

Shine a Light

Purpose

To investigate the nature of the photoelectric effect and determine the work function of an unknown metal

Apparatus

computer

PhET simulation: "Photoelectric Effect" (available at <http://phet.colorado.edu>)

spreadsheet software (Microsoft Excel or equivalent)

Discussion

When light shines on a polished, unoxidized metal surface, electrons can be ejected from the metal. This is the photoelectric effect, a cornerstone of our understanding of light as a particle. When we discuss the particle nature of light, we refer to light particles as "photons." The use of photons to generate an electric signal is used in light-activated circuits and in the soundtrack strip of cinematic films. It was Einstein's explanation of the photoelectric effect, not his work on relativity, that was honored in his Nobel Prize.

Procedure

PART A: EXPLORATION

Step 1: Open the simulation. Set the metal to Sodium and the wavelength to 400 nm. In the Options menu, select "Show photons."

Step 2: Slowly move the intensity slider from 0% to 100% and observe the photoelectric effect. The electrons emitted from the metal are called "photoelectrons." They have the same mass and charge as any other electron.

Step 3: Move the wavelength selector back and forth and observe the results. Try changing the intensity at various wavelengths to see what effect that has.

Step 4: Carefully find the threshold wavelength for sodium. What is the wavelength of the lowest energy light at which electrons are emitted.

Threshold wavelength = _____ nm

Step 5: Use the threshold wavelength (λ_0) to calculate the threshold frequency (f_0). Show the calculation and solution.

Step 6: Use the threshold frequency (f_0) to calculate the work function of sodium. Show the calculation and solution.

Step 7: Set the wavelength to 400 nm and intensity to 100%. Notice the value of the current in the circuit. Adjust the setting on the battery to cut off the current. That is, set the voltage so that the current is just barely brought to zero.

cut-off potential at 400 nm = _____ V

Step 8: Change the wavelength by 100 nm in such a way that current once again flows.

wavelength = _____ nm

PART B: PHOTOCIRCUIT EXPERIMENT

Step 1: Switch the metal to zinc.

Step 2: Find the threshold frequency and the work function for zinc. Record your data and calculations in the space below.

Step 3: From the “threshold frequency arrangement,” set the wavelength to a smaller value by no fewer than 20 nm and no more than 40 nm. Record the new wavelength.

Step 4: Adjust the stopping potential of the battery so that it just barely stops the current. Notice that there are *two* methods for adjusting the potential. Use the method that allows for greater precision. When the condition is met, electrons are ejected from the zinc and *almost* make it to the opposite electrode. But they return to the zinc, and the current remains zero. Record the minimum stopping potential for this wavelength.

Step 5: Repeat the process of reducing the wavelength by 20–40 nm and changing the stopping potential. Mix it up a bit! Record the wavelength.

Step 6: Repeat until you have four data sets.

Step 7: Make an appropriate data table in the spreadsheet software (Excel). Include wavelength λ , stopping potential V , incident photon energy E , and ejected photoelectron energy KE .

- a. What is the equation for photon energy?

- b. What is the equation for the kinetic energy of photoelectron?

Step 8: Make a graph of photoelectron energy vs. incident light frequency.

Step 9: How can the graph be used to determine the value of the work function?

Step 10: What is the slope of the plotted data? What is the value (including units), and what does it mean?

PART C: CALCIUM

Step 1: Change the metal to calcium.

Step 2: Repeat the photo circuit experiment.

Step 3: What are the similarities and differences for the calcium results compared to the zinc results?

GOING FURTHER: MYSTERY METAL

What is the metal labeled “????”? Describe the method used, record appropriate data, and show calculations.