Colorimetry: Quantitative Analysis with Light

INSTRUCTOR RESOURCES

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Learning Objectives

The purpose of this experiment is to . . .

- Learn to match the observed spectra of colored solutions with spectrophotometric charts of percent transmission and wavelength.
- learn to predict the visible results of color mixing.
- learn to make a set of solutions of known concentrations by dilution of a standard.
- use colorimetry to determine the concentration of an unknown colored solution.
- colorimetrically determine the concentration of chlorine in pool and tap water samples.

Procedure Overview

- the observed spectra of colored solutions projected on the screen by an overhead projector are matched with ***MicroLAB*** Spectrum Profiles of percent transmission and wavelength

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- Observe the origin of color using colored solutions and predict the visible results of color mixing
- make a set of five standard food dye solutions of known concentrations by dilution of a given standard.
- Beer's law is derived and used to determine the concentration of an unknown colored solution.
- colorimetrically determine the concentration of chlorine in pool and tap water samples.

Colorimetry: Quantitative Analysis with Light

Report Sheet

1. From the projected spectra of the five colored solutions, and comparison with the five unidentified color spectra profiles in the experiment text, identify the color of each spectrum profile.

Colored Solution	**Spectrum Profile Sample Number**
Red food color	
Yellow food color	
Green food color	
Blue food color	
Potassium permanganate	

2. Complete the following table of your experiment on mixing colors. There are ten possible combinations. For each one, draw in the predicted profile **BEFORE** you electronically do the mix, then draw in the actual profile after mixing, then place the two vials one in front of the other, hold them up to the light and describe the color you observe. Discuss the color with your partner. Be sure to print out the profile of each mixture, following the instructions given in **Note 1** of your experiment.

First color	Second color	Predicted Profile	Actual Profile	Observed color
blue	yellow			
blue	green			
blue	red			
blue	KMnO4			
yellow	red			
yellow	green			
yellow	KMnO4			
red	green			
red	KMnO4			
green	KMnO4			

Colorimetry: Quantitative Analysis with Light

Report Sheet (page 2)

3. Complete the following table for the food coloring standard solutions, the linear curve fit equation, correlation value and the results for your unknown for inclusion in your report.

Food Color Data	Concentration	Percent Transmission	Absorbance
Standard 1 (Blank)	0		
Standard 2	2		
Standard 3	4		
Standard 4	6		
Standard 5	8		
Standard 6	10		

Equation: Conc. = **Correlation**:

Food Color Unknown	Percent Transmission	Absorbance	Concentration
unknown K	44.4	0.353	4.41

4. Complete the following table for the chlorine standard solutions, the linear curve fit equation, correlation value and the results for your tap and pool water samples for inclusion in your report.

Chlorine data	Concentration	Percent Transmission	Absorbance
Standard 1	0		
Standard 2	2		
Standard 3	4		
Standard 4	6		
Standard 5	8		
Standard 6	10		

Equation :Conc. (ppm) **Correlation:**

Chlorine Unknowns	Percent Transmission	Absorbance	Concentration
Pool water	34.5	0.462	3.703
Tap water	73.1	0.136	1.064

Colorimetry: Quantitative Analysis with Light

Tips and Traps

1. **Overhead projector color spectra:** The holographic diffraction grating used to obtain the spectrum of the colored solutions can be obtained from Edmond Scientific, internet address http://scientificsonline.com/product.asp_Q_pn_E_3054509, catalog number 3054509, sheet size: 12" x 6" (Set of 2) for $7.95. One of these, cut to 4" by 4", is mounted on a heavy cardboard frame with a 3" by 3" hole cut out of the middle, which is attached to the projection lense of the overhead projector with large rubber bands. A black felt cloth large enough to cover the entire projection surface of the projector has a section cut out of the middle about 1" by 3" over which is placed a divided petri dish containing one of the food colors in one half of the dish. Each food color solution should contain enough of the food coloring in 100 ml such that the absorption spectrum is clearly visible in the projection on the screen, but not so concentrated that a good spectrum does not show. The five petri dishes can then be rotated back and forth so that the students can qualitatively see which regions of the spectrum are absorbed out for each color. They are then required to identify the colors of the five sample spectrum profiles shown in Figure 3 in their experiment.

2. Students should be lead through a sample mixing with the **Color Mixer Experiment** program, using an LCD projector, if that is possible. It helps them immensely to be able to see an example first before they are required to do it on their own, even though all of the instructions are in their experiment.

3. It is also very helpful to demonstrate the **Colorimeter Experiment** program in the same manner.

4. The food coloring solution to be used for the Colorimetry experiment should be mixed in sufficient volume that there is at least 50% more than expected usage. In addition, the concentration of the entire volume should be adjusted so that the absorbance is about 1.20 on the ***MicroLAB***.

5. The chlorine standard solution should be mixed at 5 ppm so that it will exceed the expected range of zero to 3 ppm. Assume fresh bleach is 5% NaOCl and final solution density is 1.00 g/ml.

$$\frac{5 \text{ X } 10\text{-}3 \text{ g NaOCl}}{1.00 \text{ L soln}} \left| \frac{100 \text{ g bleach}}{5.0 \text{ g NaOCl}} \right| \frac{100 \text{ ml soln}}{100 \text{ g soln}} = \frac{0.10 \text{ ml Bleach}}{1.00 \text{ L soln}}$$

   Pipet 1.00 ml of fresh commercial bleach into a 1000 ml volumetric flask and dilute to the mark.

6. The chlorine test strips (Free Chlorine in solutions) can be obtained from Industrial Test Systems (ITS), 1875 Langston Street, Rock Hill, SC 29730, phone: 803-329-9712, web: http://www.sensafe.com. The test strips are very easy to use. Just place 10 mL of the solution to be tested in the colorimeter vial, dip in a test strip and wave it back and forth and up and down for thorough mixing for 30 seconds, then measure the absorbance with the ***MicroLAB*** colorimeter.

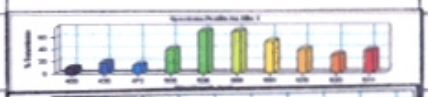
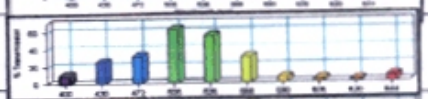
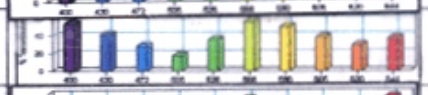
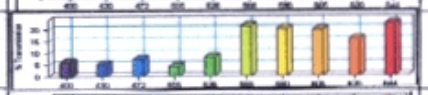
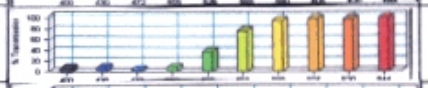
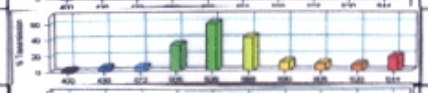
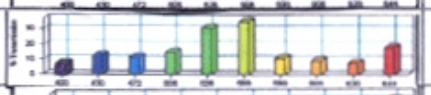
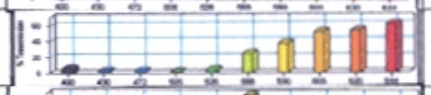
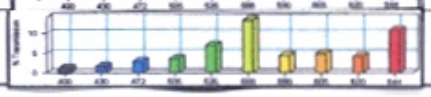
Colorimetry: Quantitative Analysis with Light

Suggested Answers to Report Sheet

1. From the projected spectra of the five colored solutions, and comparison with the five unidentified color spectra profiles in the experiment text, identify the color of each spectrum profile.

Colored Solution	Spectrum Profile Sample Number
Red food color	**Sample 2**
Yellow food color	**Sample 5**
Green food color	**Sample 3**
Blue food color	**Sample 1**
Potassium permanganate	**Sample 4 (This one is not as obvious as the others)**

2. Complete the following table of your experiment on mixing colors. There are ten possible combinations. For each one, draw in the predicted profile **BEFORE** electronically do the mix, then draw in the actual profile after mixing, then place the two vials one in front of the other, hold them up to the light and describe the color you observe. Discuss the color with your partner.

First color	Second color	Predicted Profile	Actual Profile	Observed color
blue	yellow			green.
blue	green			dark green
blue	red			dark brown
blue	KMnO4			black
yellow	red			red
yellow	green			yellow-green
yellow	KMnO4			purple
red	green			black
red	KMnO4			orange-red
green	KMnO4			black

Suggested Answers to Report Sheet

3. Complete the following table for the food coloring standard solutions, the linear curve fit equation, correlation value and the results for your unknown for inclusion in your report.

Food Color Data	Concentration	Percent Transmission	Absorbance
Standard 1 (Blank)	0	100	0
Standard 2	2	57.3	0.242
Standard 3	4	34.5	0.463
Standard 4	6	21.7	0.664
Standard 5	8	13.4	0.872
Standard 6	10	8.89	1.051

Equation: Conc. = 1.05 Abs + 0.02 **Correlation: 0.999**

Food Color Unknown	Percent Transmission	Absorbance	Concentration
unknown K	44.4	0.353	4.41

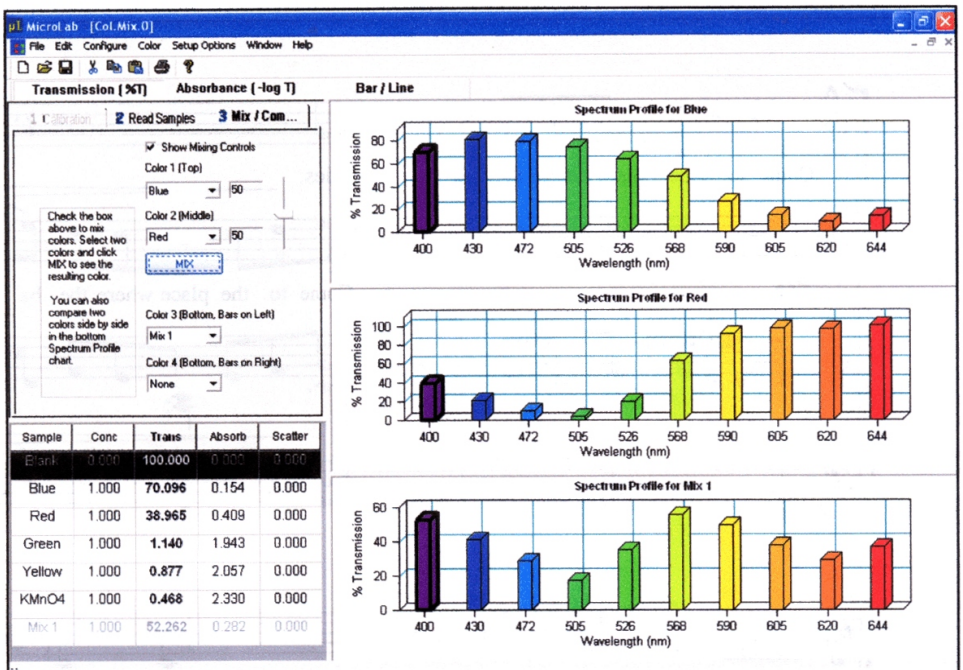
4. Complete the following table for the chlorine standard solutions, the linear curve fit equation, correlation value and the results for your tap and pool water samples for inclusion in your report.

Chlorine data	Concentration (ppm)	Percent Transmission	Absorbance
Standard 1	0	100	0
Standard 2	1	57.7	0.239
Standard 3	2	31.5	0.501
Standard 4	3	16.8	1.775
Standard 5	4	9.94	1.01
Standard 6	5	6.03	1.22

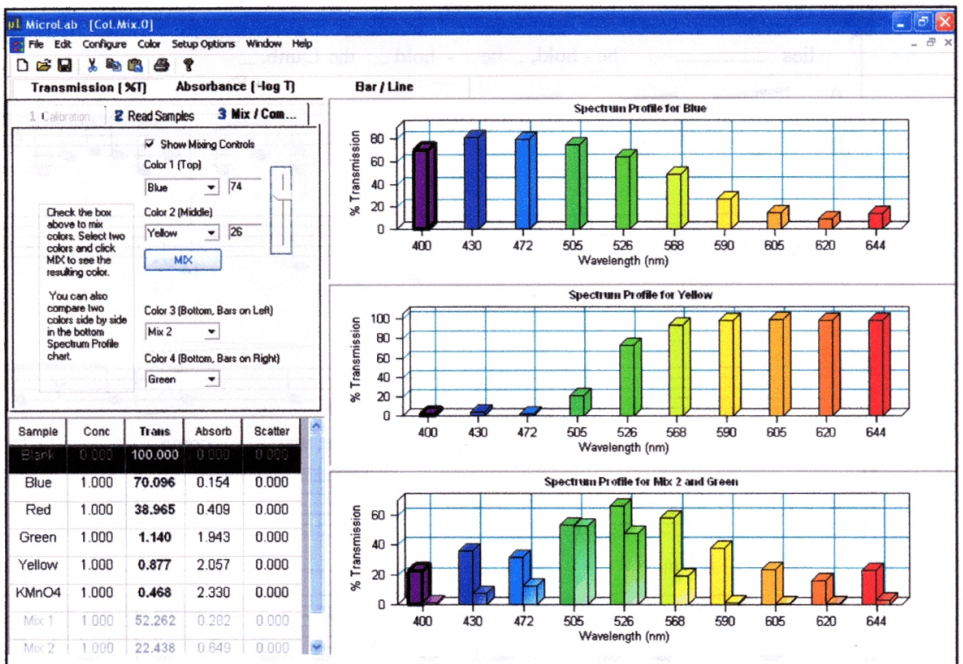
Equation :Conc. (ppm) = 0.1247 Abs + 0.004 **Correlation: 0.999**

Chlorine Unknowns	Percent Transmission	Absorbance	Concentration
Pool water	34.5	0.462	3.703
Tap water	73.1	0.136	1.064

Sample Screen Captures, Color Mixer Experiment Program

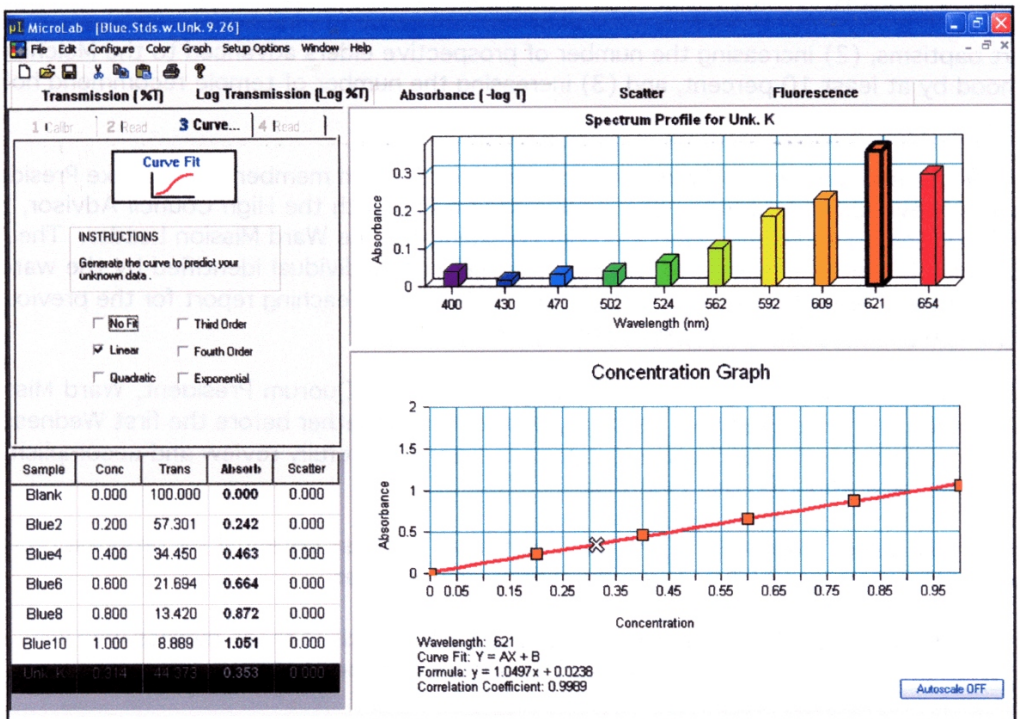


Screen capture of the Color Mixer Experiment program with blue, red and their 50/50 mixture color spectrum profiles.



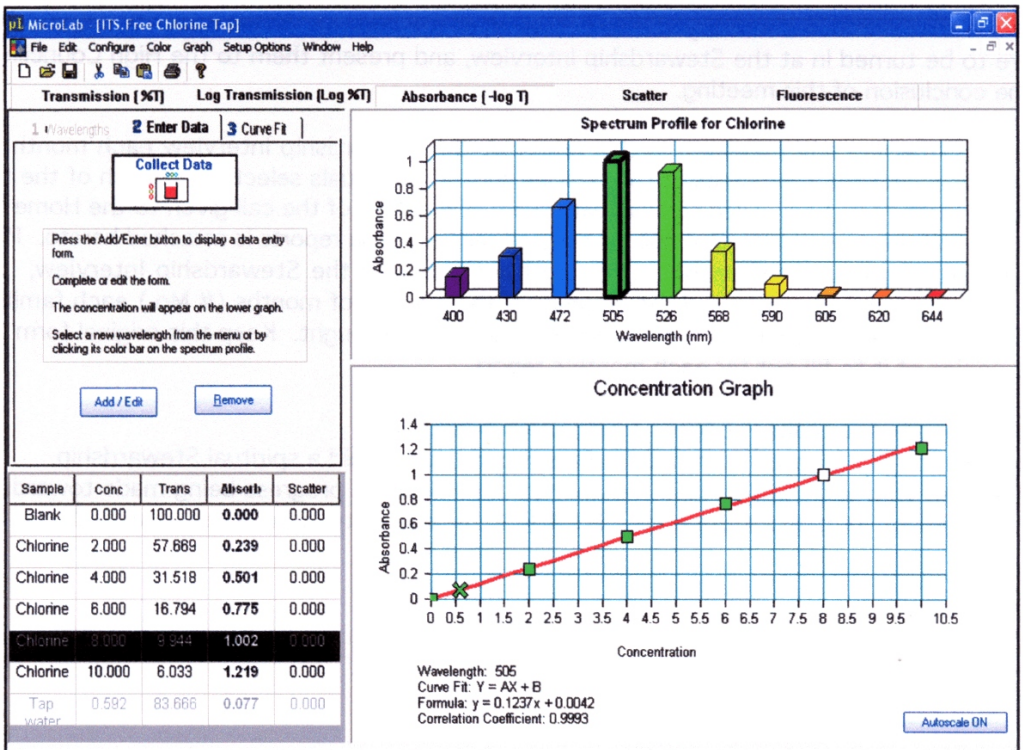
Screen capture of Color Mixer program with blue, yellow, their mixture, and the green scanned color overlayed to the right of the mixture. The mixture has been adjusted to 74% blue/26% yellow to try to match the spectrum profiles. Because they cannot be made to match, the green color is not a mixture of the blue and yellow dyes.

Sample Screen Captures, Colorimeter Experiment Program



Sample	Conc	Trans	Absorb	Scatter
Blank	0.000	100.000	**0.000**	0.000
Blue2	0.200	57.301	**0.242**	0.000
Blue4	0.400	34.450	**0.463**	0.000
Blue6	0.600	21.694	**0.664**	0.000
Blue8	0.800	13.420	**0.872**	0.000
Blue10	1.000	8.889	**1.051**	0.000
Unk. K	0.314	44.373	**0.353**	0.000

Screen capture of the Colorimeter Experiment program showing a Beer's law plot with an unknown marked by the X. The linear curve fit equation and the correlation value is given at the bottom of the graph.



Sample	Conc	Trans	Absorb	Scatter
Blank	0.000	100.000	**0.000**	0.000
Chlorine	2.000	57.669	**0.239**	0.000
Chlorine	4.000	31.518	**0.501**	0.000
Chlorine	6.000	16.794	**0.775**	0.000
Chlorine	8.000	9.944	**1.002**	0.000
Chlorine	10.000	6.033	**1.219**	0.000
Tap water	0.592	83.666	**0.077**	0.000

Screen capture of the Colorimeter Experiment program showing a Beer's law plot for the free chlorine analysis with a tap water unknown.

Colorimetry: Quantitative Analysis with Light

Laboratory Preparation (per student station)

Equipment

- ***MicroLAB*** colorimeter
- 8 colorimeter vials, 2.54 cm path length with caps
- 0 - 10 ml pipetters with disposable tips

Supplies

- KimWipes

Chemicals

Actual quantities needed are given below. A 50% excess is recommended.

- 40 ml blue solution, absorbance about 1.1
- 40ml green solution, absorbance about 1.1
- 40 ml yellow solution, absorbance about 1.1
- 40 ml red solution, absorbance about 1.1
- 40 ml $KMnO_4$ solution, absorbance about 1.1
- 1 or more unknowns for each student within the range of 0.2 to 1.1 absorbance.
- 10 - Free Chlorine test strips from ITS
- 20 ml swimming pool water

Safety and Disposal

- all resulting solutions may be flushed down the drain with plenty of water.
- have students wash hands with soap and water before leaving the lab.