InkPhysics

ANSWER BOOK

Collisions of electrons with atoms

Quantum phenomena · Year 12

AQA 3.2.2.2 · CIE 22.1.4, 22.4.1, 22.4.3 · OCR A 4.5.1(d), 5.5.2(a), 5.5.2(d)

19 questions · 55 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Excitation lifts an electron to a higher energy level within the atom (1); ionisation gives the electron enough energy to be removed from the atom completely (1). [2]

A2 $3.4\ \text{eV} = 3.4 \times 1.60 \times 10^{-19}$ (1)
$= 5.44 \times 10^{-19}$ J (1) [2]

A3 $(8.0 \times 10^{-19})/(1.60 \times 10^{-19})$ (1)
$= 5.0$ eV (1) [2]

A4 The minimum energy needed (1) to remove an electron completely from an atom in its ground state (1). [2]

A5 250 eV: an electron gains one electronvolt for each volt of accelerating pd (1). [1]

A6 They are equal, both 100 eV (1). The energy transferred is QV, and the two charges have the same magnitude (1). [2]

SECTION B · Standard

B1 One electronvolt is the energy gained by an electron accelerated through a potential difference of one volt (1). $12.1\ \text{eV} = 12.1 \times 1.60 \times 10^{-19} = 1.94 \times 10^{-18}$ J (1). [2]

B2 $E_k = eV = 1.60 \times 10^{-19} \times 5.0$ (1)
$E_k = 8.00 \times 10^{-19}$ J (1)
$v = \sqrt{(2E_k/m)} = 1.33 \times 10^{6}\ \text{m s}^{-1}$ (1) [3]

B3 Yes: 6.0 eV exceeds 4.9 eV (1), so excitation occurs (1)
The electron loses 4.9 eV, keeping 6.0 − 4.9 = 1.1 eV (1)
$= 1.76 \times 10^{-19}$ J (1) [4]

B4 $E_k = 13.6\ \text{eV} = 2.18 \times 10^{-18}$ J (1)
$v = \sqrt{(2E_k/m)}$ (1)
$v = 2.19 \times 10^{6}\ \text{m s}^{-1}$ (1) [3]

B5 Energy is conserved: the incident electron keeps what is left after paying the ionisation energy and the freed electron's share (1). 12.0 − 10.4 − 0.4 = 1.2 eV (1) = 1.92×10^{-19} J (1). [3]

B6 Visible photon: $E = hc/\lambda = (6.63 \times 10^{-34} \times 3.0 \times 10^{8})/(546 \times 10^{-9}) = 3.64 \times 10^{-19}$ J = 2.28 eV (1). Energy retained = 4.9 - 2.28 = 2.6 eV per photon (1). It is transferred to internal (thermal) energy of the coating (1). [3]

B7 (a) 16.6 V, because an electron gains one electronvolt per volt of pd, so it then carries exactly 16.6 eV (1). (b) $E_k = 16.6 \times 1.60 \times 10^{-19}$ (1) = 2.66×10^{-18} J (1). [3]

B8 Initial kinetic energy = 5.0 eV (1). After two excitations: 5.0 - (2 × 2.1) = 0.8 eV (1) = 1.28×10^{-19} J (1). This is less than 2.1 eV, so the next collision is elastic: the atom absorbs nothing and the electron keeps its kinetic energy (1). [4]

SECTION C · Stretch

C1 Accelerated electrons collide with mercury atoms, exciting or ionising them (1). As the excited atoms de-excite they emit ultraviolet photons (1). These strike the phosphor coating on the tube (1), which absorbs them and re-emits the energy as visible light (1). [4]

C2 The electron carries 12 eV, so both excitations, 4.9 eV and 6.7 eV, are possible (1) [4]
For the 4.9 eV transition: $f = E/h = (4.9 \times 1.60 \times 10^{-19})/(6.63 \times 10^{-34})$ (1)
$f = 1.18 \times 10^{15}$ Hz (1)
$\lambda = c/f$ = 254 nm (1)

C3 The atom can only accept energy in the exact amounts that lift an electron between its energy levels (1). An electron with less than the first excitation energy cannot supply a whole step, so no energy is absorbed (1) and the collision is elastic: the electron continues with its kinetic energy unchanged (1). [3]

C4 $E_k = \frac{1}{2}mv^2 = 0.5 \times 9.11 \times 10^{-31} \times (1.3 \times 10^{6})^2$ (1) = 7.70×10^{-19} J (1) = 4.8 eV (1). This is less than the 4.9 eV needed, so the electron cannot excite the atom: the collision is elastic (1). [4]

C5 Each electron gains a maximum of 6.5 eV from the pd (1). A gas can be excited, and so emit photons on de-excitation, only if the electron's energy reaches its first excitation energy (1). Mercury (4.9 eV) and sodium (2.1 eV) can be excited, so either could emit light (1). Helium (19.8 eV) and neon (16.6 eV) cannot: those collisions are elastic and no photons are emitted (1). [4]