Experiment 5: Spectrophotometric Study of Colored Solutions

Chemistry 110 Laboratory
Prelab Lecture

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What is the purpose of this lab?

In this lab we're going to try to understand the relationship between the color of a substance and the wavelengths of light that are absorbed by the substance.

Why is this important?

There are two primary reasons. One is simply that it can help us understand the greenhouse effect that makes our planet habitable, and the enhanced greenhouse effect which leads to global warming. Although the light involved in the greenhouse effect is in the infrared, while the light we'll use in this experiment is in the visible, the principles are the same.

Another reason is that a graph of the amount of light absorbed as a function of the wavelength (color) of the light is often used to identify molecules. This is a technique that's frequently used to identify pollutants, and to determine their concentrations, both in water and in the air. In fact, this is one of the techniques that Professor Stevenson uses in his research.

Is there a special name for the graph of light absorbed versus wavelength?

The graph is called a spectrum, and the technique of collecting the data and plotting it is called spectroscopy.

What do we actually measure in spectroscopy?

We measure two characteristics of the light that's absorbed. One is called the wavelength of the light absorbed. The wavelength of the light is the distance in nanometers (10^{-9} meters) between the peaks of the waves.

The second is called the intensity of the light absorbed. The intensity of the light absorbed is simply how much of the light is absorbed.

What is visible light?

Visible light is that portion of the electromagnetic spectrum that we can see. Other portions include the infrared (longer wavelengths than red light and the part of the spectrum responsible for the greenhouse effect), and ultraviolet (shorter wavelengths than violet light and responsible for tans, sunburn, and skin cancer), which are invisible. Visible light has wavelengths between about 650 nm and about 420 nm. Visible light when passed through a prism or bounced from a grating can be broken down into its component colors, the colors of the rainbow. The order of these colors from longest to shortest wavelength is given by the mnemonic device

ROY G BIV

for Red Orange Yellow Green Blue Indigo Violet. One of your tasks today will be to assign wavelength ranges for each of these visible colors.

How are frequency and intensity measured?

With a device called a spectrophotometer. A spectrophotometer has the following components:

1. A light source.
2. A light dispersion device (a prism or grating)
3. A pair of slits (to select among the dispersed wavelengths)
4. A sample cell
5. A detector of some sort.

How does a spectrometer work?

It works by comparing the amount of light detected when the sample is there (I) with the amount of light detected when the sample is not there (I^0). A small computer within the spectrometer then converts this to either Transmittance (%T) or absorbance (A).

%T is defined as $\%T = \frac{I}{I^0} x100\%$

[Show a graph of transmittance vs wavelength and show what it looks like when lots of light comes through and when little light comes through.]

A is defined as $A = \log\left(\frac{I^0}{I}\right)$.

Does spectroscopy work equally well for all samples?

The experiment tends to fail if the sample absorbs too much light. How much is too much depends on the spectrophotometer. The ones that we are using are completely unreliable for samples that absorb more than 99% of the light. In order to make sure that our results are reliable we'll limit our experiments to samples that absorb 90% or less of the light at the point where the most light is absorbed, i.e., that have % transmittance of 10% or greater.

What do we do if our sample has a minimum transmittance that is less than 10%?

We dilute our sample until the minimum transmittance is greater than 10%. We've already done this for your red, blue and green food coloring solutions, but you may need to do this yourselves for the samples you brought in.

Experimental Tips

Part I: Determine the wavelength range for each color.The chalk pieces are precut for you and are already rubbed to give the correct angle. Open up the sample compartment and place the tube with the chalk in it, and then follow the directions in part I.

The only thing that I want to you to do differently is to write down the range of wavelengths that correspond to each color. I.e., since there is not just one wavelength that appears red, you should write down the first and last wavelengths that appear red, the first and last that appear orange, and so on.

You may need to turn the lights out or down to be able to properly see some of the colors.

Part II and IV

i. The directions on how to use the spectrometers are next to the spectrometers.
ii. Follow the directions in the manual for the spectra of the red and blue solutions.
iii. Use the plastic cuvettes.
iv. The cuvettes should be filled just over ½ full.
v. Note – it's tedious, but after moving to each new wavelength, you need to put the cuvette with the water into the spectrometer and press the 100%T button.
vi. To make your measurements more efficient, take 3 cuvettes. Put water in one, red solution, and blue solution in two others. Then collect the data for both the red and blue together. Then quickly graph these two spectra, and predict where the green solution will absorb. Then take the spectra for the green solution and the sample you brought as in 1 above.
vii. To find the minimum transmittance (the most strongly absorbed light): graph a smooth line of the %T vs wavelength. Sketch this in your notebook before doing it on the report.
viii. After collecting the spectra for all four samples you may need to go back and redo your unknown after diluting the sample, if the minimum transmittance is less than 10%. To test if the minimum transmittance is acceptable at the new dilution, set the spectrophotometer to the wavelength at which the minimum transmittance was found, and keep making measurements at that wavelength until the transmittance is higher than 10%. Then take the full spectrum.

Lab Report

The lab report will consist of the data sheet on page 35, the graphs on pages 37 - 40, and the answers to the questions on page 34. Make sure that you answer the questions associated with each graph.