Solutions

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

2.1

- thin foil: so that each α-particle is scattered by **one nucleus only** (and is not absorbed)
- evacuated: so that the α-particles are not **absorbed or scattered by air**

2.2

- all the kinetic energy becomes electric potential energy at the closest approach: $E_k = \dfrac{2Ze^2}{4\pi\varepsilon_0 d}$
- $E_k = (4.0 \times 10^6)(1.60 \times 10^{-19}) = 6.4 \times 10^{-13}$ J

$$d = \frac{2(79)(1.60 \times 10^{-19})^2}{4\pi(8.85 \times 10^{-12})(6.4 \times 10^{-13})} = \mathbf{5.7 \times 10^{-14}}\ \text{m}$$

2.3

- nucleon number unchanged, proton number falls by one

$$^{22}_{11}\text{Na} \rightarrow\ ^{22}_{10}\text{Ne} +\ ^{0}_{+1}\beta +\ ^{0}_{0}\nu$$

- the third particle is a (electron) **neutrino**, because this is β^+ decay

2.4

- an antiparticle has the **same mass** as the particle but the **opposite charge**
- the antiparticle of the electron is the **positron**

2.5

- mass $= A \times 1$ u $= 40 \times 1.661 \times 10^{-27}$

$$= \mathbf{6.6 \times 10^{-26}}\ \text{kg}$$

2.6

- the **nucleon number** (the top numbers)
- the **charge**, i.e. the proton number (the bottom numbers)

3.1 C

- $A = \dfrac{3.99 \times 10^{-26}}{1.661 \times 10^{-27}} = 24.0$
- A and B are too light and D is nearly three times too heavy

3.2

- each α takes 4 from A and 2 from Z; each β^- leaves A alone and adds 1 to Z
- $A = 232 - 4 - 4 = \mathbf{224}$
- $Z = 90 - 2 + 1 - 2 = \mathbf{87}$

3.3

(a) the α-particle is **repelled** by the nucleus, so it slows down and its kinetic energy decreases

- that kinetic energy is converted into **electric potential energy**, and at the closest approach all of it has been converted

(b) $E_\mathrm{k} = (5.0 \times 10^6)(1.60 \times 10^{-19}) = 8.0 \times 10^{-13}$ J

- $d = \dfrac{2Ze^2}{4\pi\varepsilon_0 E_\mathrm{k}}$

$$d = \frac{2(79)(1.60 \times 10^{-19})^2}{4\pi(8.85 \times 10^{-12})(8.0 \times 10^{-13})} = \mathbf{4.5 \times 10^{-14}}\ \mathrm{m}$$

3.4

- β^- decay raises the proton number by one and β^+ decay lowers it by one, so Z has the **same proton number as X**
- the β^- decay also emits an (electron) **antineutrino**
- the β^+ decay also emits an (electron) **neutrino**

3.5

(a) the unit of mass defined so that an atom of carbon-12 has a mass of exactly 12 u

(b) an α-particle has a mass of 4 u

$$m = 4 \times 1.661 \times 10^{-27} = \mathbf{6.6 \times 10^{-27}}\ \mathrm{kg}$$

(c) charge $= pe$ and mass $= 40 \times 1.661 \times 10^{-27} = 6.64 \times 10^{-26}$ kg

- $p = \dfrac{(4.8 \times 10^7)(6.64 \times 10^{-26})}{1.60 \times 10^{-19}} = 19.9$
- $p = \mathbf{20}$, so the nuclide is ${}^{40}_{20}\mathrm{Ca}$

(d) an α-particle carries $2e$ and has a mass of 4 u:

$$\frac{2(1.60 \times 10^{-19})}{4(1.661 \times 10^{-27})} = \mathbf{4.8 \times 10^7}\ \mathrm{C\ kg^{-1}}$$

- both carry exactly **half an elementary charge per nucleon** (2 protons in 4 nucleons, 20 protons in 40), and the ratio depends only on that