



ANSWER BOOK

Constituents of the atom

Particles · Year 12

AQA 3.2.1.1 · CIE 11.1.2, 11.1.3, 11.1.4, 11.1.5 · OCR A 6.4.1(b), 6.4.1(d)

19 questions · 54 marks

NAVY EDITION

SECTION A · Warm-up

- A1** Proton: charge $+1.60 \times 10^{-19}$ C, relative mass 1. Neutron: charge 0, relative mass 1 (1). Electron: charge -1.60×10^{-19} C, relative mass about $1/1836$ (1). [2]
- A2** Specific charge = $Q/m = (1.60 \times 10^{-19})/(1.67 \times 10^{-27})$ (1) [2]
 $= 9.58 \times 10^7$ C kg⁻¹ (1)
- A3** Isotopes are atoms of the same element, so with the same number of protons and the same Z (1), that have different numbers of neutrons and so different mass numbers A (1). [2]
- A4** 63 is the nucleon number A, the total number of protons and neutrons in the nucleus (1). 29 is the proton number Z, the number of protons (1). [2]
- A5** Zero (1). Specific charge is charge divided by mass, and the neutron has mass but no charge, so $Q/m = 0$ (1). [2]
- A6** Carbon dating: the ratio of carbon-14 to carbon-12 in dead material falls with age, so measuring it dates archaeological finds (1). (Accept any valid use, e.g. identifying the origin of a sample from its isotopic signature.) [1]

SECTION B · Standard

- B1** Specific charge = $(1.60 \times 10^{-19})/(9.11 \times 10^{-31})$ (1) [3]
 $= 1.76 \times 10^{11}$ C kg⁻¹ (1)
 Far larger than the proton's, because the electron has the same magnitude of charge but a much smaller mass (1)
- B2** Protons: 6, since $Z = 6$ (1). Neutrons: $A - Z = 14 - 6 = 8$ (1). The neutral atom has 6 electrons (1). [3]
- B3** Charge = $2e = 3.2 \times 10^{-19}$ C (1) [3]
 Mass $\approx 4 \times 1.67 \times 10^{-27} = 6.68 \times 10^{-27}$ kg (1)
 Specific charge = 4.79×10^7 C kg⁻¹ (1)
- B4** Charge = $2 \times 1.60 \times 10^{-19} = 3.2 \times 10^{-19}$ C (1) [3]
 Mass $\approx 16 \times 1.67 \times 10^{-27} = 2.67 \times 10^{-26}$ kg (1)
 Specific charge = 1.20×10^7 C kg⁻¹ (1)

- B5** Number of protons = $Q/e = (4.80 \times 10^{-19})/(1.60 \times 10^{-19}) = 3$ (1). Number of nucleons = $m/m_{\text{nucleon}} = (1.17 \times 10^{-26})/(1.67 \times 10^{-27}) = 7$ (1). $Z = 3$ and $A = 7$, so the nucleus is lithium-7 (1). [3]
- B6** $Q = \text{specific charge} \times m = 2.0 \times 10^{-4} \times 2.4 \times 10^{-15} = 4.8 \times 10^{-19} \text{ C}$ (1). Number removed = $Q/e = (4.8 \times 10^{-19})/(1.60 \times 10^{-19}) = 3$ electrons (1). [3]
- B7** Both nuclei have 17 protons (1). Chlorine-35 has $35 - 17 = 18$ neutrons and chlorine-37 has 20 (1). Chemical properties are set by the electrons, and both neutral atoms have the same number of electrons (17, equal to Z), so their chemistry is identical (1). [3]

SECTION C · Stretch

- C1** Protons: 92 (1)
Neutrons: $238 - 92 = 146$ (1)
Charge = $92e = 1.47 \times 10^{-17} \text{ C}$ (1)
Specific charge = $(92 \times 1.60 \times 10^{-19})/(238 \times 1.67 \times 10^{-27}) = 3.70 \times 10^7 \text{ C kg}^{-1}$ (1) [4]
- C2** Proton: $(1.60 \times 10^{-19})/(1.67 \times 10^{-27}) = 9.58 \times 10^7 \text{ C kg}^{-1}$ (1)
Alpha: $4.79 \times 10^7 \text{ C kg}^{-1}$ (1)
The proton's is greater, by about twice, because the alpha has twice the charge but four times the mass (1) [4]
- C3** Specific charge is charge divided by mass (1). The electron carries the same magnitude of charge as the proton but has a mass roughly 1836 times smaller (1), so its charge-to-mass ratio is far larger than that of the proton or the uncharged neutron (1). [3]
- C4** $Q = 2e = 3.20 \times 10^{-19} \text{ C}$ and $m = 3 \times 1.67 \times 10^{-27} = 5.01 \times 10^{-27} \text{ kg}$ (1). Specific charge = $Q/m = 6.39 \times 10^7 \text{ C kg}^{-1}$, which is about $6 \times 10^7 \text{ C kg}^{-1}$ (1). A helium-4 nucleus has the same charge of $2e$ but one more neutron, so a larger mass (1). The same charge divided by a larger mass gives a smaller specific charge, so helium-3's is the greater (1). [4]
- C5** A singly ionised atom carries charge $Q = e$ (1). Neon-20: specific charge = $e/(20 \times 1.67 \times 10^{-27}) = 4.79 \times 10^6 \text{ C kg}^{-1}$; neon-22: $e/(22 \times 1.67 \times 10^{-27}) = 4.35 \times 10^6 \text{ C kg}^{-1}$ (1). The measured $4.36 \times 10^6 \text{ C kg}^{-1}$ matches the neon-22 value closely but is about 9% below the neon-20 value (1). The ion is neon-22 (1). [4]

- C6** For a nucleus, specific charge = $Ze/(A \times m_{\text{nucleon}})$, which is (Z/A) times the [3]
proton's specific charge e/m_p (1). Every nucleus has $A = Z + N$ with $N \geq 0$, so $Z/A \leq 1$ (1).
The specific charge therefore cannot exceed e/m_p , with equality only for hydrogen-1,
which is a single proton (1).
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