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BEER LAMBERT'S LAW - KSCIBLL

BEER LAMBERT'S LAW

1. Key Concepts

- Interaction of EM waves with matter.
- Absorption spectra

2. Introduction

EM radiation interacts with matter in the following ways: emission, absorption, transmission, and reflection or scattering. Depending on the physical and chemical properties of the matter under interaction, there can be one or more ways in which EM interacts. It is because of these interactions EM radiation can be used as a probe to measure the physical and chemical properties of materials.

3. Objective

- To verify Beer - Lambert's law.
- To determine the concentration of a given solution by analysing the data from the absorption vs concentration graph.

4. Theory

In the current experiment, let the focus be on the phenomena of absorption of light as it undergoes transmission through a material medium. The atoms/molecules that make up a given materials consists of distinct energy levels that are occupied by the electrons following the selection rules. When a broad spectrum EM radiation is irradiated on the material, the electrons absorb the EM radiation of a specific wavelength and thereby undergo a transition to a higher energy level form a lower energy level. The energy gained by the electrons is equal to the frequency of the absorbed radiation times the Planck's constant. The factors that determine how much of EM radiation is absorbed by the material are:

5. **Transition probability**: the probability of the number of atoms/molecules of a given material initially in the state from which the transition to an excited state occurs. These are governed by selection rules.

6. **Population of states**: the absorption/emission of EM radiation will be more if the population of the energy level involved in the absorption/emission is more.
7. **Length of the absorbing medium**: as the length of the material through which the EM radiation is undergoing transmission increases, greater is the energy lost by it.
8. **Concentration of the sample**: as the concentration of the absorbing species increases in the sample, the greater will be the energy lost by the radiation.

If, EM radiation of intensity I_0 is incident on a material and the material absorbs a certain amount of light. Then the intensity of the radiation after transmission through the material is attenuated. The relation between the intensities of incident and transmitted radiation, the concentration (*c*) and the path length (*l*) of the material medium though the radiation undergoes transmission is given by **Beer-Lambert's law**.

Consider a transparent material of length (l), a light of intensity I_0 is incident in the sample. The intensity of the transmitted light is I. For a medium of constant length and having a constant concentration of light absorbing species, the intensity of the transmitted light remains a constant. The mathematical relation is given by the following equation.

$$T = \frac{I}{I_0} - - - - - - - (1)$$

Where, *T :* transmittance, I_0 *:* intensity of the incident light, and I : intensity of the transmitted light.

To calculate the amount of light that is absorbed by the material, a term called **absorbance** is defined. It is given by the following mathematical relation

$$A = log \frac{I}{I_0} - - - - (2)$$

A major application of the Beer-Lambert's law is to calculate the concentration of an absorption specie in a given sample. Having a prior knowledge of which specie in the given sample is responsible for the absorption of light, there by knowing its molar absorptivity (ϵ). Its concentration in the given sample can be calculated form the following relation.

$$c = \frac{A}{\epsilon l} - - - (3)$$

Where, A: absorbance, *l:* length of the sample, (ϵ): molar absorptivity, and *c*: is the concentration,

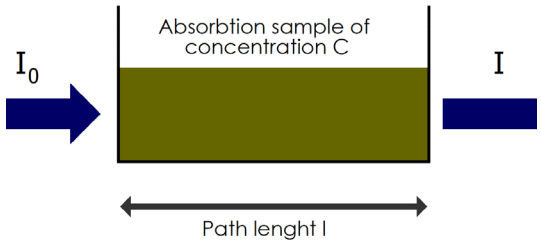


Figure 1: Absorption of light by the sample

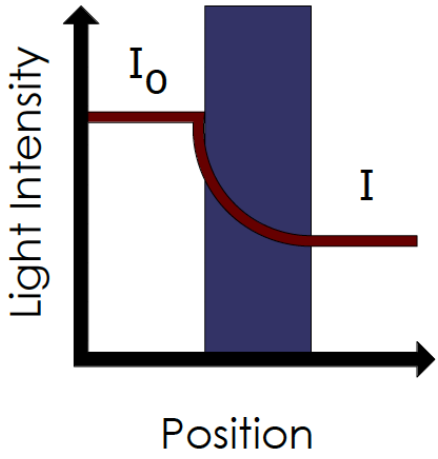


Figure 2: Change in the intensity of the light as undergoes transmission through a medium.

NOTE : The effects of scattering by the same sample and reflection of light by the cuvette are ignored

5. Equipment

Sr. No.	Equipment	Specifications	Quantity
1	Optical Bench Set 0.8m	**KSCIOB1**	**1**
2	Light Source Holder	**KSCIHA001**	**1**
3	Polarizer Holder	**KSCIHA004**	**1**
4	Analyzer Holder	**KSCIHA006**	**1**
5	Cuvette Holder	**KSCIHA025**	**1**
6	Light Sensor Holder	**KSCIHA510**	**1**
7	Cuvette	**KSCIAC006**	**1 pair**
8	Regulated DC Power Supply	**KSCIPSLS**	**1**
9	Adjustable Collimating Slit Holder	**KSCIHA012**	**1**
10	Data Processor	**KSCIDP1**	**1**

6. Safety Instruction

- Optical bench and power supplies are heavy, handle it with care.
- Cuvettes need to be handled delicately while placing and removing from the setup.

7. Experimental Setup

- Place the optical bench on a flat horizontal surface and use the sprit level to adjust it so that it is perfectly horizontal to the surface of the work bench.
- The current experiments requires 6 uprights. Place the uprights on the optical bench and tighten it to the bench using the side lock screw.
- Place the components required for the current experiment on the uprights (in the order given in the figure 3 from: L-R). Connect the light source to the power supply.
- The intensity of the light incident on the cuvette can be controlled by adjusting the relative angle of between the polariser and analyser.
- Place the cuvette in the cuvette stand with its transparent sides in aligned to the optical axis.
- Turn on the power supply and check if the light passing through the polariser-analyser, the slit and the empty cuvette is falling on the light sensor (by checking light sensor value on the data processor).
- Do not disturb the position of the light sensor during the experiment.

8. Experiment

- Provide appropriate voltage to the light source, adjust the slit such that, the light falls on the central region of the cuvette.
- The intensity of the light incident on the cuvette is controlled through the polarizer.
- Measure the intensity of the light transmitted through the empty cuvette. This value is referred to as I_0 . Do not alter the positions of the uprights after the I^0 is measured.
- Fill the cuvette with the solution of known concentration of copper sulphate (not included) and measure the intensity of the light after it undergoes transmission through the sample. This is I.
- Repeat the process for different concentrations of the solution.

Note

- The cuvette has to be rinsed thoroughly with distilled water. Every time before filling it with a solution whose absorption has to be determined.
- The transparent faces to the cuvette should be aligned along the optical path.
- The transparent sides of the cuvette should be cleaned with a clean tissue paper before each measurement. Touching the transparent sides of the cuvette should be avoided.
- The light sensor has optimal detection capability between 400 to 2000 lux. Therefore, the experiment is best to be conducted with the light intensity (I_0) in the above mentioned range.

9. Tabulation

Concentration of the sample	**Intensity of the transmitted light (I)**	$\frac{I_0}{I} = Relative-itensity$	**Log(Relative intensity)**

Value of I_0 = _____

Length of the sample = _____

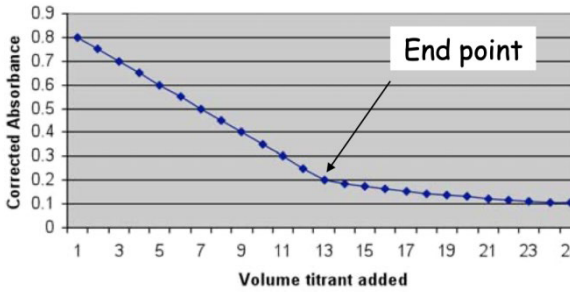
Light intensity transmitted through a sample of unknown concentration. _____

10. Applications

In spectrophotometry, Beer-Lambert's was is very essential for the analysis of the given sample. One advantage here is, there is no need for extensive pre-processing of the given sample. A Few examples of applications of Beer- Lambert's law are given below.

1. The Determination of bilirubin in blood plasma samples: With the knowledge of the absorption spectrum of pure bilirubin and its molar absorbance.Measurements of transmitted light intensities are made at one specific wavelength that is unique for bilirubin. The results can be used to determine concentration in the particular substance sample.

2. Photometric titration: If the analyte has absorbance in the UV/vis spectral region, a spectrometer can be used to observe the progress of the titration, to find out the equivalence point



11. References

- Photometric titrations: J. B. Headridge, Proceedings of the society of analytical chemistry, https://pubs.rsc.org/en/journals/journalissues/sa#!issueid=sa1965_2_2&type=archive&issnprint=0037-9697

- Beer-Lambert's law http://blamp.sites.truman.edu/files/2012/11/322-UV-Vis-Techniques.pdf

12. Appendix

Appendix A: Sample Reading

Sample: Copper Chloride

I_0 = 800 lx

Concentration of the sample	**Intensity of the transmitted light (I) lx**	$\frac{I_0}{I} = Relative-itensity$	**Log (Relative intensity)**
0.05	698	1.146131805	0.1363926249
0.1	650	1.230769231	0.2076393648
0.2	585	1.367521368	0.3129998804

Light intensity after transmission though a sample of unknown concentration: 670 Lx

Intensity of the transmitted light (I) lx	$\frac{I_0}{I} = Relative-itensity$	**Log (Relative intensity)**
670	1.194029851	0.1773340153

The concentration of the unknown sample can be obtained by drawing an intercept from the relative intensity axis to the curve and reading the corresponding value on the concentration axis.

From this data, the concentration of the unknown sample was estimated to be **0.087 molar.**

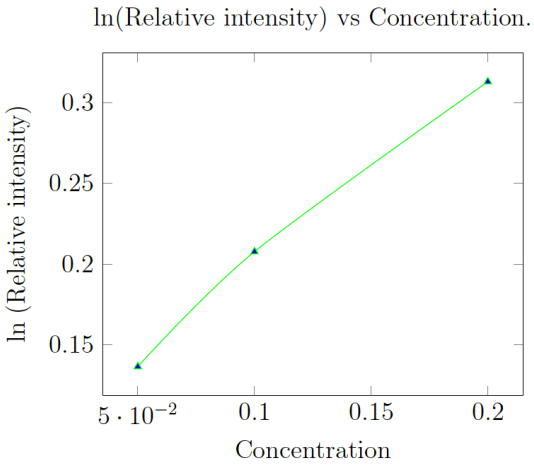


Figure 5: Graph for Copper chloride

Appendix B: Preparation of a primary standard solution

A procedure to prepare a standard solution of **0.1M** Potassium Dichromate of volume 500 mL.

1. Accurately weigh 14.7g of Potassium Dichromate which has been dried in an oven at 110oC for 3 hrs and cooled in a desiccator for 30 minutes into a beaker.
2. Dissolve the potassium dichromate by adding a small volume of distilled water to the beaker. Transfer the solution quantitatively, with the aid of a glass funnel and stirring rod, to a clean 500-mL volumetric flask.

Note: To ensure that the potassium dichromate solution is transferred quantitatively, let the solution drain as completely as possible from the beaker into the funnel. Then place a small volume of distilled water into the beaker, rinse all the inside surface that had contacted the solution, and add the rinse solution to the volumetric flask. Two or three repetitions should be sufficient if each drainage has been as complete as possible and the solution has not beaded on the surface of the funnel due to improper cleaning.

3. Add distilled water to the volumetric flask to bring the solution up to the calibration

mark, stopper the flask, and mix the solution thoroughly.

Note: Since beading of solution on the inside of the neck of the volumetric flask will

make it impossible to obtain an accurate adjustment of volume, initially clean the

flask thoroughly and check for beading of the distilled water used to rinse the flask

From the weight of potassium dichromate used, calculate the concentration of the solution. Be sure to label the volumetric flask containing your standard solution.

1. To make solution of 0.05M potassium Dichromate of volume 500 ml.

Take a 500 ml volumetric flask, fill it half with 0.1 M solution and the rest of the volume with distilled water up to the mark on the volumetric flask. Now the resulting solution is of 0.05 M concentration.