InkPhysics

QUESTION WORKBOOK

The photoelectric effect

Quantum phenomena · Year 12

AQA 3.2.2.1 · CIE 22.1.1, 22.1.2, 22.1.3, 22.1.4, 22.1.5, 22.2.1, 22.2.2, 22.2.3, 22.2.4, 22.2.5
OCR A 4.5.1(a), 4.5.1(b), 4.5.1(c), 4.5.1(d), 4.5.1(e)(i), 4.5.2(a)(i), 4.5.2(b), 4.5.2(c), 4.5.2(d), 4.5.2(e), 4.5.2(f)

19 questions · 58 marks

PRINT EDITION

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SECTION A · Warm-up

A1 State two observations of the photoelectric effect that the wave model of light cannot explain. [2]

A2 A photon has a frequency of 5.0×10^{14} Hz. Taking $h = 6.63 \times 10^{-34}$ J s, calculate its energy. [2]

A3 Define the work function of a metal. [2]

A4 A student shines light of frequency 9.0×10^{14} Hz onto a clean gold surface. Gold has a work function of 8.2×10^{-19} J. Explain, with a calculation, why no electrons are emitted, however intense the light ($h = 6.63 \times 10^{-34}$ J s). [2]

A5 A graph of the maximum kinetic energy of photoelectrons against the frequency of the incident light is a straight line. State what the gradient of this line represents. [1]

A6 Light of a fixed frequency, above the threshold frequency, falls on a metal surface. The intensity of the light is doubled. State and explain the effect of this change on the number of electrons emitted per second. [2]

SECTION B · Standard

B1 A metal has a work function of 3.2×10^{-19} J. Calculate its threshold frequency ($h = 6.63 \times 10^{-34}$ J s). [3]

B2 Light of frequency 8.0×10^{14} Hz falls on a metal of work function 3.0×10^{-19} J. Calculate (a) the maximum kinetic energy of the emitted electrons and (b) their maximum speed ($m_e = 9.11 \times 10^{-31}$ kg). [4]

B3 A photon has an energy of 3.31×10^{-19} J. Calculate the photon energy in electronvolts ($e = 1.60 \times 10^{-19}$ C). [2]

B4 In a photoelectric experiment, electrons leave a metal surface with a maximum kinetic energy of 2.30×10^{-19} J. Calculate the stopping potential, the minimum potential difference across the cell that reduces the photoelectric current to zero ($e = 1.60 \times 10^{-19}$ C). [3]

B5 In a photoelectric experiment a student varies the frequency of the light falling on a metal cathode and plots the maximum kinetic energy of the photoelectrons against frequency. The straight line obtained meets the frequency axis at 4.6×10^{14} Hz. Determine the work function of the metal, in J and in eV ($h = 6.63 \times 10^{-34}$ J s, $e = 1.60 \times 10^{-19}$ C). [3]

B6 Light of frequency 7.5×10^{14} Hz falls on the cathode of a vacuum photocell. The photoelectric current falls to zero when the stopping potential is 0.60 V. Determine the work function of the metal, in eV ($h = 6.63 \times 10^{-34}$ J s, $e = 1.60 \times 10^{-19}$ C). [3]

B7 A green laser pointer emits light of wavelength 500 nm. The beam falls on a caesium surface of work function 1.9 eV. Calculate the maximum kinetic energy of the emitted electrons, in J ($h = 6.63 \times 10^{-34}$ J s, $c = 3.0 \times 10^{8}$ m s^{-1}, $e = 1.60 \times 10^{-19}$ C). [3]

SECTION C · Stretch

C1 A metal has a work function of 2.0 eV. Taking $h = 6.63 \times 10^{-34}$ J s, $c = 3.0 \times 10^{8}$ m s^{-1} and $e = 1.60 \times 10^{-19}$ C, calculate the longest wavelength of light that can release an electron. [4]

C2 Light of wavelength 400 nm falls on the same metal (work function 2.0 eV). Calculate (a) the maximum kinetic energy of the emitted electrons and (b) the stopping potential. [4]

C3 Explain, using the photon model, why increasing the intensity of light of a fixed frequency does not increase the maximum kinetic energy of the emitted electrons. [3]

C4 A student is designing a light sensor that must respond to every wavelength of visible light, from 400 nm to 700 nm. Three photocathode coatings are available: coating X has a work function of 1.4 eV, coating Y 2.2 eV and coating Z 4.3 eV. Deduce which coating the student should choose ($h = 6.63 \times 10^{-34}$ J s, $c = 3.0 \times 10^{8}$ m s^{-1}, $e = 1.60 \times 10^{-19}$ C). [4]

C5 In a vacuum photocell, ultraviolet radiation of wavelength 365 nm and power 2.4 mW falls on the cathode. On average, one photoelectron is emitted for every 120 photons striking the cathode. Calculate the photoelectric current ($h = 6.63 \times 10^{-34}$ J s, $c = 3.0 \times 10^{8}$ m s^{-1}, $e = 1.60 \times 10^{-19}$ C). [5]

C6 A zinc plate is given a negative charge and placed on the cap of a gold-leaf electroscope, so that the leaf rises. When ultraviolet radiation is shone on the plate, the leaf slowly falls. When very bright visible light is used instead, the leaf stays up, however long the light shines. The work function of zinc is 6.9×10^{-19} J. Explain both observations. [6]