

## Lab 2 – Absorption

### I. Introduction

When a beam of light of an appropriate wavelength is passed through a sample, some or all of that light may be absorbed. In this lab, the light source that will be used will be a helium-neon laser. This laser emits light at a wavelength of 633 nm. The sample to be studied is a colored organic food dye. As a result of performing the following experiments, the student will become familiar with the concepts of absorption and how it varies with concentration of the sample.

### II. Objective

The purpose of this experiment is

- (1) To introduce a method of quantitatively measuring absorbance of a specific solution.
- (2) To determine from Beer's law, the characteristic absorption coefficient of the organic dye.

### III. Procedure

#### Equipment

HeNe laser and stand  
Chopper  
2 mirrors in kinematic mounts  
Dual filter wheel  
Lock-in Amplifier  
Photodiode  
x-y translation stages  
Magnetic Stirrer and stir bar  
Rectangular Cell  
Food Coloring dyes

Set up apparatus according to the schematic diagram in Figure 1.

#### **PART A:**

- (1) Measure the *inner* dimension of the rectangular cell.
- (2) Place 25 mL of *room temperature* water in the rectangular cell. If cold water is used, water vapor may condensate on the rectangular cell thereby adding an additional loss of transmitted light.
- (3) Position the rectangular cell on the magnetic stirrer so that the beam passes through the center of the cell along its length. Place a magnetic stir bar in the water and turn on the stirrer. Choose a relatively slow mixing speed such that no vortex is generated in the water. Make sure that the height of the laser beam through the rectangular cell is adjusted such that the laser beam is not affected by either the spinning stir bar or by being too close to the water surface.
- (4) Mount the photodiode on the x-y translation stages and then center the photodiode on the transmitted beam.
- (5) Set up the lock-in amplifier and chopper to detect the amount of transmitted light. Determine that the photodiode used in the experiment is not saturated and is operating in a linear fashion (as per Lab 1). Use the neutral density filter wheel to lower the incident intensity. Think about where these filters should be optimally placed to eliminate any unwanted background light. Optimize the position of the

detector. Once you have completed this step DO NOT TOUCH THE RECTANGULAR CELL or you will have to realign EVERYTHING from the beginning.

### **PART B:**

- (1) Record the signal observed with only the initial level of water in the rectangular cell.
- (2) Add 1 drop of dye. If the transmission does not drop to less than 10% of its initial value, add another drop of dye. You will get better results if this initial solution absorbs over 90% of the initial light. Record the signal level with this concentration of dye.
- (3) Without moving your rectangular cell, dilute your dye solution by adding an additional 10 mL of room temperature water. Allow sufficient time for the dye to thoroughly mix. Using the lock-in, record the new transmitted light level.
- (4) Repeat step (3) four times. Each time you add water, the concentration of the dye is decreased.
- (5) Repeat the measurement using a second dye.
- (6) Repeat the measurement using the red dye.

### **III. Data Analysis**

The Beer-Lambert Law can be written as

$I = I_0 e^{-\alpha x}$  where  $\alpha$  is the absorption coefficient and  $x$  is the distance the light travels through the medium. The absorption coefficient is proportional to the concentration of absorbing dye molecule  $\alpha = \sigma N_0 = kC$ , where  $N_0$  is the number of molecules per unit volume,  $\sigma$  is the absorption cross-section of the dye molecule,  $C$  is the concentration of dye molecules in the water and  $k$  is a constant.

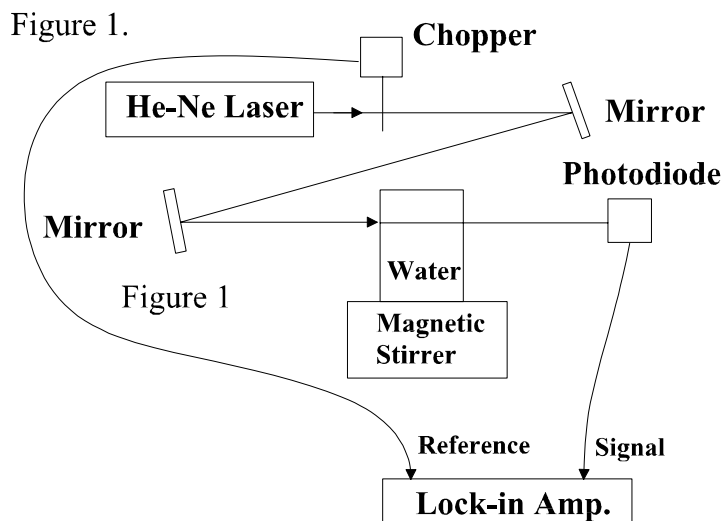
$$\ln\left(\frac{I_0}{I}\right) = kCx \quad \text{or} \quad \ln\left(\frac{V_0}{V}\right) = kxC$$

Where  $V_0$  = Lock-in Voltage from unattenuated light and  $V$  = lock-in voltage from light attenuated by different concentrations of dye in water.

- (1) Using the acquired data, plot  $\ln(V_0/V)$  as a function of concentration.
- (2) Fit the data to a linear curve to determine the constant  $k$  of the organic dye. You may use the fundamental unit of dye concentration as "1 drop".

Note that the absorbance,  $A$ , also called the "optical density" is given by

$$A = \log_{10}\left(\frac{1}{T}\right) = \log_{10}\left(\frac{I_0}{I}\right) = \log_{10}(e^{\alpha x}) = \alpha x \log_{10}(e) = 0.434\alpha x$$



Water volume	Signal for first dye	Signal for second dye	Signal for red dye
25 mL (no dye)			
25 mL			
35 mL			
45 mL			
55 mL			
65 mL			
75 mL			

Attach your plots of  $\ln\left(\frac{V_0}{V}\right)$  versus concentration.

(1) Do your results follow the Beer-Lambert law?

Why or Why not?

(2) What was the absorption coefficient for your first dye solution?

Second dye?

(3) What was the absorbance (optical density) of your first dye solution?

Second dye?

(4) What was the absorbance of the red dye solution?

Was it greater or less than your measurements for the first and second dyes?

Why?

(5) Why is it important not to move the rectangular cell once you start your measurements?

(6) In determining the absorption coefficient, do you need to know the reflection coefficient for light from the air/glass interface?

How about the glass/water interface?

(7) Why can we neglect the fact that the laser light passes through the wall of the rectangular cell? (Do we need to include the absorption of the rectangular cell?)