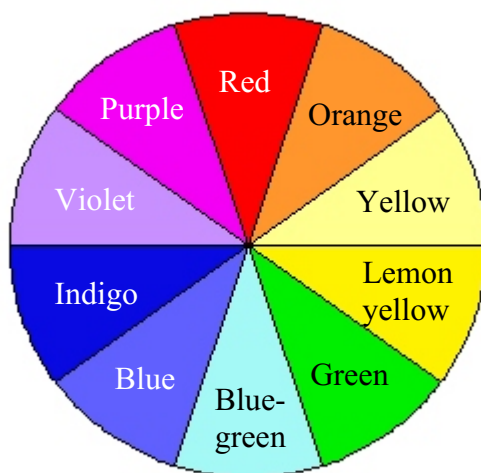


EXPERIMENT: BEER'S LAW

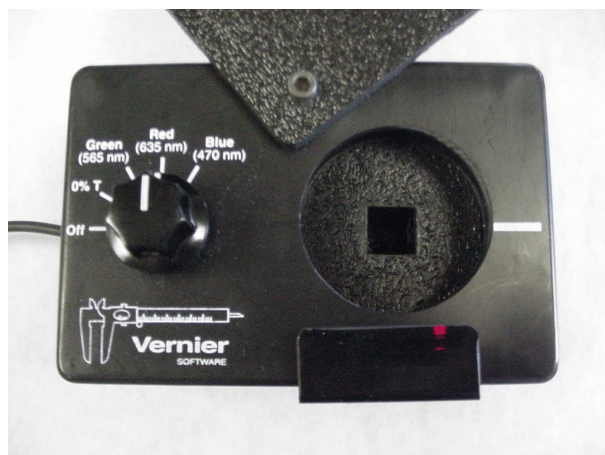
They say that beauty is in the eye of the beholder. Well, color is in the brain of the beholder. Our perception of color can be caused by the addition of or the subtraction of color. As a result there are additive primary colors (Red, Green, Blue) for light and subtractive primary colors (Red, Yellow, Blue) for pigments. When two primary colors are added together the results are the secondary colors. For light, the secondaries are magenta (red + blue), cyan (blue + green), and yellow (red + green). For pigments they are violet/purple (red + blue), green (yellow + blue) and orange (red + yellow). The concept of color is pretty complicated but the general relationships among the colors can be shown using a color wheel.



In this experiment we will be investigating the color produced when light is absorbed by a transparent solution. The color a solution will appear to us can be predicted by using the color wheel. If the chemicals in the solution absorb only red light, the solution will appear blue-green. Blue-green is the color directly opposite red on the color wheel. Colors opposite one another on the color wheel are called complementary colors. Red and blue-green are complementary colors. If a solution appears blue then we would find that the chemicals are absorbing orange light since blue and orange are complementary. We would also expect that as the concentration of the absorbing chemicals increase the amount of light absorbed would probably increase also. This relationship is called "Beer's Law."

Part 1: The Instrument

The instrument we will use to measure the absorption of light is called a colorimeter. It has a rotary dial to select one of three light emitting diodes (LED). Although the LEDs are called “red”, “green”, and “blue” you might want to be more descriptive of the colors when you see them.



Connect the colorimeter to the computer interface and boot up the computer. The light produced by the LED originates from the right side of the colorimeter. Turn the rotary dial to the “Green” setting and place a narrow piece of white paper in the square sample holder so that the light beam coming from the right side hits the paper and you can see the color. Record the color of the light for each of the three settings of the colorimeter. Using the color wheel, predict what color a solution would be if it strongly absorbed light of each of these colors.

Part 2: Beer’s Law

Open Logger-Pro. Then open the file called “Beer’s Law”. The program will ask you to confirm that you have the colorimeter attached so click OK. Save the file to your own diskette in the A: drive.

Prepare two dilutions of the stock crystal violet solution. Using one of your 10 mL graduated cylinders add 20.0 mL of distilled water to a 50 mL beaker. Using the other 10 mL graduated cylinder and 10.0 mL of crystal violet solution to the same beaker and stir the solution until it is uniform. Into a second, 50 mL beaker measure 10.0 mL of water and 20.0 mL of crystal violet using their respective graduated cylinders. Stir until uniform. Calculate the concentration of crystal violet after dilution assuming the volumes are additive.

You will place the solutions to be measured in a plastic cuvette. It is important to insert the cuvette into the colorimeter with the same orientation each time. You can mark one of the ribbed sides with a marker so you can keep track of the orientation. To avoid having fingerprints interfere with the light readings, always handle the cuvettes by the ribbed sides or by the top. Add distilled water to the cuvet until it is at least 3/4 full. The cuvette must always be filled at least this much in order to insure that the light beam passes through the sample. Wipe off the

outside carefully with a tissue and insert the cuvette into the colorimeter so that the ribbed sides are facing toward the top and bottom of the colorimeter (as viewed from the top). Remember that the light beam passes from right to left. Close the colorimeter top and calibrate the colorimeter by selecting from the toolbar “Experiment”, “Calibrate”, “Colorimeter” and “Calibrate Now.” Set the rotary switch on the colorimeter to 0% T, enter “0” for “Reading 1” and then “Keep.” Rotate the switch to the “Green” position, enter “100” for “Reading 2” and then “Keep” and “Done”. The colorimeter is now calibrated and the current Absorbance reading should be close to 0.000.

Start the data collection by clicking on the green button on the toolbar. The button should turn red. Click on the aperture symbol to the right side of this button. Enter the concentration of the solution (in this case, 0) as prompted. Click “OK”. Empty the cuvette, rinse it several times with SMALL portions (no more than about 1/4 full) of one of your diluted solutions. Fill the cuvette at least 3/4 full, wipe off the outside, and insert the sample into the colorimeter with the correct orientation. Close the lid and click on the aperture symbol. Enter the concentration of this sample. Pour out the contents of the cuvette into a large waste beaker. Fill the cuvette with 1 M HCl to remove any crystal violet that may have stained the plastic. Discard the acid into your waste beaker and thoroughly rinse the cuvette with distilled water. Check the absorbance of the distilled water to make sure that the colorimeter reading is still close to 0.000. If it isn't, recalibrate the colorimeter. Rinse and fill the cuvette with the other dilute solution and click on the “aperture” symbol. Enter the concentration when prompted. Repeat the process of rinsing with HCl and water and checking the calibration until you have measured the absorbance of distilled water, your two diluted solutions and the stock solution of crystal violet. Data collection will then be terminated by clicking on the red button on the toolbar (which now turns green). **SAVE YOUR FILE TO YOUR DISK.**

Part 3: Analysis of Solution

Prepare a dilution of the stock solution of crystal violet by pipeting 10.0 mL of the crystal violet stock solution into a 50 mL volumetric flask. Dilute to the calibration ring on the flask using distilled water. Stopper, invert and shake the flask. Repeat sufficiently to thoroughly mix the solution. Calculate the concentration of crystal violet after dilution.

Empty the cuvette and fill it with 1 M HCl. Discard the HCl into your waste beaker and thoroughly rinse the cuvette with distilled water. Then fill the cuvette with water, wipe off the outside and measure its absorbance. If it does not read close to 0.000 then recalibrate the colorimeter. Then rinse and fill the cuvette with the solution you prepared. Measure its absorbance and record the value in your report sheet.

Drawing the Graph:

To draw the line of best fit for your data, select from the toolbar, “Analyze”, “Linear Fit” and click OK. You can move the box on the graph to convenient locations then **SAVE YOUR FILE TO YOUR DISK.**

Concentration of Your Solution:

Select “Analyze” from the toolbar and then “Interpolate.” The mouse or the arrow keys can now be used to move the cursor along the lines of best fit in order to read points on the graph. Move the cursor to the Abs green reading you recorded for your unknown. You can now read the concentration of crystal violet. You will notice that the cursor moves in steps. The larger the graph is the smaller the steps. You can minimize the step size by highlighting the portion of the graph you want to read (do this by “click, hold, and drag” the mouse) and then selecting “Analyze”, “Zoom Graph In.” Move the cursor to your recorded Absorbance reading for your solution and record the interpolated concentration on your report sheet. Using this value and the value calculated from dilution, calculate the % error in your two values. Assume that your diluted concentration value is the “accepted” value. Close the interpolate box and the box that contains the slope and intercept information.

Part 4: Effect of Wavelength

From the toolbar select “Experiment”, “Store Latest Run”. Double click on the column heading in the table labeled “Abs green” and a column menu will appear. Under “Column Definition” change the column name to “Absorbance Red” and the short name to “Abs red”. Select “Options” from the top of the menu and change the point protector style to open square and the color to black. Then click “Done.” You are now ready for the second trial. Fill the cuvette with 1 M HCl to remove any of the crystal violet that may have stained the plastic. Discard the acid in your waste beaker and rinse the cuvette thoroughly with distilled water. Then fill the cuvette with water, wipe off the outside and calibrate the colorimeter as before only turn the rotary switch to the red setting before entering 100 for Reading 2 during the calibration. After calibration, start the experiment by clicking the green toolbar button and enter the concentration. Repeat as you did in Part 2 until you have measured distilled water, the stock crystal violet solution and the two dilutions. Terminate the experiment by clicking on the red toolbar button. **SAVE YOUR FILE TO YOUR DISK.**

Drawing the Graph:

To draw both lines of best fit on the same set of axes, select from the toolbar, “Analyze”, “Linear Fit”. Leave both trials highlighted and click OK. You can move the boxes on the graph to convenient locations then **SAVE YOUR FILE TO YOUR DISK.**

Part 5: Effect of Wavelength on Error

Select “Interpolate” as described in “Concentration of Your Solution.” With both graphs displayed “Interpolate” will display the absorbance values for both lines. Zoom in as described before so you are viewing absorbances close to the absorbance reading you had for your solution. On your report sheet, record the absorbance reading and the concentration reading for the “green light” line and the absorbance reading for the “red light” line for the same concentration value. To see what effect a small error in absorbance has on the interpolated concentrations, add 0.005 absorbance units to each of the two absorbance values and see what concentration each of these new readings would have on their respective lines. Record the new concentration values in your report and calculate the changes in the concentration that have occurred due to the 0.005 absorbance increase.

Printing Your Graph:

Take your disk to the computer lab in Romney 201. Open Logger Pro and then open your file. If you have zoomed in on your graph you will need to adjust the scaling so that the graph is an appropriate size. One way of rescaling is to click on the graph, select “Options” from the toolbar, then “Graph Options”, then “Axes Options.” You will find some scaling options listed for both the x and y axes. To reset the autoscaling of the graph click on either “autoscale” or “autoscale from 0” for each axis (which ever one is NOT currently displayed) and then “Done”. If this doesn’t give you what you want, go back and select the other autoscale option. Print the graph as you would any file. In the file menu you will find “Print Graph.” The pop-up menu then allows you the option to add your name as a footer to the graph.

EXPERIMENT: BEER'S LAW

Name: _____

Partner: _____

Part 1:

colorimeter setting	observed color	predicted color a solution would be if it absorbed the "observed color" of the LED
"Green"		
"Red"		
"Blue"		

Parts 2 and 4: Beer's Law and the Effect of Wavelength

solution	concentration (M)	Absorbance _{green}	Absorbance _{red}
distilled water			
Dilution 1			
Dilution 2			
stock solution			

Part 3: Analysis of Solution

concentration	absorbance	concentration _{from graph}	% error

Part 5: The Effect of Wavelength on Concentration Error

	concentration (M)	error in concentration (M)
absorbance _{green}		
absorbance _{green} + 0.005		
absorbance _{red}		
absorbance _{red} + 0.005		

Questions:

1.
 - a. Experimentally, which color, red or green, did crystal violet absorb more strongly? Explain how you made your decision.

 - b. Explain how the color wheel would have predicted your answer in question 1a.

2.
 - a. To minimize the error in determining the concentration of a solution using Beer's Law, a wavelength of light that the compound absorbs (strongly, weakly) should be used.

 - b. Potassium chromate solutions are yellow. Which setting on the colorimeter would be best to use if you were going to use Beer's Law to determine the concentration of potassium chromate?