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Laboratory Safety

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Experiment 9

Absorption of Light

Ann M. Cappellari, Frederick H. Juergens,
Arthur B. Ellis and George C. Lisensky

Notes for Instructors

Purpose

To determine the effect of solution path length, concentration, and color on the fraction of light intensity transmitted through a solution.

Method

Current as measured from a solar cell in this experiment depends directly on the amount of light reaching the cell (*see* Chapter 8). The intensity of a monochromatic laser beam is varied by passing the beam through solutions that vary in path length, concentration, and color in this experiment.

The fraction of light intensity transmitted through a solution (see student directions) is the transmittance of the solution and the –log(transmittance) is the absorbance. The –log(transmittance) is directly proportional to path length and to concentration, where the proportionality constant is a function of the wavelength and the color of the solution. This relationship is commonly referred to as Beer's law. *See* Demonstration 8.4 for data using different path lengths and concentrations.

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Materials

Laser (670 nm, 5 mW)

Small portion of a solar cell (Radio Shack), approximately the size of the laser beam, with wires soldered to opposite sides. To trim a solar cell, score once with a diamond pencil (Aldrich) and then snap along the line. *See* Figure 1. Alternatively a larger mounted solar cell (Edmund Scientific) can be masked with black electrical tape to leave only a beam-size portion of the solar cell showing. Packaged solar cells are more robust in student hands and are easier to keep aligned in use.

Digital multimeter (ammeter)

Disposable plastic cuvettes (1 cm × 1 cm)

0.15 M $CuSO_4$ (37.5 g of $CuSO_4 \cdot 5H_2O$/L). Add a few drops of H_2SO_4 if the solution is cloudy.

0.03 M $CuSO_4$ (7.5 g of $CuSO_4 \cdot 5H_2O$/L)

Dark red aqueous solution, prepared by adding red food coloring to water (McCormick red food color does not absorb the 670-nm laser light, and is a mixture of FD&C Red No. 40 and FD&C Red No. 3).

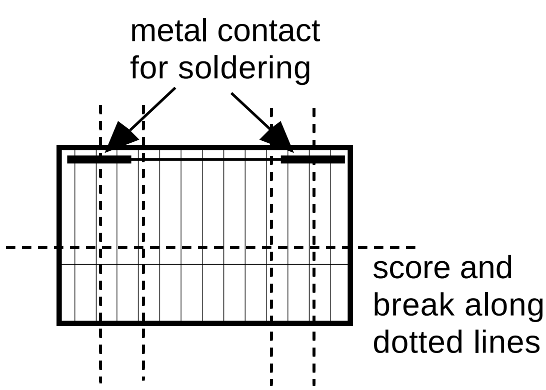

Figure 1. A Radio Shack solar cell can produce four usable pieces (two from the upper left and two from the upper right), because each piece must contain enough of the metal contact to solder a connection to the front. The entire back is metal-coated so the second wire can be soldered anywhere on the back side; the cell is easiest to tape down if the two wires are soldered to opposite ends of the piece.

Absorption of Light

Purpose

To determine the effect of solution path length, concentration, and color on the fraction of light intensity transmitted through a solution.

Procedure

Wear eye protection.

Clamp or fasten a small laser pointer and solar cell with attached wires such that the laser beam strikes the solar cell, as shown in Figure 1. One way to do this is to tape the laser and the wires to the bench top. **CAUTION: Do not look into the laser or aim the laser at another person, as it can damage the eye.**

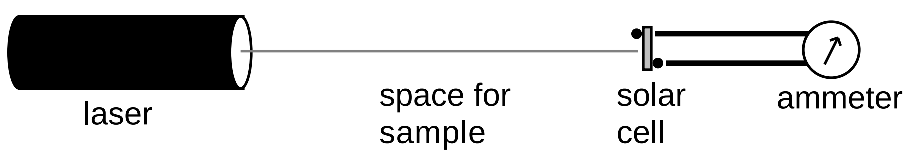

Figure 1. Arrangement of equipment.

The solutions to be studied are put in a 1-cm × 1-cm plastic cuvette, and the cuvette is placed in the beam. Both the sample cuvette and the solar cell should be oriented perpendicular to the laser beam.

Current from a solar cell depends directly on the amount of light reaching the solar cell; to measure light intensity, connect the solar cell to a digital multimeter reading milliamps. To measure the fraction of light intensity transmitted through a sample placed in the beam, you will also need to record the value obtained when your sample is not present (a blank):

$$\text{fraction of light intensity transmitted} = \frac{\text{milliamps for sample}}{\text{milliamps for blank}}$$

The solar cell also responds to changes in room light. Using a small solar cell helps, but try to maintain constant lighting in the room.

NOTE: This experiment was written by Ann M. Cappellari, Frederick H. Juergens, and Arthur B. Ellis, Department of Cheimstry, University of Wisconsin—Madison, Madison, WI, 53706; and George C. Lisensky, Department of Chemistry, Beloit College, Beloit, WI, 53511.

Investigations

1. How does the path length of a 0.03 M copper sulfate solution affect the amount of light reaching the solar cell? Keep the concentration of the solution constant and vary the path length by using more than one cuvette.
2. How does the concentration of the copper(II) solution affect the amount of light reaching the solar cell? Keep the path length of the solution constant by using only one cuvette and vary the concentration by diluting a 0.15 M copper sulfate solution.
3. Some light intensity may also be lost by reflection at the interfaces (where the index of refraction changes) even for clear solutions. The beam encounters interfaces in going from air to plastic, plastic to water, water to plastic, and plastic to air. Keeping the cell perpendicular to the beam minimizes reflections, but a better choice of blank can help: measure the milliamps for the blank when a water-filled cuvette is in the beam. Using a water-filled cuvette as the blank, measure the change in light intensity due to only the presence of copper sulfate in the solution. Measure the change in light intensity due to only the presence of red food coloring in the solution. Is there a difference in how much light passes through the blue solution and through the red solution? Does color matter?

Questions

Plot the current as a function of the tested variables. Also plot log(current) as a function of the tested variable. Which is more linear?

Write an equation to describe the relationship between light intensity (solar cell current) and the variables you tested.

If you measured a 50% reduction in light intensity when the beam passes through a solution of copper sulfate in a single cuvette in your apparatus, what would be the concentration of the copper sulfate?

Would you suggest any changes in the experimental procedure if you wanted to measure concentrations of red food coloring in a solution?