Solutions

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

2.1

- a few millimetres of aluminium

2.2

- any two of: radon gas in the air; rocks and buildings; food and drink; cosmic rays from space

2.3

- corrected $= 250 - 30$
- 220 **counts/min**

2.4

- alpha: a helium nucleus (2 protons and 2 neutrons), charge $+2$
- beta: a fast-moving electron, charge -1

2.5

- nucleon number $210 - 4 = 206$
- proton number $84 - 2 = 82 \Rightarrow {}^{206}_{82}\mathrm{Pb}$

2.6

- $18 \div 6 = 3$ half-lives
- $960 \to 480 \to 240 \to 120$
- 120 **counts/min**

2.7

- any two, each with its reason: reduce the time spent near the source, because the dose received rises with the exposure time; stand further away (use tongs), because the radiation spreads out so the intensity falls with distance; work behind lead shielding, because the lead absorbs the radiation before it reaches the body

3.1 B

- paper stops alpha, so there is no alpha; aluminium stops beta and would not stop gamma, so the source emits beta only
- **A** and **D** would have been blocked by the paper; **C** would still pass through the aluminium

3.2 A

- a neutron becomes a proton, so the proton number rises by one while the total number of nucleons is unchanged
- **C** describes alpha decay

3.3

(a) the reading with the source shut away is the background radiation, which is always present and must be subtracted so the count rate is due to the source alone

- corrected $= 824 - 24 =$ **800** counts/min

(b) $800 \to 400 \to 200 \to 100$ is 3 half-lives

- half-life $= 12 \div 3 =$ **4** hours

(c) a neutron in the nucleus changes into a proton

- and an electron, which is emitted as the beta particle

(d) **no**

- beta passes through smoke without being absorbed, so the current would not change when smoke entered — an alarm needs an alpha source

3.4

(a) ${}^{237}_{93}\mathrm{Np}$ and ${}^{4}_{2}\alpha$

(b) the alpha particles are emitted from the americium

- and collide with (or pass close to) molecules in the air between the plates
- knocking electrons out of them so the air contains ions and conducts

(c) any two, each with its explanation: alpha is easily absorbed by smoke particles, so the current drops as soon as smoke enters, while gamma would pass straight through and the alarm would not respond; alpha is much more ionising, so it makes the air conduct well enough to give a steady current; alpha has a very short range and is stopped by the plastic case, so it is far less harmful to people in the house than gamma would be

(d) the activity stays almost constant for the whole life of the alarm, so it does not need replacing

3.5

(a) gamma is the most penetrating, so it passes out of the body to the detector outside

- alpha would be absorbed within a few centimetres of tissue, giving a large dose to the patient and no signal outside

(b) a 6-hour half-life means the activity falls to a safe level within a day, so the patient's dose is small

- a 6-year half-life would keep irradiating the patient long after the scan

(c) $24 \div 6 = 4$ half-lives

- mass left $= 80 \div 2^4 = 80 \div 16 = 5.0\ \mu$g
- mass decayed $= 80 - 5.0 =$ **75** μg

(d) any two of: cell death; mutation of the genes; cancer