To close the yellow note, click once to select it and then click the box in the upper left corner.
To open the note, double click (Mac OS) or right click (Windows) on the note icon.

#05 Color Me Analytical

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INTRODUCTION

Description

This lab is an introduction to colorimetry on two levels. First, the students are learning how to physically manipulate the colorimeters (It should be noted that this lab presumes the students will already be familiar with the PCs and Vernier™ software - in this teacher's case, this is a lab for advanced chemistry students who have at least one year of experience with the software and platforms.) Secondly, the students are starting on a pathway of discovery to one of the most important principles in analytical chemistry: Beer's Law. The lab is inquiry-based, designed to be completed by the student one page at a time (i.e., students must check their answers for each page with the teacher before they receive the next page). The lab is designed for students to work cooperatively in teams of 3-4.

Student Audience

Second-year high school chemistry course or honors high school chemistry first-year course

Goals

- to become familiar with the operation of the Vernier colorimeters
- to begin the process of discovering Beer's Law
- to review dilution calculations for solutions

Recommended Placement in the Curriculum

This activity could be used anytime in a second-year high school course or toward the end of the year in a first-year high school course (after solution chemistry). (I use it during the first grading period.)

STUDENT HANDOUTS

(see following pages)

Developed through the National Science Foundation-funded
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ONE:

This lab will introduce you to the technique of colorimetry. We'll use this technique in later labs to find the concentration of a solution. To begin, look at the printing on this page through the piece of colored film, then fold the film in half and look at the print through two layers of film, then fold the film in half again and look through four layers of film. How did your view of the printing change? Why? Check your answers with your team, then with your teacher.

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TWO:

As more and more layers of plastic cover the printing, less and less light gets through. We'll use the colorimeters to measure the amount of transmitted light that "gets through" our colored copper (II) sulfate solution. Before we do that, however, solve the following problem:

You have landed on a barren alien planet with our fearless hero, Astronaut Anton. The inhabitants are friendly (unlike our intrepid explorer's usual close encounters), and give Anton permission to take back some rock samples. The rocks seem heavy, and not wanting to overload his spacecraft, Anton asks the aliens how much one of the rocks weighs. The aliens reply, "about 3 quargs." Can our hero safely blast off? Check with your team, then your teacher.

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THREE:

Anton does NOT have enough information for a safe blastoff. Anton needs a way of equating quargs and newtons. We're going to be measuring the amount of light transmitted through a solution, but we'd like to know the concentration of that solution. How is our problem similar to Anton's? Check with your team, then your teacher.

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FOUR:

We need a way to relate transmitted light to concentration. To do this, we'll mix a series of copper (II) sulfate solutions of known concentrations, measure the light transmitted through each one, and look for a pattern. **PLEASE PUT ON YOUR GOGGLES AT THIS TIME, AND LEAVE THEM ON FOR THE REMAINDER OF THE LAB.** Your team will need three 10-mL graduated cylinders and two 50-mL beakers. Note that each container has a pipette. **The pipettes must stay with their respective containers; do not use a pipette from one container to withdraw liquid from a different container.** Into one beaker pour approximately 40 mL of distilled water; in the other beaker, pour a similar amount of stock (0.400 M) copper (II) sulfate solution. Into one of the three graduated cylinders pipette 2.4 mL of stock solution, then - using the distilled water - dilute to 10.0 mL. Similarly, pipette 5.0 mL and 7.4 mL, respectively, into the two remaining cylinders and dilute to 10.0 mL. What is the concentration of copper (II) sulfate in each of the three cylinders? Check with your team, then your teacher. Then label the cylinders and the beaker with the appropriate concentration.

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FIVE:

a. Choose the **monitor input vs. keyboard** option. When prompted for **label,** enter "concn"; when prompted for **unit,** enter "mole/L". The colorimeter will begin measuring the light transmitted. Make sure the colorimeter light control switch is set to the "red" position.

b. Starting with the lowest concentration (0.096 M) solution, rinse the colorimeter cuvette twice with the solution, then fill the cuvette 2/3 full and insert in the colorimeter, always lining up the mark on the cuvette with the mark on the colorimeter. Then close the lid and wait for the readings to stabilize. Press **space bar** and enter the concentration of the solution.

c. Following the onscreen prompts, repeat procedure (b) for each of the other concentrations, including the stock solution.

d. Choose the **save data** option to save your data under a name you'll remember.

e. Print out a data table for each team member.

f. Choose the **plot graph** option, turning on the **regression line, point protector, and statistics** options. Accept the defaults for all other settings, and view your graph. Remember, we're looking for a pattern to relate transmitted light to concentration. Considering your R values from the statistics display, does there appear to be a direct proportion between light transmitted and concentration? Check with your team, then your teacher.

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SIX:

Since we still seem to be searching for a pattern, think about these two questions for tomorrow:

1. If we can't find a linear (straight line) relationship between two factors, how else might the two be related mathematically (consider other natural phenomena).

2. What is the **solution** doing to change the amount of light being transmitted?

INSTRUCTOR NOTES

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Time Required
50 minutes

Group Size
Teams consist of 3-4 students. You can have as many teams as you have equipment and space.

Materials
Each team needs the following:
- PC
- Vernier colorimeter and computer interface (MPLI, gameport, ULI, or serial)
- two 50-mL beakers
- three 10-mL graduated cylinders
- five plastic pipettes (any size)
- distilled water (40 mL)
- three-four pieces of colored plastic film
- stock copper (II) sulfate solution (0.400 M, 40 mL)
(99.8 g of $CuSO_4 \cdot 5H_2O$ are added to 500 mL of water, add 5 mL of concentrated sulfuric acid, dissolve, and dilute to 1.00 L

Safety, Handling, and Disposal
Students must wear goggles during the lab, and wash their hands after the lab. Dispose of used reagents according to local ordinances.

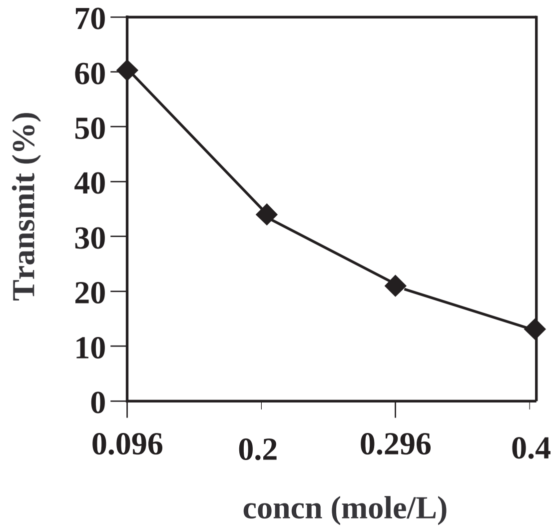
Points to Cover in Pre-Lab Discussion
Encourage students to thoroughly discuss answers to the lab questions with their team before checking with the teacher.

Procedural Tips and Suggestions
- While this is a guided inquiry process, each teacher will need to use his/her judgement as to how much guidance to provide.
- The colorimeters should be calibrated each time they are used. This is a useful exercise for the students, but will require additional time. The instructor may choose to calibrate the colorimeters for this first lab, and have the students calibrate in subsequent labs. Complete instructions for calibration are provided by Vernier Data should be collected with the color switch in the “red” position.

Sample Results

Concentration (mole/L)	Transmit (%)
0.096	60.3
0.200	34.0
0.296	21.0
0.400	13.1

Figure 1



Note: This data table and graph were assembled in other software (files from the Vernier programs cannot be imported into Microsoft Word™).

Plausible Answers to Student Questions

Answers to most of the questions are given in the next handout the student receives. For handout number four, the concentrations are 0.096 M, 0.200 M, and 0.296 M, respectively. For handout number five, there is not a direct, linear relationship between transmitted light and concentration.

Extensions and Variations

This lab could be performed with Spec-20's and spreadsheets/graphing calculators/etc. I prefer using the Vernier colorimeters because I follow up this lab with a session on the computers using Vernier's powerful Graphical Analysis program. With it, the students finally derive Beer's Law by figuring out they need to:

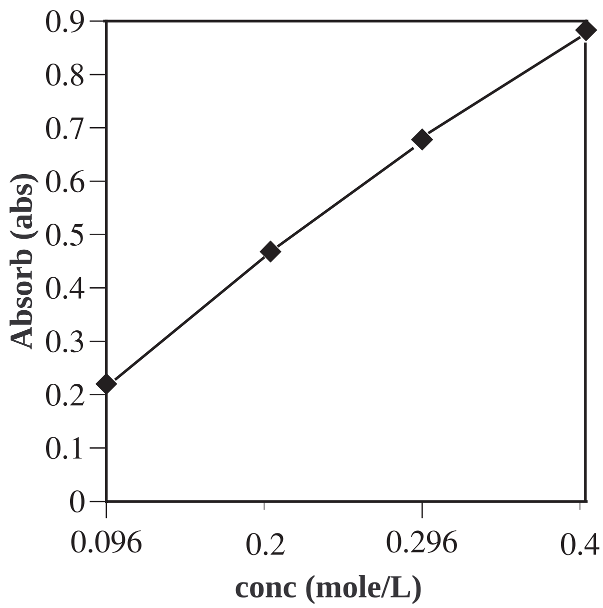
1. Consider a logarithmic function (like our eyes and ears)
2. Invert transmitted light (since the solution is absorbing light).

   (see student handout number 6)

In short, students determine that absorbance = log(100/%transmit), and that absorbance is directly proportional to concentration. Results are similar to the following:

Concentration (mole/L)	Absorb (abs)
0.096	0.220
0.200	0.468
0.296	0.678
0.400	0.883

Figure 2



Note: Once again, this data table and graph are not from the Vernier program.

One reason I prefer the Vernier software is that various statistical measures are calculated automatically by the software (it also runs on DOS, which is all my lab computers can muster!).

Once the students are comfortable with the colorimeters and Beer's Law, we use these tools to analyze local water samples for total iron content.

References

Holmquist, Dan D.; Volz, Donald L. "Chemistry with Computers"; Vernier Software: Portland, OR, 1993, pp 73-80

Colorimeters and software: Vernier Software, 8565 S.W. Beaverton-Hillsdale Hwy., Portland, OR 97225-2429, telephone: 503/297-5317 www.vernier.com