AQA AS Photoelectric Effect, Energy Levels and Wave–Particle Duality worksheet

35–40 minutes independent practice + 15–20 minutes review | 39 marks

Specification points covered

• 3.2.2.1(a) Threshold frequency and the photon model. • 3.2.2.1(b) Work function and stopping potential. • 3.2.2.1(c) Use $hf = \varphi + E_k(max)$. • 3.2.2.1(d) Meaning of maximum photoelectron kinetic energy. • 3.2.2.1(e) Stopping-potential method is not required. • 3.2.2.2(a) Excitation and ionisation by electron collision. • 3.2.2.2(b) Fluorescent tubes. • 3.2.2.2(c) Electronvolt–joule conversion.	• 3.2.2.3(a) Line spectra and discrete energy levels. • 3.2.2.3(b) Use $hf = E_1 - E_2$. • 3.2.2.3(c) Energy levels in joules or electronvolts. • 3.2.2.4(a) Electron diffraction as wave evidence. • 3.2.2.4(b) Photoelectric effect as particle evidence. • 3.2.2.4(c) Use de Broglie $\lambda = h/(mv)$. • 3.2.2.4(d) Diffraction and particle momentum. • 3.2.2.4(e) Evidence, peer review and changing scientific understanding.

Orbital materials laboratory

A spacecraft laboratory selects a photoelectric contamination sensor, calibrates a fluorescent coating and studies a graphite battery electrode with electron diffraction.
Connect every observation to an energy-transfer model and show numerical work in SI units.

1. Photoelectric sensor

1. The laboratory illuminates a contamination sensor with ultraviolet light of wavelength 310 nm. Calculate the energy of one photon in joules and electronvolts. [2 marks]

2. The candidate sensor surfaces have work functions: caesium 2.14 eV, magnesium 3.66 eV and zinc 4.31 eV. State which surfaces emit photoelectrons under the 310 nm light and justify each decision. [3 marks]

2. Testing the photon model

3. For the magnesium surface, calculate the maximum kinetic energy of an emitted electron in joules and the stopping potential. **[3 marks]**

4. The intensity of the 310 nm light is increased without changing its wavelength. Explain the effect on (a) the photoelectric current and (b) the maximum kinetic energy of the electrons. **[3 marks]**

5. Calculate the threshold frequency for magnesium. Use its work function from Question 2. **[2 marks]**

6. Electrons in a fluorescent calibration tube collide with gas atoms. Distinguish excitation from ionisation and state what determines whether either process occurs. **[3 marks]**

3. Fluorescent calibration

7. The gas has energy levels 0, 2.10, 3.40 and 5.10 eV above its ground state. An electron with kinetic energy 4.00 eV excites an atom through the largest possible energy change. State the excited level and calculate the electron's remaining kinetic energy. [2 marks]

8. An atom falls from the 5.10 eV level to the 2.10 eV level. Calculate the wavelength of the emitted photon and identify the region of the electromagnetic spectrum. [3 marks]

9. A coating absorbs 4.00 eV ultraviolet photons and emits 2.35 eV visible photons. Calculate the wavelength of the visible light and explain why the emitted photon has less energy. [3 marks]

4. Electron diffraction

10. A beam of electrons produces rings after passing through a thin graphite sample. Explain why this is evidence for wave behaviour and why the photoelectric effect is evidence for particle behaviour of electromagnetic radiation. [3 marks]

11. Electrons of kinetic energy 1.20 keV enter the graphite. Calculate their de Broglie wavelength. Treat the electrons as non-relativistic. [4 marks]

12. The accelerating potential is increased from 1.20 kV to 4.80 kV. Determine the factor change in electron momentum and de Broglie wavelength, and predict what happens to the diffraction-ring diameters. [3 marks]

5. Evaluating the evidence

13. Evaluate the laboratory claim: ‘Electrons are particles, so the diffraction rings must be an equipment fault.’ Use both experiments, the photon and de Broglie models, and the role of repeatable evidence and peer validation. [5 marks]

Review and improve

- ☐ I separate photon energy from photon arrival rate.
- ☐ I use differences between discrete energy levels.
- ☐ I connect diffraction, momentum and de Broglie wavelength.