



ANSWER BOOK

Stable and unstable nuclei

Particles · Year 12

AQA 3.2.1.2 · CIE 11.1.6, 11.1.10, 11.1.11 · OCR A 6.4.1(e), 6.4.3(c)

19 questions · 60 marks

NAVY EDITION

SECTION A · Warm-up

- A1** The strong nuclear force holds nucleons together. It is attractive over separations from about 0.5 fm to about 3 fm (1), and becomes repulsive at very small separations (below about 0.5 fm), which stops the nucleus collapsing (1). It is very short-ranged. [2]
- A2** A decreases by 4 (1) and Z decreases by 2 (1). [2]
- A3** A beta-minus particle is a fast-moving electron created in and emitted from the nucleus (1) when a neutron changes into a proton (1). [2]
- A4** The nucleon (mass) number A (1) and the proton number Z, i.e. the charge (1). [2]
- A5** Two protons and two neutrons, i.e. a helium-4 nucleus (1). Notation: ${}^4_2\text{He}$ (1). [2]

SECTION B · Standard

- B1** ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} (1) + {}^4_2\text{He}$ (the alpha particle) (1). Mass numbers: $238 = 234 + 4$ (1); proton numbers: $92 = 90 + 2$ (1). [4]
- B2** ${}^{14}_6\text{C} \rightarrow {}^{14}_7\text{N} (1) + {}^0_{-1}\text{e} (1) + \text{anti-}\nu_e (1)$. Mass numbers: $14 = 14 + 0$; charge: $6 = 7 + (-1)$ (1). [4]
- B3** Beta particles are emitted with a range of kinetic energies up to a maximum, rather than a single fixed value (1). To conserve energy (and momentum) (1), a second, unseen particle must carry away the balance; this was the antineutrino (1). [3]
- B4** Beta-minus decay (1). A neutron becomes a proton, so Z rises by 1 (1) while A is unchanged (a proton and neutron have the same mass number), and an electron is emitted (1). [3]
- B5** Beta-minus: A is unchanged and Z rises by 1, giving A = 214, Z = 84 (1). Alpha: A falls by 4 and Z falls by 2 (1), giving A = 210 and Z = 82 (1). [3]
- B6** Beta-minus decay (1). A neutron changes into a proton (1), so the neutron number falls by one while the proton number rises by one, reducing the neutron excess (1). [3]

B7 The antineutrino carries the difference between the total energy released and the electron's share (1). $E = 0.156 - 0.049$ (1) = 0.107 MeV (1). [3]

B8 $A = 220 - 4 = 216$ (1). $Z = 86 - 2 = 84$ (1). $Z = 84$ is polonium, so X is polonium-216 (1). [3]

SECTION C · Stretch

C1 ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn}$ (1) + ${}^4_2\text{He}$ (1). The radon nucleus has $222 - 86$ (1) = 136 neutrons (1). [4]

C2 At separations below about 0.5 fm the force is strongly repulsive (1). From about 0.5 fm to about 3 fm it is attractive (1), peaking then falling (1). Beyond about 3 fm it is effectively zero (1), because the force is very short-ranged. [4]

C3 The strong force acts only over a very short range, so a nucleon is attracted only to its nearest neighbours (1), whereas the electrostatic repulsion between protons acts across the whole nucleus (1). In large nuclei the long-range repulsion of many protons outweighs the short-range attraction, making them unstable (1). [3]

C4 In beta-minus decay the fixed energy released is shared between the electron and the antineutrino (1), so beta-minus electrons show a continuous spread of energies from near zero up to a maximum (1). A single fixed energy is inconsistent with this, so the electrons cannot be beta-minus particles (1). [3]

C5 Daughter nucleon number $A = 241 - 4 = 237$ (1). Daughter proton number $Z = 95 - 2 = 93$ (1). Neutrons = $237 - 93 = 144$ (1). $144 > 140$, so the claim is correct (1). [4]

C6 Alpha decay: the nucleus emits an alpha particle, two protons and two neutrons bound as a helium-4 nucleus (1). A falls by 4 and Z falls by 2, so a new element two places lower in the periodic table is formed (1). Beta-minus decay: a neutron in the nucleus changes into a proton (1), and a fast electron (the beta particle) is created and emitted together with an electron antineutrino (1). A is unchanged and Z rises by 1 (1). The antineutrino shares the released energy with the electron, which is why beta particles are emitted with a continuous range of energies up to a maximum (1). [6]