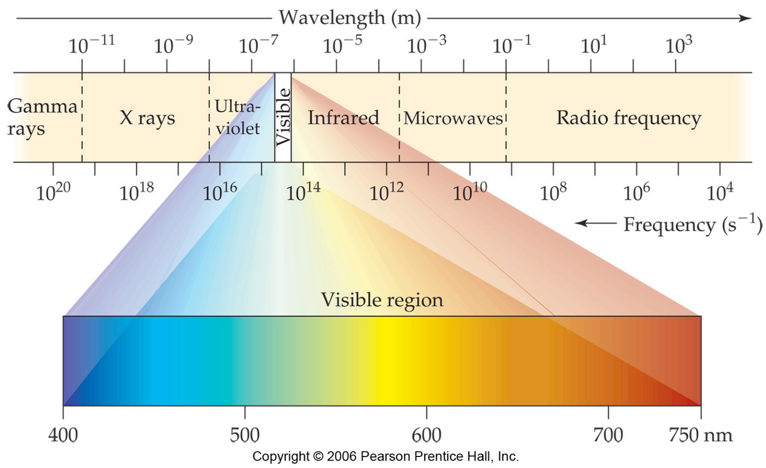
Lab 8: Light and the Electronic Structure of an Atom

Light, or **electromagnetic (EM) radiation,** is described in your text (and shown below) as having a specific wavelength/frequency/energy. Due to the differences in the energy of light, the EM spectrum is divided into the following groups: gamma rays (highest energy), X-rays, ultraviolet, visible, infrared, microwave, and radio radiation (lowest energy).



During this experiment you will gain experience with the visible portion of the EM spectrum and, by analogy, an understanding of other parts of the EM spectrum. In this activity you will:

- Use mathematics to describe the relationship between the wavelength, frequency, and energy,
- Separate "white" light into its colored components,
- See how "white" light interacts with colored solutions,
- Examine the transmission and absorption of light by a colored solution,
- Examine the visible **spectra** from several common sources of light, and
- Study the "flame emission spectra" of several elements, and

Background:

During this laboratory, you will use a **visible spectrophotometer**. A spectrophotometer is an instrument that is used to "apply" light to a sample of interest. Light, described by the wavelength (or frequency or energy), interacts with the sample providing information about the sample.

A visible spectrophotometer consists of a light source, a wavelength selector (a grating or prism), a sample, and a detector. Figure 1 illustrates the configuration of these parts:

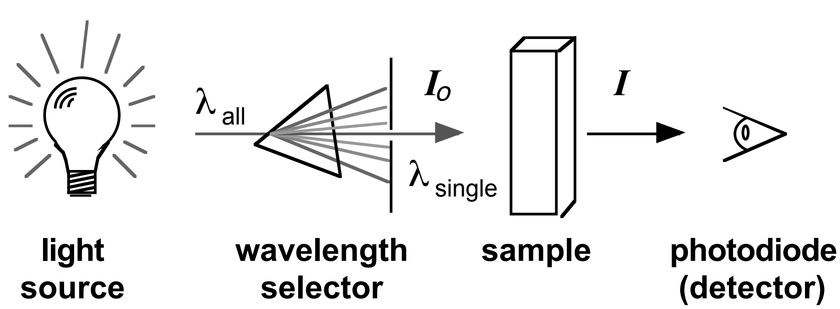


Figure 1. Spectrophotometer.

The following is a description of how the spectrophotometer works; please read carefully.

A single wavelength of light (λ_{single}) generated by the **light source** is selected from all wavelengths generated (λ_{all}) by rotating a **wavelength selector**. The intensity of λ_{single} is denoted I_o. λ_{single} passes through the **sample** and is detected by the **photodiode**. If the sample absorbs any λ_{single}, then intensity of the light coming from the sample (I) will be different then the incident light intensity (I_o). The spectrophotometer can present data either as "transmittance" or "absorbance." Consider a situation where a sample absorbs the majority of the incident light (I_o); the amount of light transmitted (I) is close to zero. Under these conditions, we would say that due to the sample, very little light was "transmitted". We could also say that the sample "absorbed" most of the incident light.

We define the % transmittance (%T) as: $\%T = \frac{I}{I_0} \text{ x } 100$, where I and I_o are defined above.

We define the absorbance (Abs) as: $Abs = -\log\frac{I}{I_0} = 2 - \log\%T$

Procedure

Please prepare your lab notebook by entering the header information and purpose.

<u>Experiment I : Emission Spectra</u>

The first part of this experiment will be done by the instructor. At the front of the lab there will be multiple light sources: 1) a tungsten bulb, 2) a fluorescent tube, 3) mercury "lamp," and 4) LEDs. Other light sources will be presented.

<u>Experiment 2: Emission Spectra of Atoms</u> (work in pairs or small groups)

In this experiment you will observe the emission spectra for a variety of atoms. In this experiment you will observe the emission spectra using the "flame excitation" method. The procedure will be demonstrated. As always, enter your observations in your lab notebook, under a proper heading (see below).

Observing the emission spectra

The solutions for testing will contain the following metals: barium (Ba), boron (B), calcium (Ca), copper (Cu), lithium (Li), potassium (K), sodium (Na), and strontium (Sr). Please indicate the full chemical name and formula in your notebook, but also be aware that the observed emission spectrum is from the metal atom (the cation) only. Write down your **observations concerning the colors of the flame** resulting from each of the metal ions. You may want to repeat some of the metals more than once.

Identification of unknown metal ion.

Go ***independently*** to a station where an unknown is setup. Write the unknown number in your lab notebook. Show your lab notebook to the TA in order to check results. When you have correctly identified an unknown…independently…your TA will initial your notebook indicating that you have correctly identified the unknown; if you fail to identify the correct metal, return to collect additional data. Re-check your results with the TA until the metal has been identified.

Experiment 3: Determining the Color of the Wavelengths (work in groups of 3-4)
In this activity, you will observe the color of the light selected by the spectrophotometer and record this information in your lab notebook. Consider re-reading the Background information above about the spectrophotometer.

Place the cuvette with the white plastic (in the bottom) in the spectrophotometer and set the wavelength at **560 nm**. ***Please note that this is NOT the normal type of sample used in the spectrophotometer; this white plastic is use to reflect the light for demonstration purposes.***

- Look down into the cuvette to observe the **white plastic** and the reflected light (ie. light of 560 nm). Adjust the plastic if necessary to maximize the reflected light.

- Have each group member observe the reflected light and allow each to record their observations [make a table with two columns: wavelength (nm) and color observed].

- Now change the wavelength to 520 nm and allow all members to observe and record. Repeat for the following wavelengths; 480, 440, 400 nm, and then 600, 640, 680, 720 nm. If the reflected light is not observed, make note in your lab notebook.

- Do you see ROY G. BIV?

Experiment 4: Collecting a Absorption Spectrum of a Colored Solution (work in groups of 3-4)
An absorption spectrum is a plot of wavelength vs. absorption. In this activity you will collect data that will be plotted later to make an absorption spectrum.

- There are **two clean cuvettes** in a beaker by the spectrophotometer.

- Fill one with **deionized water** (this is the BLANK – used to determine the I_o value for EACH wavelength) and put in the spectrophotometer; set the wavelength selector set at 400 nm.

- Press the "**100% T/0 Abs"** button to "zero" the spectrophotometer**.** This is a critical step that defines in the instrument the incident light (I_o). This I_o value will be stored in the computer of the spectrophotometer and will be used to present the absorbance or transmittance value. If you have any problems, see the instructor or TA for assistance. (*Save the cuvette filled with water because you'll need to calibrate the spectrophotometer at every wavelength you measure. This is because the intensity of the light source and the sensitivity of the detector vary with wavelength*).

- Fill the **second cuvette** with the **colored solution** (**RED OR BLUE**).

- Place the cuvette with the colored solution in the spectrophotometer and measure the % transmittance (%T) at 400 nm. Make a table in your notebook to organize this data and the data to follow.

- Change the wavelength to 440 nm, ***blank the spectrophotometer with DI water,*** and again measure %T; record the data in your notebook.

- repeat the absorbance measurement for wavelengths up to 720 nm at 40 nm increments.

- Obtain the %T data (from another group) for the other solution (red or blue).

******Now, request an "example" of this weeks Reporting Sheet…instructions******

Setup information

- in lab setup (done by instructor)
    - lamps: tungsten, fluorescent, mercury, sodium
    - emission tubes (if desired) mercury, hydrogen, neon
    - Ocean Optics spectrometer (if desired) with computer software.

- Need spectrophotometers
- cuvette with white plastic piece to reflect light (can use chalk if necessary)

- need two clean cuvettes in a small beaker for Exp 4 (absorption spectrum)
- need a red and blue solution (food coloring okay) at a concentration useful to make an absorption spectrum…the red and blue spectra will be plotted on the same graph so, please make these solutions with ~ the same absorbance.

- need nichrome wire connected to glass rod
- need ~500 ml of 1.0 M HCl for cleaning wires.
- need salt solutions with the following cations:
    barium (Ba),
    boron (B),
    calcium (Ca),
    copper (Cu),
    lithium (Li),
    potassium (K),
    sodium (Na), and
    strontium (Sr).