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QUESTION WORKBOOK

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 SCREEN EDITION

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SECTION A · Warm-up

A1 Distinguish between excitation and ionisation of an atom by a colliding electron. [2]

A2 Calculate the energy, in J, equivalent to 3.4 eV ($e = 1.60 \times 10^{-19}$ C). [2]

A3 Calculate the energy, in eV, equivalent to 8.0×10^{-19} J. [2]

A4 Define the ionisation energy of an atom. [2]

A5 An electron is accelerated from rest through a potential difference of 250 V. State its kinetic energy, in electronvolts. [1]

A6 An electron and a proton are each accelerated from rest through a potential difference of 100 V. State and explain how their final kinetic energies compare. [2]

SECTION B · Standard

B1 Define the electronvolt, and express 12.1 eV in joules. [2]

B2 An electron is accelerated from rest through a potential difference of 5.0 V. Calculate its kinetic energy in joules and its final speed ($m_e = 9.11 \times 10^{-31}$ kg). [3]

B3 An atom has a first excitation energy of 4.9 eV. An electron with a kinetic energy of 6.0 eV collides with it and excites it. State whether excitation is possible and calculate the kinetic energy the electron has left afterwards, in joules. [4]

B4 A hydrogen atom has an ionisation energy of 13.6 eV. Calculate the minimum speed an electron must have to ionise it (m_e = 9.11 × 10^{-31} kg). [3]

B5 A mercury atom has an ionisation energy of 10.4 eV. An electron with 12.0 eV of kinetic energy collides with a mercury atom and ionises it. The electron freed from the atom moves away with 0.4 eV of kinetic energy. Calculate the kinetic energy, in J, of the incident electron after the collision (e = 1.60 × 10^{-19} C). [3]

B6 In a fluorescent tube, de-exciting mercury atoms emit ultraviolet photons of energy 4.9 eV. The phosphor coating absorbs each ultraviolet photon and emits a photon of visible light of wavelength 546 nm. Calculate the energy per photon, in eV, retained by the coating, and state what becomes of this energy (h = 6.63 × 10^{-34} J s, c = 3.0 × 10^{8} m s^{-1}, e = 1.60 × 10^{-19} C). [3]

B7 The neon atoms in an indicator lamp have a first excitation energy of 16.6 eV. Electrons are accelerated from rest between the lamp's electrodes. (a) State the minimum pd across the lamp for excitation of neon to be possible, giving a reason. (b) Calculate the kinetic energy, in J, of an electron accelerated through this pd ($e = 1.60 \times 10^{-19}$ C). [3]

B8 In a sodium street lamp the sodium atoms have a first excitation energy of 2.1 eV. An electron accelerated through 5.0 V makes two successive exciting collisions with different sodium atoms. Assume the electron gains no further energy from the field between the collisions. Calculate its kinetic energy, in J, after the second collision, and state what happens when it next collides with a sodium atom ($e = 1.60 \times 10^{-19}$ C). [4]

SECTION C · Stretch

C1 Explain how excitation and ionisation lead to the emission of light in a fluorescent tube. [4]

C2 An atom has excitation energies of 4.9 eV and 6.7 eV. It is struck by an electron accelerated through 12 V. State which excitations are possible, and calculate the wavelength of the photon emitted when the atom de-excites from the 4.9 eV level ($h = 6.63 \times 10^{-34}$ J s, $c = 3.0 \times 10^{8}$ m s^{-1}). [4]

C3 Explain why an electron with less than an atom's first excitation energy passes through the gas without transferring energy to the atoms. [3]

C4 An electron travelling at 1.3×10^{6} m s^{-1} approaches a mercury atom. The first excitation energy of mercury is 4.9 eV. Deduce whether this electron can excite the atom ($m_e = 9.11 \times 10^{-31}$ kg, $e = 1.60 \times 10^{-19}$ C). [4]

C5 The table gives the first excitation energy of four gases: helium 19.8 eV, neon 16.6 eV, mercury 4.9 eV, sodium 2.1 eV. A manufacturer builds a discharge lamp in which electrons are accelerated from rest through a pd of 6.5 V. Deduce which of these gases could emit light in this lamp. [4]