Solutions

Each answer shows the steps, then the **result**.

2.1

- α: a **helium nucleus** – two protons and two neutrons
- β^-: a fast-moving **electron**
- β^+: a fast-moving **positron**, the antiparticle of the electron

2.2

- an α particle has a **large charge** of $+2e$ and moves comparatively slowly, so it interacts strongly with the atoms it passes
- it therefore **ionises** a great many atoms per unit distance
- each ionisation takes energy from it, so it loses all its energy within a very short distance: it is least penetrating **because** it is most ionising

2.3

- α and β^- are deflected in **opposite** directions
- because α carries a positive charge and β^- a negative one
- γ has **no charge**, so the magnetic force Bqv on it is zero and it travels straight on

2.4

- the radius of the path is $r = \dfrac{mv}{Bq}$, so a smaller mass gives a smaller radius and a sharper curve
- a β particle has roughly $\frac{1}{7000}$ of the mass of an α particle, so it is deflected far more

2.5

- $1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg}$
- it is defined as **one twelfth of the mass of a carbon-12 atom**

3.1 B

- a β^- particle is an electron: charge $-e$ and mass about $\frac{1}{1840}$ u
- **A** gives an α particle's mass; **C** is a positron; **D** is a γ photon

3.2

(a)

- the α spectrum drawn as **one or a few sharp, discrete lines**
- the β spectrum drawn as a **continuous curve** rising from near zero, peaking, and falling to zero at a maximum energy

(b)

- in an α decay the energy released is shared between only **two** bodies, the α particle and the recoiling nucleus

- conservation of energy and momentum then fixes the α particle's share exactly, so it is **discrete**
- in a β decay a **third** particle is emitted: an **antineutrino** in β^- decay
- the available energy is shared between the β particle and the antineutrino in **any** proportion, so the β particle's energy ranges continuously from nearly zero to a maximum

3.3

(a)

- the nucleon number falls by 4 and the proton number by 2

$$^{218}_{84}\text{Po} \rightarrow\ ^{214}_{82}\text{Pb} + \ ^{4}_{2}\alpha$$

(b)

- the nucleon number is unchanged and the proton number rises by 1
- the β^- particle is written $^{0}_{-1}\beta$

$$^{214}_{82}\text{Pb} \rightarrow\ ^{214}_{83}\text{Bi} + \ ^{0}_{-1}\beta + \bar{\nu}_\text{e}$$

- the third particle is an **antineutrino**; it carries no charge and no nucleon number, so the balance is unaffected

(c)

- **nucleon number**
- **charge**, equivalently proton number

(d)

- the energy is shared between **only two** bodies: the α particle and the recoiling daughter nucleus
- conservation of momentum and energy then fixes each share exactly, so every α from this route carries the same energy – no third particle is emitted

(e)

- the mass is about the nucleon number times 1 u

$$m \approx 218 \times 1.66 \times 10^{-27}\ \text{kg} = \mathbf{3.6 \times 10^{-25}}\ \text{kg}$$