InkPhysics

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)
$= 9.58 \times 10^{7}$ C kg^{-1} (1) [2]

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)
$= 1.76 \times 10^{11}$ 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) [3]

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)
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) [3]

B4 Charge = $2 \times 1.60 \times 10^{-19} = 3.2 \times 10^{-19}$ C (1)
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) [3]

B5 Number of protons = Q/e = $(4.80 \times 10^{-19})/(1.60 \times 10^{-19})$ = 3 (1). Number of nucleons = $m/m_{nucleon}$ = $(1.17 \times 10^{-26})/(1.67 \times 10^{-27})$ = 7 (1). Z = 3 and A = 7, so the nucleus is lithium-7 (1). [3]

B6 Q = specific charge × m = $2.0 \times 10^{-4} \times 2.4 \times 10^{-15} = 4.8 \times 10^{-19}$ C (1). Number removed = Q/e = $(4.8 \times 10^{-19})/(1.60 \times 10^{-19})$ (1) = 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 [4]

Protons: 92 (1)

Neutrons: 238 - 92 = 146 (1)

Charge = 92e = 1.47×10^{-17} C (1)

Specific charge = $(92 \times 1.60 \times 10^{-19})/(238 \times 1.67 \times 10^{-27}) = 3.70 \times 10^{7}$ C kg^{-1} (1)

C2 [4]

Proton: $(1.60 \times 10^{-19})/(1.67 \times 10^{-27})$ (1)

= 9.58×10^{7} C kg^{-1} (1)

Alpha: 4.79×10^{7} 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)

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 = 3.20×10^{-19} C and m = $3 \times 1.67 \times 10^{-27} = 5.01 \times 10^{-27}$ kg (1). Specific charge = Q/m = 6.39×10^{7} C kg^{-1}, which is about 6×10^{7} 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 = $e/(20 \times 1.67 \times 10^{-27}) = 4.79 \times 10^{6}$ C kg^{-1}; neon-22: $e/(22 \times 1.67 \times 10^{-27}) = 4.35 \times 10^{6}$ C kg^{-1} (1). The measured 4.36×10^{6} 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 = $Ze/(A \times m_{nucleon})$, which is (Z/A) times the 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). [3]