

## Solutions

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

### 2.1

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

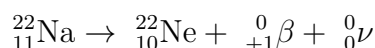
### 2.2

- all the kinetic energy becomes electric potential energy at the closest approach:  $E_k = \frac{2Ze^2}{4\pi\epsilon_0 d}$
- $E_k = (4.0 \times 10^6)(1.60 \times 10^{-19}) = 6.4 \times 10^{-13} \text{ J}$

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

### 2.3

- nucleon number unchanged, proton number falls by one



- the third particle is a (electron) **neutrino**, because this is  $\beta^+$  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

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

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

### 2.6

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

### 3.1 C

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

### 3.2

- each  $\alpha$  takes 4 from A and 2 from Z; each  $\beta^-$  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  $\alpha$ -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)  $E_k = (5.0 \times 10^6)(1.60 \times 10^{-19}) = 8.0 \times 10^{-13} \text{ J}$

- $d = \frac{2Ze^2}{4\pi\epsilon_0 E_k}$

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

### 3.4

- $\beta^-$  decay raises the proton number by one and  $\beta^+$  decay lowers it by one, so Z has the **same proton number as X**
- the  $\beta^-$  decay also emits an (electron) **antineutrino**
- the  $\beta^+$  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  $\alpha$ -particle has a mass of 4 u

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

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

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

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

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

- 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