1)

(a) α: helium nucleus

β: electron

γ: electromagnetic radiation / wave / ray *or* photon

three correct 2 / 2, two correct 1 / 2 — B2 [2]

(b) (i) atomic number / proton number / Z –2, nucleon / mass number / A –4 — B1 [1]

(ii) atomic number / proton number / Z +1
nucleon / mass number / A no change — B1 [1]

(iii) no change in proton or mass number
or "no change" — B1 [1]

2)

(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]

3)

(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 — B1
increase separation of plates — B1 [2]

(iii) α opposite charge to β (as deflection in opposite direction) — B1
β has a range of velocities OR energies (as different deflections) and
α all have same velocity OR energy (as constant deflection) — B1
α are more massive (as deflection is less for greater field strength) — B1 [3]

(b) $W = 234$ and $X = 90$ — B1
$Y = 4$ and $Z = 2$ — B1 [2]

(c) $A = 32$ and $B = 16$ and $C = 0$ and $D = –1$ — B1 [1]

4)

(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]

5)

(a)		α-particles not able to penetrate air between source and window	B1	[1]
(b)	**(i)**	rapid drop in count rate	B1	
		for small thicknesses (up to 2 mm)		
		OR most β's stopped by few mm of aluminium	B1	
	(ii)	very slow drop-off in count rate	B1	
		for thicknesses greater than 2 mm		
		OR γ much higher penetration than β	B1	[4]
		(do not allow 'γ not stopped by aluminium')		

6)

(a)	118		B1	**[1]**
(b)	path:	correct shape	M1	
		in correct position relative to nucleus	A1	**[2]**
(c)	smaller deviation		B1	**[1]**

7)

(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]

8)

(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]

9)

(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]**

10)

(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]**

11)

(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]**

12)

(a)		helium nucleus OR contains two protons and two neutrons	B1	[1]
(b)		kinetic energy = $\frac{1}{2}mv^2$	C1	
		$\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 1.07 \times 10^{-12}$	A1	
		$v = 1.8 \times 10^7$ m s^{-1}	A0	[2]
(c)	**(i)**	sum of momenta (in any direction) is constant / total momemtum is constant	M1	
		in a closed system / no external force	A1	[2]
	(ii)	momentum of francium (= 0) = momentum of α + momentum of astatine	C1	
		$204 \times V = 4 \times 1.8 \times 10^7$	C1	
		$V = 3.5 \times 10^5$ m s^{-1}	A1	[3]
		(*nuclei incorrectly identified, 0/3* *nuclei correctly identified but incorrect masses, -1 each error*)		
(d)		another particle / photon is emitted	M1	
		at an angle to the direction of the α-particle	A1	[2]
		(allow 1 mark for 'Francium nucleus is not stationary')		

13)

(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)		

14)

(a) most α-particles deviated through small angles — B1
(*accept 'undeviated'*)
few α-particles deviated through angles greater than 90° — B1 [2]

(b) **(i)** allow 10^{-9} m → 10^{-11} m — B1 [1]

(ii) allow 10^{-13} m → 10^{-15} m — B1 [1]
(*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*)

15)

(a) α-particle: *either* helium nucleus *or* contains 2 protons + 2 neutrons
or $^{4}_{2}\text{He}$ — B1
β-particle: *either* electron *or* $^{0}_{-1}\text{e}$ — 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)** $^{236}_{92}\text{U} \rightarrow {}^{232}_{90}\text{Th}$ — M1
$+ {}^{4}_{2}\text{He}$ — 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]

16)

(a) nucleus has constant probability of decay — M1
per unit time / in a given time — A1 [2]
(*allow 1 mark for 'cannot predict which nucleus will decay next'*)

(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]

17)

(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]