Measuring a chemical compounds concentration based on Beer's law with the IndiGo spectrometer

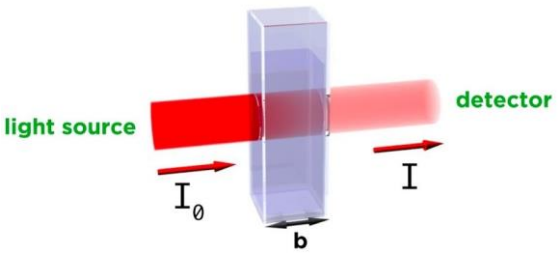
Introduction

Many applications require to measure the concentration of a specific chemical product, the analyte, in a solution. The most common technique is called titration and it relies on the controlled addition of a reagent. But it is time-consuming and requires the use of laboratory glassware, which makes it a technique limited to the laboratory environment.

Another method relies on spectroscopy, the study of how light interacts with matter. Spectroscopy is contactless, does not require laboratory glassware and it can be performed directly through a sealed vial. It is based on the idea that a highly concentrated solution absorbs more light than a non-concentrated one. This is the basic principle of Beer's law which states that there is a direct linear relationship between the absorbance of a solution and the concentration of its analytes. Beer's law can be expressed as:

$$A = \varepsilon \times b \times C$$

where A is the absorbance, ε is the molar absorption coefficient (which quantifies how much a given species absorbs a given wavelength of light), b is the optical path length (usually the width of a cuvette), and C is the concentration.



Absorbance is measured by comparing the intensity of the beam of light entering the sample (I_0), and the intensity coming out (I). Absorbance can then be expressed by:

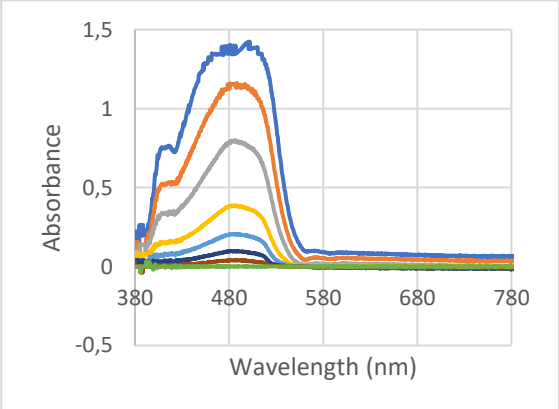
$$A = \text{Log}\,(I_0/I)$$

Given the molar absorption coefficient and the optical path length are known, it can be derived that the concentration can be measured directly from the absorbance measurement.

Building the model

As an example, we applied this principle to a solution containing Vitamin C colored with an orange pigment in a way that the pigment concentration perfectly correlates with the Vitamin C concentration. The pigment strongly absorbs light at 480 nm.

The user first records spectra showing absorbance at different known concentrations.



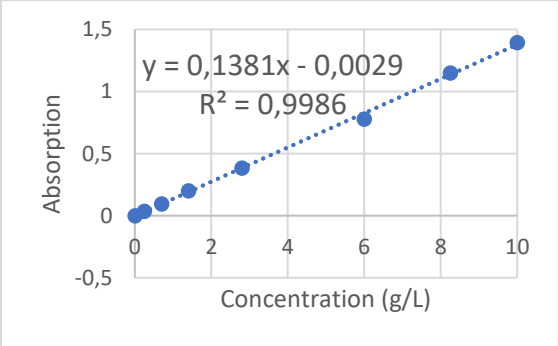
The absorbance is obtained from I_0, which is the intensity showing on the spectrometer at 480 nm on a blank solution (when no pigment is present, for instance a cuvette with distilled water only), and I, the intensity measured by

the spectrometer at 480 nm for a given solution at a known concentration.

The data is reported in the table below:

Concentration	Absorbance
0 g/L	0
0,25 g/L	0,0365938
0,7 g/L	0,09526807
1,4 g/L	0,19975518
2,8 g/L	0,38285134
6 g/L	0,77815125
8,25 g/L	1,15053715
10 g/L	1,3935752

The data can then be plotted in order to build a calibration curve showing Absorbance at 480 nm vs. Vitamin C concentration. In the graph below, one can check that the absorbance shows a perfectly linear relationship with concentration, as expected from Beer's law. This linearity reflected by a R^2~1 validates the model.



Measuring the concentration of Vitamin C

Once this calibration curve is available and the linearity has been checked, the user can start measuring samples that have unknown concentrations, as long as they fall roughly within the concentration range of the model.

There are a number of applications where measuring the concentration of various chemicals can be important. For instance, in environmental science, it can be vitally important to check that hazardous products are kept below a certain concentration. Many substances are inert below a given concentration but become dangerous above this threshold. An ever-increasing number of norms and regulations are put in place to control that these substances are kept below a certain concentration limit. This is particularly true in the food and drugs industry.

The compact and easy to use design of the IndiGo, combined with the cuvette-holder accessory, offers a great solution for teaching students about the importance of chemical analysis using Beer's law. It is also a powerful and portable spectrophotometer that is battery-operated and which can be carried in a small bag for measurements outside a laboratory environment.

Conclusion

Together with the cuvette-holder accessory, the IndiGo is a compact and affordable device for performing spectrophotometric measurements on liquid samples. The GoyaLab mobile app enables analysis with a simple smartphone, which opens the door to measuring chemical concentrations in the field with a portable device. Contact us for more information.