## Solutions

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

**2.1**

- any two: the atom is **mostly empty space**; it has a **tiny nucleus**; the nucleus is **positively charged**; most of the atom's **mass** is in the nucleus

**2.2**

- protons $= Z = 6$, and a neutral atom has as many electrons, 6
- the neutron number is the nucleon number minus the proton number

$$N = A - Z = 14 - 6 = \mathbf{8}$$

**2.3**

- nuclides of the **same element**, with the same number of protons but **different numbers of neutrons**

**2.4**

- thin: so that each $\alpha$-particle is scattered by **one nucleus at most** and is not absorbed in the foil
- vacuum: so that the $\alpha$-particles are not **absorbed or scattered by air**, in which they travel only a few centimetres

**2.5**

- protons $= Z = \mathbf{17}$
- neutrons

$$N = A - Z = 35 - 17 = \mathbf{18}$$

- a charge of $-e$ means one electron has been gained

$$n_\mathrm{e} = Z + 1 = 17 + 1 = \mathbf{18}$$

**2.6**

- the mass of a nucleus is about $A$ u

$$m = A \times 1 \text{ u} = 40 \times 1.66 \times 10^{-27} \text{ kg} = \mathbf{6.64 \times 10^{-26}} \text{ kg}$$

**3.1 B**

- isotopes have the same proton number, so they are the same element, and different numbers of neutrons
- **A** describes two different elements; **D** is wrong because a neutral atom has $Z$ electrons, the same for every isotope

**3.2 C**

- the mass of a nucleus is about $A$ u, so

$$A = \frac{m}{1 \text{ u}} = \frac{3.99 \times 10^{-26} \text{ kg}}{1.66 \times 10^{-27} \text{ kg}} = 24$$

**3.3**

(a) almost all of the $\alpha$-particles pass **straight through** the foil, undeflected

- so the atom is **mostly empty space**

(b) such a large deflection needs a strong repulsion, so the nucleus carries a concentrated **positive charge**

- the $\alpha$-particle is turned back, so the nucleus is **much more massive** than the $\alpha$-particle
- it happens very rarely, so the nucleus is **very small** compared with the atom

**3.4**

(a) one twelfth of the mass of an atom of **carbon-12**

(b) the mass of a nucleus is about $A$ u

$$m = A \times 1 \text{ u} = 7 \times 1.66 \times 10^{-27} \text{ kg} = \mathbf{1.16 \times 10^{-26}} \text{ kg}$$

(c) the mass of the nucleus

$$m = A \times 1 \text{ u} = 27 \times 1.66 \times 10^{-27} \text{ kg} = 4.48 \times 10^{-26} \text{ kg}$$

- its charge is $Ze$, so

$$Z = \frac{(Q/m) \times m}{e} = \frac{(4.6 \times 10^{7} \text{ C kg}^{-1})(4.48 \times 10^{-26} \text{ kg})}{1.60 \times 10^{-19} \text{ C}} = 12.9$$

- a whole number of protons, $Z = \mathbf{13}$, and then

$$N = A - Z = 27 - 13 = \mathbf{14}$$

(d) the ratio depends only on the number of protons per nucleon

- helium has 2 protons in 4 nucleons, exactly a half; this nucleus has 13 in 27, less than a half, because heavier nuclei have more neutrons than protons