

13. The Lambert-Beer Law



Figure 1

Introduction

The amount of light penetrating a solution is known as transmittance, expressed as the ratio between the intensity of the transmitted light, I_t , and the initial light intensity of the light beam, I_0 :

$$T = \frac{I_t}{I_0}$$



Where: T – Transmittance

I_t – Intensity of the transmitted light

I_0 – Intensity of the initial light beam

Even though the relationship between transmittance and absorbance would appear to be a simple inverse relationship, the true relationship between these two variables is inverse and logarithmic (base 10):

$$A = \log\left(\frac{1}{T}\right) = -\log T$$

Where: A – Absorption

T – Transmittance as a number between 0 and 1 $\left(\frac{T\%}{100}\right)$

The absorption A of a dissolved substance is a linear function of its concentration, the so-called Lambert-Beer Law. The length of the light path (thickness of the cell) and the Extinction coefficient (a substance specific constant) determine the slope of the linear plot.

$$A = \epsilon cd$$

Where: c – Concentration

d – Thickness of the cell

ϵ – Extinction coefficient


The Lambert-Beer Law however is valid only for diluted solutions. The limits for its validity differ for different materials. As a general rule, one can understand that every material showing absorption of up to 0.5 - 0.6 still obeys the Lambert-Beer Law.

In this experiment, we follow the behavior of the linear absorption increase of CuSO_4 with increasing concentration in order to determine its extinction coefficient at a given wavelength within its absorption area.

Equipment

- Nova5000
- 4 $\text{CuSO}_4 \times 5 \text{H}_2\text{O}$ - solutions ranging from 0.006 to 0.05 mol/L
- Colorimeter sensor

Equipment Setup Procedure

1. Launch MultiLab.
2. Connect the Colorimeter sensor to Input 1 (I/O-1) of the Nova5000.
3. Click **Setup**  on the main toolbar and program the data logger according to the setup specified below.

Data Logger Setup

Sensors:

Input 1: Colorimeter


Rate:

Manual




Samples:

10 samples

Experimental Procedure

1. Insert the red filter slide into the Colorimeter.
2. Calibrate the Colorimeter sensor (refer to the appropriate chapter in the Colorimeter sensor sheet).
3. Click **Run**  on the upper toolbar to begin recording data.



4. Measure your samples in the order of increasing concentration. Collect the data manually. Click **Run**  on the upper toolbar each time you wish to record a data sample.
5. Click **Stop**  on the upper toolbar to stop collecting data.
6. Save your data by clicking **Save**  on the upper toolbar.

An example of the graph obtained in this experiment is shown below:

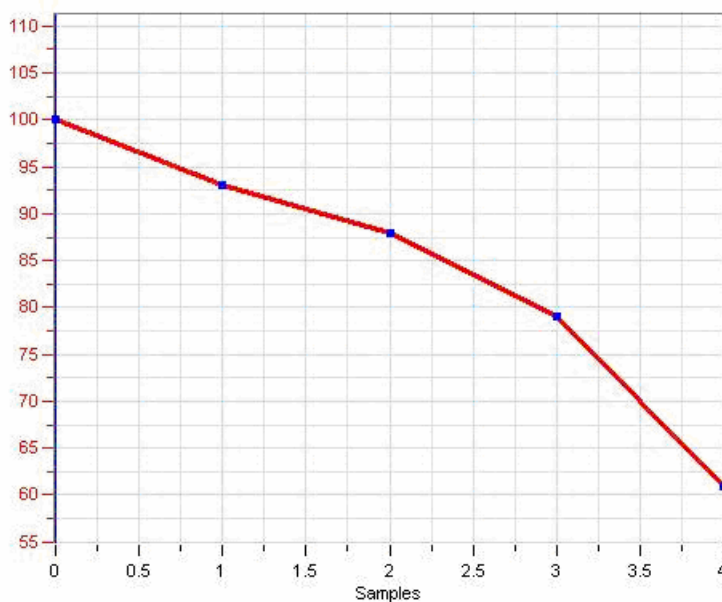






Figure 2

Data Analysis

1. Note that your initially measured variable is transmission, which must be converted into absorption:
 - a. Use the First cursor  to select the graph.
 - b. Click **Functions**  on the main toolbar, and then click the **Functions** tab.
 - c. In the **Functions** drop-down menu select **Log10**.
 - d. In the **A** text box enter -1 . In the **B** text box enter 0.01 .
 - e. In the **Name** text box enter a name (e.g. Absorption).

- f. Click **OK**.
2. Enter the CuSO_4 concentration data into a manual column:
 - a. Click **Table view**  on the main toolbar to display the table.
 - b. Click **Tools** on the menu bar.
 - c. Click **Add Manual Column**.
 - d. In the **Column title** text box enter a name (e.g. Concentration).
 - e. In the **Unit** text box enter a unit (e.g. ml/L).
 - f. Click **OK**.
 - g. In the table, click the first cell of the new column and enter the concentration of the first sample. Move to other cells and fill in the column.
3. Display a graph of **Absorption** vs. **Concentration**.
 - a. Hide the data obtained in this experiment (Transmission vs. Sample) by clicking on the experiment on the Data Map and clicking **Hide**.
 - b. Click **Format graph**  on the lower toolbar.
 - c. Select **Concentration** in the X-axis drop-down menu and then click **OK**.

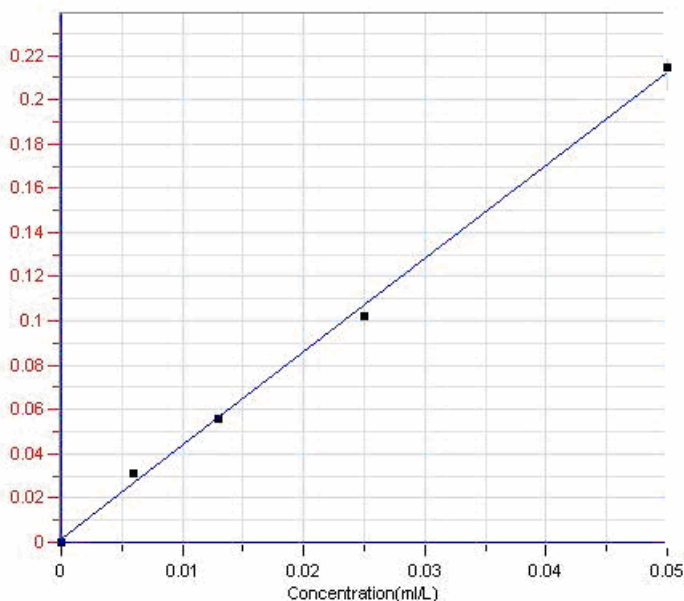



Figure 3



4. Apply linear fit to obtain the extinction coefficient of CuSO_4 :

- a. Click **Linear fit**  on the main toolbar. The fit equation will be displayed in the information bar at the bottom of the graph window.
- b. Divide the slope by the thickness of the cell to obtain the extinction coefficient of CuSO_4 .