Topic 22.2 — The Photoelectric Effect

Cambridge International AS & A Level Physics 9702 — Interactive Simulation Worksheet

Name: ____________________ Date: ____________ Class: ________

Constants: $h = 6.63 \times 10^{-34}$ J s $c = 3.00 \times 10^{8}$ m s^{-1} $e = 1.60 \times 10^{-19}$ C $m_e = 9.11 \times 10^{-31}$ kg 1 eV $= 1.60 \times 10^{-19}$ J

Open the photoelectric effect simulation. A vacuum photocell is connected to a variable stopping voltage supply and an ammeter. Use the wavelength slider to change the frequency of light, the intensity slider to change the brightness, and the stopping voltage slider to oppose the electron current. The wires and ammeter glow pink when a current flows.

Section A — Threshold Wavelength

Set intensity to maximum and stopping voltage to zero. Select each metal in turn and increase the wavelength from 100 nm until you find the longest wavelength at which the ammeter just begins to glow pink. This is the threshold wavelength λ_0.

1. Record the threshold wavelength for each metal. Use $\Phi = hc/\lambda_0$ to calculate the work function in eV.

Metal	**Threshold λ_0 / nm**	**$\Phi = hc/\lambda_0$ / J**	**Φ / eV**
Caesium (Cs)			
Potassium (K)			
Zinc (Zn)			
Copper (Cu)			
Gold (Au)			
Platinum (Pt)			

2. Visible light has wavelengths between approximately 400 nm and 700 nm. State which metals emit photoelectrons when illuminated with visible light and explain your answer.

[2]

3. For one metal of your choice, show a full calculation to verify the work function value you recorded in the table.

[2]

Section B — Effect of Wavelength

Select Caesium (Cs). Set intensity to 50% and stopping voltage to zero. Decrease the wavelength from 600 nm down to 100 nm in steps.

4. Describe and explain what happens to each of the following as the wavelength decreases below the threshold:

(a) The photon energy.

[2]

(b) The maximum kinetic energy $E_{k\,\max}$ of emitted electrons.

[2]

(c) The ammeter reading. ★ **Tricky!**

[3]

5. Set the wavelength to 250 nm with Caesium. Now increase the wavelength above the threshold. Describe what happens to the electron emission and explain why the change is abrupt rather than gradual.

[3]

6. Comment on the way photons are represented in the simulation. What does this tell you about the nature of light?

[2]

Section C — Effect of Intensity

Select Caesium (Cs). Set the wavelength to 300 nm and the stopping voltage to zero.

7. Describe what happens to the ammeter reading as the intensity is increased from 10% to 100%, and explain why.

[3]

8. What happens to $E_{k\,\mathrm{max}}$ as you vary the intensity? Explain using the photon model.

[3]

9. A student claims that using a brighter lamp is a good way to emit electrons from a platinum cathode when using UV light at 225 nm wavelength. Evaluate this claim.

[3]

Section D — Stopping Voltage

Select Zinc (Zn). Set intensity to 100% and wavelength to 200 nm.

10. Slowly increase the stopping voltage until the ammeter just stops glowing pink. Record the stopping voltage V_s.

Stopping voltage V_s: ________________ V

11. Show that your stopping voltage is consistent with $eV_s = hc/\lambda - \Phi$. Use $\Phi = 4.30$ eV for Zinc.

[3]

12. Reduce the stopping voltage to half the value found in question 10. What happens to the current, and why?

[2]

13. Without changing the wavelength, switch to Caesium (Cs, $\Phi = 2.10$ eV).

(a) Predict whether the stopping voltage will be larger or smaller than for Zinc. Explain your reasoning.

[2]

(b) Test your prediction and record the result. Was your prediction correct?

[1]

Section E — Examination-Style Questions

14. Light of wavelength 350 nm is incident on a caesium cathode ($\Phi = 2.10$ eV).

(a) Calculate the energy of one photon in joules.

[2]

(b) Calculate $E_{k\,\max}$ of an emitted electron in eV.

[2]

(c) Calculate the stopping voltage required to reduce the photocurrent to zero.

[2]

(d) State and explain what would happen to the stopping voltage if the wavelength were decreased to 280 nm.

[2]

15. A student increases the intensity of light on a copper cathode while keeping the wavelength constant. Describe and explain the effect on: (i) the maximum kinetic energy of emitted electrons; (ii) the rate at which electrons are emitted.

[4]

16. Use the simulation with Gold (Au, $\Phi = 5.10$ eV) at $\lambda = 150$ nm to determine the Planck constant. Record the stopping voltage and show your working.

[4]