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_2He 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.

1

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 × 1.66 × 10^{-27} C1
= 3.95 × 10^{-25} kg .... A1 [2]

(ii) volume = $\frac{4}{3}\pi \times (8.9 \times 10^{-15})^3$ (= 2.95 × 10^{-42}) C1

density = (3.95 × 10^{-25})/(2.95 × 10^{-42})
= 1.3 × 10^{17} kg m^{-3} .... A1 [2]

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

Q8.

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

(ii) e.g. range is a few cm in air/sheet of <u>thin</u> 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 × 1.6 × 10^{-13} = 1.76 × 10^{-13} J C1
$E_K = \frac{1}{2}mv^2$ C1
1.76 × 10^{-13} = ½ × 4 × 1.66 × 10^{-27} × v^2 .... C1
v = 7.3 × 10^6 m s^{-1} .... A1 [4]
use of 1.67 × 10^{-27} kg for mass is a maximum of 3/4

Q9.

3

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 $2e$
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) 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   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 ~ 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 x 1.66 x 10^{-27} C1
             (allow x 1.67 x 10^{-27} but 0/2 for use of 26 or 30)
                = 9.3 x 10^{-26} kg...................................... A1

      (ii)   density = mass/volume where volume = 4/3 x π x r^3.......... C1
                = (9.3 x 10^{-26})/(4/3 x π x {5.7 x 10^{-15}}^{3})
                = 1.2 x 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   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) <u>nucleus</u> has constant probability of decay   M1
      per unit time / in a given time   A1   [2]
      (*allow 1 mark for 'cannot predict which <u>nucleus</u> 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]

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) $^{185}_{75}$Re B1

either $^{0}_{-1}$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   B2   [2]
                (allow 1 mark for 'straight through' / undeviated)

        (ii)   small fraction of α-particles deviated through large angles   M1
               greater than 90° (allow rebound back)   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   B1
          to form a different / more stable nucleus   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   B1
          and a different number of neutrons   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	9.11×10^{-31} kg	0
speed	0.01 to 0.1 c	up to 0.99c	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* $\dfrac{(2 \times 1.6 \times 10^{-19}) \times (9.11 \times 10^{-31})}{(1.6 \times 10^{-19}) \times 4 \times (1.67 \times 10^{-27})}$

               or   [2e × 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
$n/t = 4.7 \times 10^6 \, \mathrm{s^{-1}}$ — A1 [3]

Q30.

7 (a) $^3_2\mathrm{He} + ^3_2\mathrm{He} \rightarrow ^4_2\mathrm{He} + 2\, ^1_1\mathrm{p} + Q$
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) $13.8\,\mathrm{MeV} = 13.8 \times 1.6 \times 10^{-19} \times 10^6 \ (= 2.208 \times 10^{-12})$ — C1
$60 = n \times 13.8 \times 1.6 \times 10^{-13}$
$n = 2.7(2) \times 10^{13} \, \mathrm{s^{-1}}$ — A1 [2]

Q31.

11

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	
			$v^2 = \dfrac{2 \times 9.12 \times 10^{-16}}{9.11 \times 10^{-31}}$		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]