angles greater than 90°	B1 B1	 [2]
	(b)	**(i)**	allow 10^{-9} m $\rightarrow$ 10^{-11} m	B1	[1]
		(ii)	allow 10^{-13} m $\rightarrow$ 10^{-15} m (*if **(i)** and **(ii)** out of range but **(ii)** = 10^{-4} **(i)**, then allow 1 mark*) (*if no units or wrong units but **(ii)** = 10^{-4} **(i)**, then allow 1 mark*)	B1	[1]

Q20.

8	**(a)**		<u>nucleus</u> has constant probability of decay per unit time / in a given time (*allow 1 mark for 'cannot predict which <u>nucleus</u> will decay next'*)	M1 A1	 [2]
	(b)	**(i)**	count rate / activity decreases	B1	[1]
		(ii)	count rate fluctuates / is not smooth	B1	[1]
	(c)		*either* the (decay) curves are similar / same *or* curves indicate same half-life	B1	[1]

Q21.

7 **(a)** deviation shown correctly ..... B1 [1]

(b) smaller deviation (not zero deviation) M1
acceptable path wrt position of N ..... A1 [2]

(c) the nucleus is (very) small M1
in comparison to the atom ..... A1 [2]
(special *case: 'atom is mostly empty space' scores 1 mark*)

(d) deviation depends on charge on the nucleus / N / electrostatic repulsion B1
same charge so no change in deviation ..... B1 [2]

[Total: 7]

Q22.

7 **(a)** *either* forms of same element
or atoms / nuclei with same number of protons M1
atoms / nuclei contain different numbers of neutrons ..... A1 [2]
(*use of 'element' rather than atoms / nuclei scores max 1 mark*)

(b) **(i)** decay is not affected by environmental factors ..... B1 [1]
(*allow two named factors*)

(ii) *either* time of decay (of a nucleus) cannot be predicted
or nucleus has constant probability in a given time ..... B1 [1]

(c) $^{185}_{75}\text{Re}$ B1
either $^{0}_{-1}\text{e}$ *or* $^{0}_{-1}\beta$ ..... B1 [2]

[Total: 6]

Q23.

7 **(a)** *either* different forms of same element
or nuclei have same number of protons M1
different numbers of neutrons (in the nucleus) A1 [2]

(b) **(i)** proton number conserved B1
nucleon number conserved B1
mass-energy conserved B1 [3]

(ii) **1.** $Z = 36$ A1 [1]
2. $x = 3$ A1 [1]

Q24.

7	(a)	(i)	most α-particles were deviated through small angles (*allow 1 mark for 'straight through' / undeviated*)	B2	[2]
		(ii)	small fraction of α-particles deviated through large angles greater than 90° (allow rebound back)	M1 A1	[2]
	(b)		e.g. β-particles have a range of energies β-particles deviated by (orbital) electrons β-particle has (very) small mass (*any two sensible suggestions, 1 each, max 2*)	B2	[2]

Do not allow β-particles have negative charge or β-particles have high speed

Q25.

9	(a)		nucleus emits α-particles or β-particles and/or γ-radiation to form a different / more stable nucleus	B1 B1	[2]
	(b)	(i)	fluctuations in count rate (not 'count rate is not constant')	B1	[1]
		(ii)	no effect	B1	[1]
		(iii)	if the source is an α-emitter *either* α-particles stopped within source (and gain electrons) *or* α-particles are helium nuclei	B1 B1	[2]

allow 1/2 for 'parent nucleus gives off radiation to form daughter nucleus'

Q26.

7	(a)		nuclei with the same number of protons and a different number of neutrons	B1 B1	[2]
	(b)	(i)	(mass + energy) (taken together) is conserved momentum is conserved one point required max. 1	(B1) (B1) B1	[1]
		(ii)	$a = 1$ and $b = 0$ $x = 56$ $y = 92$	B1 B1 B1	[3]
	(c)		proton number = 90 nucleon number = 235	B1 B1	[2]

Q27.

7 **(a) (i)** the half life / count rate / rate of decay / activity is the same no matter what external factors / environmental factors **or** two named factors such as temperature and pressure changes are applied B1 [1]

(ii) the observations of the count rate / count rate / rate of decay / activity / radioactivity during decay shows variations / fluctuations B1 [1]

(b)

property	α-particle	β-particle	γ-radiation
charge	**(+)2*e***	**−*e***	0
mass	4*u*	**9.11×10^{-31} kg**	0
speed	**0.01 to 0.1 *c***	up to 0.99 *c*	***c***

one mark for each correct line B3 [3]

(c) collision with molecules B1
causes ionisation (of the molecule) / electron is removed B1 [2]

Q28.

6 **(a) (i)** greater deflection M0
greater electric field / force on α-particle A1 [1]

(ii) greater deflection M0
greater electric field / force on α-particle A1 [1]

(b) (i) *either* deflections in opposite directions M1
because oppositely charged A1
or β less deflection (M1)
β has smaller charge (A1) [2]

(ii) α smaller deflection M1
because larger mass A1 [2]

(iii) β less deflection because higher speed B1 [1]

(c) *either* $F = ma$ and $F = Eq$ *or* $a = Eq / m$ C1
ratio = *either* $\frac{(2 \times 1.6 \times 10^{-19}) \times (9.11 \times 10^{-31})}{(1.6 \times 10^{-19}) \times 4 \times (1.67 \times 10^{-27})}$
or [2*e* × 1 / 2000 u] / [*e* × 4u] C1

ratio = 1 /4000 *or* 2.5×10^{-4} *or* 2.7×10^{-4} A1 [3]

Q29.

6 **(a)** 92 protons in the nucleus and 92 electrons around nucleus B1
143 neutrons (in the nucleus) B1 [2]

(b) **(i)** α-particle travels short distance in air B1 [1]

(ii) very small proportion in backwards direction / large angles B1
majority pass through with no /small deflections B1
either most of mass is in very small volume (nucleus) and is charged or most of atom is empty space B1 [3]

(c) $I = Q / t$ C1
$n/t = (1.5 \times 10^{-12}) / (2 \times 1.6 \times 10^{-19})$ C1
$n/t = 4.7 \times 10^{6}\,s^{-1}$ A1 [3]

Q30.

7 **(a)** ${}^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + 2\,{}^{1}_{1}p + Q$
A numbers correct (**4** and **1**) B1
Z numbers correct (**2** and **1**) B1 [2]

(b) both nuclei have 2 protons B1
the two isotopes have 1 neutron and two neutrons B1 [2]
[allow 1 for 'same number of protons but different number of neutrons']

(c) proton number and neutron number B1
energy – mass B1
momentum B1 [2]

(d) **(i)** γ radiation B1 [1]

(ii) product(s) must have kinetic energy B1 [1]

(e) $13.8\,MeV = 13.8 \times 1.6 \times 10^{-19} \times 10^{6}\ (= 2.208 \times 10^{-12})$ C1
$60 = n \times 13.8 \times 1.6 \times 10^{-13}$
$n = 2.7(2) \times 10^{13}\ s^{-1}$ A1 [2]

Q31.

6	(a)	(i)	electron	B1	[1]
		(ii)	any **two:** can be deflected by electric and magnetic fields or negatively charged / absorbed by few (1 – 4) mm of aluminum / 0.5 to 2 m or metres for range in air / speed up to 0.99c / range of speeds / energies	B2	[2]
		(iii)	decay occurs and cannot be affected by external / environmental factors or two stated factors such as chemical / pressure / temperature / humidity	B1	[1]
	(b)		3 and 0 for superscript numbers 2 and –1 for subscript numbers	B1 B1	[2]
	(c)		energy = $5.7 \times 10^{3} \times 1.6 \times 10^{-19}$ (= 9.12×10^{-16} J)	C1	
			$v^2 = \frac{2 \times 9.12 \times 10^{-16}}{9.11 \times 10^{-31}}$	C1	
			$v = 4.5 \times 10^{7}\ \text{m s}^{-1}$	A1	[3]
	(d)		both have 1 proton and 1 electron 1 neutron in hydrogen-2 and 2 neutrons in hydrogen-3 (special case: for one mark 'same number of protons / atomic number different number of neutrons')	B1 B1	[2]

Q32.

7	(a)	(i)	the direction of the fields is the same OR fields are uniform OR constant electric field strength OR $E = V / d$ with symbols explained	B1	[1]
		(ii)	reduce p.d. across plates increase separation of plates	B1 B1	[2]
		(iii)	α opposite charge to β (as deflection in opposite direction) β has a range of velocities OR energies (as different deflections) and α all have same velocity OR energy (as constant deflection) α are more massive (as deflection is less for greater field strength)	B1 B1 B1	[3]
	(b)		$W = 234$ and $X = 90$ $Y = 4$ and $Z = 2$	B1 B1	[2]
	(c)		$A = 32$ and $B = 16$ and $C = 0$ and $D = -1$	B1	[1]