Atoms and Light

1.0 Introduction

Early in the exploration of the nature of atoms, scientists determined that atoms interact with the various forms of electromagnetic radiation (light). Atoms absorb and emit various forms of light on a continual basis. This is the principle that lies behind the production of x-rays, the colors of neon lights and MRI units in hospitals. In fact, our ability to see color is nothing more than our detection that various wavelengths of visible light have been absorbed while other wavelengths have been transmitted or reflected.

In this experiment we will study the absorbance of various wavelengths (colors) of visible light. The scientific instrument that allows us to accurately measure the amounts of light that a substance absorbs (or emits) is often called a “spectrometer”. It takes a spectrum (range) of something and measures (meters) it. A photo spectrometer is a light measuring instrument. Sometimes a visible light spectrometer is called a “colorimeter” – that is, it measures color or various wavelengths of light. The scientist who takes various spectra (plural of a spectrum) with a spectrometer is often called a spectroscopist. So a spectroscopist studies the spectroscopy of various substances with spectrometers. What a tongue twister!

Today we will use a simple visible spectrometer to measure the absorbance of some colored liquid samples. The liquids have a color because they absorb certain wavelengths of light and allow others to be transmitted. We will measure the absorbance of each of three samples to see how the color of the sample is related to the light it absorbs. Then we will dilute one of the samples to see how absorbance is related to the concentration of the sample. Perhaps you can already guess how these factors are related to one another? If not, you are about to learn more.

2.0 Procedure

Spectrometers will be set up in the lab labeled RED, GREEN and BLUE. That is each spectrometer has been set to a wavelength within these color ranges. The actual wavelengths in nm are 635 nm for red, 515 nm for green and 470 nm for blue. Notice how the wavelength shortens as light goes from red to blue. In order to make each sample measurement two cuvette sample tubes are needed, one for a “blank” and one for the sample to be measured. The blank is always measured first to zero the spectrometer. This essentially means that the instrument will adjust for the absorbance of the tube and solvent so that when the sample is measured only the substance that is added to the solvent will be measured. In this case the blank tube will contain DI water.

In the first cuvette tube fill the tube about 2/3 full of DI water. This blank will be used throughout the experiment. Fill the second cuvette tube 2/3 full of the red liquid. Measure the absorbance of this red liquid in all three spectrometers (RED, GREEN and BLUE). For each measurement, first place the blank in the instrument and zero the spectrometer. Usually there is a zero button to press. Next place the sample tube in the spectrometer and record its absorbance reading. For each reading align the tube the same way and close the sample cover before taking the reading. Do you notice any change in the absorbance of light by the sample? Does the red liquid absorb much of the red light?

Repeat this procedure for the green and the blue liquids. If several cuvette tubes are available you can use a fresh tube, otherwise rise the sample tube and place the new colored liquid in it. Always keep the blank the same.

Remove the sample cuvette and fill it 2/3 full with the red liquid. The use of caps on the cuvettes are strongly encouraged so liquids do not get spilled, particularly into the colorimeter unit. Place the cuvette in the S slot, close the lid and record the absorbance reading for the red liquid. Now repeat the measurement for the green and the blue liquids. Clean the cuvette and fill it 2/3 full with each liquid in turn and place the cuvette in the S (sample) slot. Close the lid and once the reading is steady on the screen record the absorbance for the green and then the blue liquids.

When you have completed this procedure you will have nine absorbance measurements – a set of three for each of the three colors of liquid. Now let's measure the effect of the sample concentration on the absorbance. To do this we will do a series of dilutions on one of the colored liquids and take absorbance readings for each of the samples. Select one of the colored liquids since we will only work with one liquid this time. For the liquid that is selected, use the spectrometer that gave the highest absorbance value in the previous set of measurements made on the liquids.

First, read the absorbance again for your undiluted liquid. Use the blank to zero the spectrometer and then measure the sample. Next, carefully add 9 mL of the liquid to a graduated cylinder followed by 1 mL of water. This will be a 10 % dilution so the concentration is 90%. Pour this solution into a beaker, swirl to mix well then fill a cuvette and take the absorbance reading.

Next measure 8 mL of the original liquid and add 2 mL of water. Pour this solution into a beaker, swirl to mix well then fill a cuvette and take the absorbance reading.

This is a 20% dilution or 80% concentration. Measure and record its absorbance.

Next measure 7 mL of the original liquid and add 3 mL of water. Pour this solution into a beaker, swirl to mix well then fill a cuvette and take the absorbance reading. Follow this by 6 mL of the original and 4 mL of water. Record all of the absorbance values for this series.

3.0 Before You Leave

Before you leave the lab for the day you should clean up your glassware rinsing each piece with DI water. Also clean your work area including water spills. The solutions are only food coloring and water so they can go in the sink. Make sure to put away all of your equipment and you can go for the day.

4.0 Absorbance Analysis

For each of the colored liquids find the color of light that was most and least absorbed. Can you explain these results?

For the series of absorbance values we can call the concentrations 60, 70, 80, 90 and 100. This happens to be the % that each is of the original concentration. In order to see how these really relate to each other we should make a graph of absorbance vs concentration. In order to plot the data, you can use the least squares program on the computers at school or even download the program from the CSM chem. lab website for use at home. How does the absorbance of light relate to the concentration of each sample?