

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 ${}^4_2\text{He}$ 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 $A = A_{\text{Pu}}$ and with $Z = (Z_{\text{Pu}} + 1)$ B1 [2]

Q3.

- 8 (a) nucleus emits α - or β - particles and/or γ -rays M1 A1 [2]
 (b) decay unaffected by environmental changes such as temperature, pressure etc. (one e.g. is sufficient) M1 A1 [2]
 (c) constant probability of decay (per unit time) of a nucleus cannot predict which particular nucleus will decay next B1 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 ${}^4_2\text{He}$ 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) ${}^{236}_{92}\text{U} \rightarrow {}^{232}_{90}\text{Th} + {}^4_2\text{He}$ M1
 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_1p or 1_1H B1 [2]
- (ii) 1 initially, α -particle must have some kinetic energy B1 [1]
- (ii) 2 $1.1 \text{ MeV} = 1.1 \times 1.6 \times 10^{-13} = 1.76 \times 10^{-13} \text{ J}$ 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
 $v = 7.3 \times 10^6 \text{ m s}^{-1}$ 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 = $(8.5 \times 10^{-13}) / (1.6 \times 10^{-13})$ = 5.3 MeV	M1 A0	[1]
	(ii) number = $(5.3 \times 10^6) / 31$ = 1.7×10^5 (allow 2 s.f. only)	C1 A1	[2]
	(iii) number per unit length = $(1.7 \times 10^5) / (a)(ii)$ correct numerical value correct unit	A1 B1	[2]

Q10.

7 (a) (i)	2 protons and 2 neutrons	B1	[1]
	(ii) e.g. positively charged 2e 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) <u>mass-energy</u> is conserved difference in mass 'changed' into a form of energy energy in the form of kinetic energy of the products / γ -radiation photons / e.m. radiation	B1 B1 B1	[3]

Q11.

7 (a)	W = 1 and X = 0 Y = 2 Z = 55	A1 A1 A1	[1] [1] [1]
	(b) explanation in terms of mass – energy conservation energy released as gamma or photons or kinetic energy of products or em radiation	B1 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 B1 [2]
 other radiation is γ
- (b) magnetic field perpendicular to direction of radiation B1
 look for a count rate in expected direction / area if there were negatively B1 [2]
 charged radiation present. If no count rate recorded then β not present.

Q13.

- 7 (a) the majority/most went straight through B1
 or were deviated by small angles
- a very small proportion/a few were deviated by large angles B1
 small angles described as $< 10^\circ$ and large angles described as $>90^\circ$ 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.

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- 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 B1 [1]
 or two examples temperature and pressure

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 $\sim 10^{-10}$ m or size of nucleus $\sim 10^{-15}$ 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 ${}^4_2\text{He}$ OR ${}^4_2\alpha$ B1
 and ${}^{216}_{85}\text{At}$ (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)
 = 9.3×10^{-26} kg..... A1
- (ii) density = mass/volume where volume = $\frac{4}{3} \times \pi \times r^3$ C1
 = $(9.3 \times 10^{-26}) / (\frac{4}{3} \times \pi \times \{5.7 \times 10^{-15}\}^3)$
 = 1.2×10^{17} kg m⁻³ A1 [4]
- (c) nucleus occupies only very small fraction of volume of atom
 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 $> 90^\circ$ and in correct direction B1 [3]

Q19.

- 7 (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 \rightarrow 10^{-11} m B1 [1]
- (ii) allow 10^{-13} m \rightarrow 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)

Q20.

- 8 (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 B1 [1]
or curves indicate same half-life

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 B1
either α -particles stopped within source (and gain electrons)
or α -particles are helium nuclei 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 (B1)
momentum is conserved (B1)
one point required max. 1 B1 [1]
- (ii) $a = 1$ and $b = 0$ B1
 $x = 56$ B1
 $y = 92$ B1 [3]
- (c) proton number = 90 B1
nucleon number = 235 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	(+)2e	-e	0
mass	4u	$9.11 \times 10^{-31} \text{ kg}$	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 $[2e \times 1 / 2000 u] / [e \times 4u]$ 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
143 neutrons (in the nucleus) B1
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
 $n/t = 4.7 \times 10^6 \text{ s}^{-1}$ A1 [3]

Q30.

- 7 (a) ${}^3_2\text{He} + {}^3_2\text{He} \rightarrow {}^4_2\text{He} + 2 {}^1_1\text{p} + Q$
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) $13.8 \text{ MeV} = 13.8 \times 1.6 \times 10^{-19} \times 10^6 (= 2.208 \times 10^{-12})$ C1
 $60 = n \times 13.8 \times 1.6 \times 10^{-13}$
 $n = 2.7(2) \times 10^{13} \text{ s}^{-1}$ 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]