inkPhysics

ANSWER BOOK

Energy levels and photon emission

Quantum phenomena · Year 12

AQA 3.2.2.3 · CIE 22.4.1, 22.4.2, 22.4.3
OCR A 5.5.2(a), 5.5.2(b), 5.5.2(c), 5.5.2(d), 5.5.2(e), 5.5.2(f)

19 questions · 57 marks

NAVY EDITION

SECTION A · Warm-up

A1 Each line corresponds to a photon of a definite energy, emitted when an electron falls between two levels (1). Sharp, discrete lines show the electron energies are quantised (only certain values are allowed), not continuous (1). [2]

A2 3.0 eV = $3.0 \times 1.60 \times 10^{-19}$ (1) [2]
= 4.80×10^{-19} J (1)

A3 $hf = E_1 - E_2$ (1), where E_1 and E_2 are the higher and lower energy levels of the transition (1). [2]

A4 The lowest energy level of the atom (1). [1]

A5 The zero of energy is taken as an electron just free of the atom, at ionisation (1). A bound electron has less energy than a free one, since energy must be supplied to remove it, so every level lies below zero (1). [2]

A6 The gas absorbs only photons whose energy exactly matches a gap between two of its energy levels (1). Light of those frequencies is removed from the beam (and re-emitted in all directions), leaving dark lines at those positions (1). [2]

SECTION B · Standard

B1 $\Delta E = (-1.5) - (-3.4) = 1.9$ eV (1) [4]
$\Delta E = 3.04 \times 10^{-19}$ J (1)
(a) $f = \Delta E/h = 4.59 \times 10^{14}$ Hz (1)
(b) $\lambda = c/f = 654$ nm (1)

B2 $\lambda = hc/\Delta E$ (1) [3]
$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8})/(2.55 \times 1.60 \times 10^{-19})$ (1)
$\lambda = 488$ nm (1)

B3 $\Delta E = (-0.54) - (-3.40) = 2.86$ eV (1) [3]
$\lambda = hc/\Delta E$ (1)
$\lambda = 435$ nm (1)

B4 $E = hc/\lambda = (6.63 \times 10^{-34} \times 3.0 \times 10^{8})/(486 \times 10^{-9})$ (1) [3]
$E = 4.09 \times 10^{-19}$ J (1)
$E = 2.56$ eV (1)

B5 Photon energy $E = hc/\lambda = (6.63 \times 10^{-34} \times 3.0 \times 10^{8})/(656 \times 10^{-9}) = 3.03 \times 10^{-19}$ J (1) = 1.90 eV (1). Upper level = -3.40 + 1.90 = -1.50 eV (1). [3]

B6 $\Delta E = (-3.04) - (-5.14) = 2.10$ eV $= 3.36 \times 10^{-19}$ J (1). $f = \Delta E/h$ (1) $= 5.07 \times 10^{14}$ Hz (1). [3]

B7 Photon energy $E = hc/\lambda = (6.63 \times 10^{-34} \times 3.0 \times 10^{8})/(122 \times 10^{-9}) = 1.63 \times 10^{-18}$ J (1) = 10.2 eV (1). The only gap of this size is (-3.40) - (-13.6) = 10.2 eV (1), so the line comes from electrons falling from the -3.40 eV level to the ground state (1). [4]

SECTION C · Stretch

C1 $\Delta E = (-1.5) - (-13.6) = 12.1$ eV (1) [4]
$\Delta E = 1.94 \times 10^{-18}$ J (1)
$\lambda = hc/\Delta E = 103$ nm (1)
which is in the ultraviolet (1)

C2 Three transitions are possible (3→2, 3→1, 2→1) (1) [4]
the three energy gaps are 1.9 eV, 10.2 eV and 12.1 eV, all different, so the three transitions give three distinct lines (1)
The longest wavelength comes from the smallest energy gap, -1.5 to -3.4 eV (1.9 eV) (1)
$\lambda = hc/\Delta E = 654$ nm (1)

C3 Every element has its own distinct set of electron energy levels (1), so the differences between levels, and therefore the photon energies and wavelengths emitted (1), form a pattern unique to that element, like a fingerprint (1). [3]

C4 The three gaps are 1.9 eV, 1.8 eV and 3.7 eV (1). For each, $\lambda = hc/\Delta E$ (1). 1.9 eV gives 654 nm and 1.8 eV gives 691 nm, both within 400 to 700 nm (1). 3.7 eV gives 336 nm, which is ultraviolet (1). The claim is incorrect: two lines are visible but the third is not (1). [5]

C5 Two photons, one for each downward transition (1). The gaps are 1.5 eV and 3.5 eV (1). $\lambda_1 = hc/\Delta E = 829$ nm (infrared) (1); $\lambda_2 = 355$ nm (ultraviolet) (1). [4]

C6 The photon must supply at least 3.40 eV $= 5.44 \times 10^{-19}$ J (1). The maximum wavelength goes with this minimum energy: $\lambda = hc/E$ (1) = 366 nm (1). [3]