Colorimetry: Quantitative Analysis with Light (#2.1)

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Learning Objectives

To learn to match the observed spectra of colored solutions with spectrophotometric charts of percent transmission and wavelength.

To learn to predict the visible results of color mixing.

To learn to make a set of solutions of known concentrations by dilution of a standard.

To use colorimetry to determine the concentration of an unknown colored solution.

To colorimetrically determine the concentration of chlorine in pool and tap water samples.

Background

Color is something that almost all of us take for granted. Many of us believe that color is something that is emitted by "colored" substances. Color, however, is caused by exactly the opposite effect. White light consists of all colors of the visible spectrum from violet to red. Colored substances selectively absorb some of the colors comprising the white light, and ultimately turn it into heat. The remaining colors of light are reflected or transmitted by the sample, and we see them as the "color" of the material.

Chemists have learned to use this selective absorption of light to quickly determine the concentration of solutions of colored substances. If light of a color (or wavelength) absorbed by a material is passed through a sample, the amount absorbed will be proportional to the number of colored light-absorbing molecules in the light beam. This phenomenon can be used to determine the concentration of unknown samples. Analytical chemists, routinely use this technique for determination of concentration of various materials in inorganic and biological samples. For example, the concentration of iron in blood samples is almost always determined colorimetrically.

This experiment is comprised of three sections, as follows:

1. The Formation of Color

Using an overhead projector, the laboratory instructor will show the band spectrum of blue, green, yellow and red food dye solutions, along with a solution of $KMnO_4$, to help students see which colors of light are absorbed and transmitted by each solution.

2. Spectral Transmission Charts

Students will use the ***MicroLAB*** **Colorimeter** to produce charts which correlate percentage transmission with color and wavelength, similar to Figure 1. Students will try to identify the color for each chart from their experience in Part I and the spectrum profile.

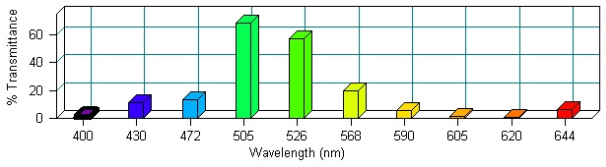

Figure 1. A % transmission sample Spectrum Profile for green food dye. The colors of the wavelength bars and their relative height help students to relate to the color of the solution.

Using the ***MicroLAB*** **Color Mixer** program, students will scan in blue, green, yellow and red food dye solutions, and use this program to determine if a mixture of the blue and yellow solutions has the same spectral profile as that of the green food dye solution.

3. Colorimetry

Colorimetry, the measurement of the concentration of solutions by measuring their absorbency of colored light, is quick, clean and quite accurate.

If blue light were transmitted through a blue solution (which is appears blue because it transmits blue light), there would be little absorption. However, if blue light is transmitted through a solution containing blue

light absorbing particles, each time a photon of blue light struck a blue-light absorbing molecule, it would be absorbed. Thus the number of photons of blue light that will make it through the solution is inversely proportional to the number of blue-light absorbing molecules in the light beam. More blue light-absorbing molecules can be obtained by making the sample container longer, **OR**, for the solution to be more concentrated.

The absorption of blue light is not linearly related to the number of light absorbing molecules in the beam. Figure 5 shows four examples of this. In example (a), a cell is present with sufficient blue light absorbing molecules to decrease the light intensity falling on the photocell to 50% of the incident light. In example (b), two cells of the same solution have replaced the original cell, each cutting the transmitted light by 50 % and thus cutting the photocell light intensity down to 25%. In example (c) a third cell containing the same blue solution is placed in the beam. This cell again absorbs half of the blue light that strikes it, resulting in 12.5 % of the initial light falling on the photocell.

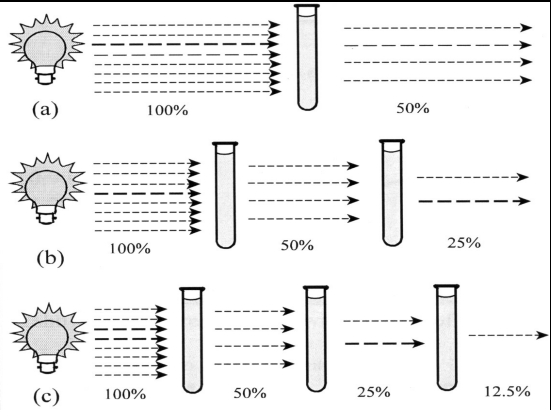

Figure 2. Cartoon showing the relationship between increased amount of absorbing molecules in the light path and decrease in the light intensity on the photocell.

A graph of the results from such an experiment is illustrated in Figure 3. Students are led to manipulate the data to produce the linear graph similar to Figure 4.

Students produce Beer's law plots from standard solutions of a food dye solution, then analyze an unknown food dye solution.

They will also produce a Beer's law plot for standard chlorine solutions in the range of 0 to 5 ppm, and then analyze tap water and pool water for their free chlorine content.

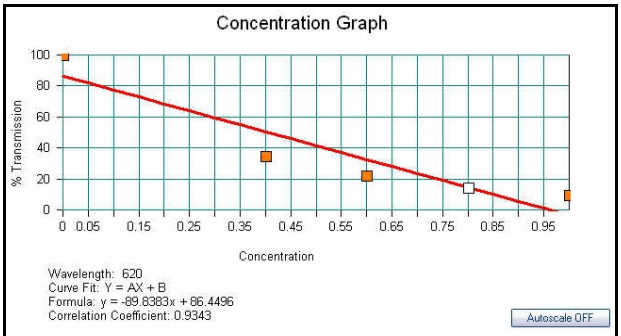

Figure 3. A Beer's law plot in percent transmission of a blue food dye solution showing the non-linearity of the data. The white square represents the particular standard measurement that was highlighted at the time.

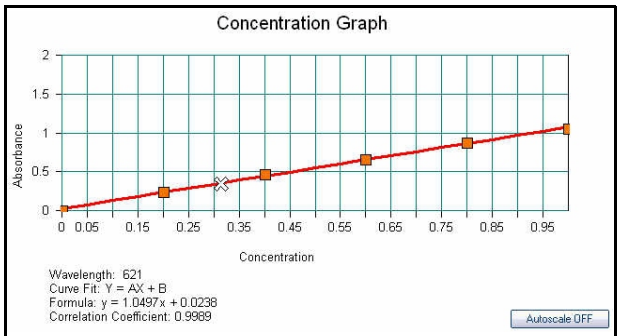

Figure 4. An absorbance Beer's Law plot showing the linearity of the data in this format. The X on the regression line represents the absorbance-concentration location of an unknown.

Instructor Resources Provided

1. Sample Report Sheets providing the format to organize the data collection with sample data.
2. Questions to consider, answer and turn-in with suggested answers.
3. Tips and Traps section to assist the instructor with potential problems and solutions.
4. Sample ***MicroLAB*** screen shots and graphs.
5. Laboratory preparation per student station.

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