Lab 10
Line Spectra, Particles and Atoms
(Oh My!)

Objectives

(1) To observe the blackbody radiation emitted by objects at different temperatures.
(2) To observe and study the photoelectric effect.
(3) To observe and study the emission spectra produced by hydrogen and other gases.
(4) To observe and study fluorescence.

Equipment

Video camera, hotplates, UV light source, zinc and aluminum surfaces, electric pom pom, plastic rod and fur, diffraction gratings, gas lamps, fluorescent paint, lasers.

Procedure

Part 1: The Photoelectric Effect

Photons hitting a metal surface can cause electrons to be ejected from the surface of the metal. The photoelectric effect will occur if the energy of the photon (hf) is greater than the work function (W₀) of the metal. In this station, you will determine whether ultraviolet (UV) light will cause electrons to be ejected from an aluminum surface.

(1) The UV light source produces two different wavelengths of light, 365 nm and 254 nm.

a) Calculate the energy in electronvolts (eV) of each of the two wavelengths emitted by the UV light source. Record your calculations.

(2) The work function of aluminum is W₀ = 4.1 eV.

b) Predict whether each wavelength of UV light will cause electrons to be ejected the aluminum surface. Record your predictions along with a brief explanation.

(4) Place the aluminum surface on top of the electric pom pom. Use the plastic rod to charge the strings of the pom pom so that they repel each other.

(5) Shine the UV light with wavelength set to 254 nm on the aluminum surface.

(6) Charge the strings of the pom pom again and then shine the 365 nm light on the aluminum surface.
c) What did you observe when each wavelength of light illuminated the aluminum surface?

d) Explain your observations in terms of the photoelectric effect.

e) Were any of your predictions incorrect? Explain.

Part 2: Light Spectra of Hydrogen

Whenever an electron in an atom jumps from a higher energy state to a lower energy state, a photon of light is emitted. The energy of the photon \((hf)\) is equal to the difference between the energy levels of the atom \((E_i - E_f)\). Each kind of atom has a unique set of energy levels. This means that each element can only emit specific frequencies of light called its line spectra. In this station, you will calculate and observe the line spectra of hydrogen gas.

(1) The energy levels of the hydrogen atom are given by:

\[
E_n = -\frac{E_1}{n^2} = -\frac{13.6\, eV}{n^2}, \quad n = 1, 2, 3, ...
\]

Use the above formula to calculate the wavelengths of light emitted by hydrogen that fall within the visible portion of the spectrum (400 – 700 nm).

f) Record your wavelengths as well as the energy level transitions responsible for each wavelength (i.e. \(n = 3 \rightarrow n = 2\)). For each wavelength, also predict what color the light will appear.

(2) Use the diffraction grating to observe the line spectra emitted by hydrogen gas.

g) Did you see all of the lines that you expected to see? Explain.

Part 3: Light Spectra of Other Gases

As stated above, each element can only emit specific frequencies of light. Astronomers use this fact to determine what a star is composed of (i.e. H, He, C, …) by observing the spectrum of light emitted by the star. In this station, you will play astronomer and determine what type of gas is contained in each of three gas lamps.

(1) Use a diffraction grating to observe the spectra of each of the three different gas lamps.

h) Sketch the spectra for each of the three different gas lamps.

i) Using the chart of different line spectra, identify what kind of gas is in each of the three lamps.
Part 4: Fluorescence

Fluorescence occurs when an atom absorbs light at one frequency but then emits light at lower frequencies. For example, an atom can absorb a UV photon and jump to a higher energy state. Rather then jumping directly back to the initial energy state (and emitting the same energy UV photon), the atom can make several smaller jumps and emit lower energy photons (such as visible light). This is how black lights work. In this station, you will observe the light emitted by different fluorescent paints that are illuminated by different frequency lasers.

(1) Shine the red laser onto each of the three different color fluorescent paints (green, red, and yellow). Use a diffraction grating to observe the spectra emitted by each paint.

(2) Shine the green laser onto each of the three different color fluorescent paints (green, red, and yellow). Use a diffraction grating to observe the spectra emitted by each paint.

(3) Shine the blue laser onto each of the three different color fluorescent paints (green, red, and yellow). Use a diffraction grating to observe the spectra emitted by each paint.

j) Which color paints does the red laser cause to fluoresce? Which color paints does the green laser cause to fluoresce? Which color paints does the blue laser cause to fluoresce?

k) Can you come up with a general rule for which color laser will cause which colors of paint to fluoresce? Explain your reasoning in terms of fluorescence and photon energies.