Abstract

I plan to design and construct an inexpensive visible light absorption spectrometer that will be used in classrooms. A spectrophotometer is an instrument used in many science laboratories that measures the amount of light that passes through a sample at a particular wavelength. A spectrometer will be constructed using simple low-cost materials: LEGO blocks, a light emitting diode, a diffraction grating, and a photodiode detector. The instrument will be controlled using a microcomputer with open source software. The software will control the wavelength of light detected and collect/process the signal. The basic spectrometer concept will be implemented in teaching environments allowing students to understand the principles that go into commercial grade spectrometers. The low-cost spectrometer performance will be compared to that of a commercial spectrometer, to evaluate the effectiveness of the low cost instrument. Labs will be developed that utilize the spectrometer.

Construction of an Inexpensive Lego Spectrometer

Visible light absorption spectrometers measure the amount of light that passes through a sample at a particular wavelength. Absorption spectrometers are used in various fields including chemistry, biochemistry, biology, and physics, and they are often used to quantitatively measure the amount of a chemical substance in a sample. The concentration of the solution is determined by measuring the amount of light that passes through the sample and comparing that concentration to a known standard. At a fundamental level absorption spectrometers consist of a light-source, a sample holder, a dispersing element to separate the light by wavelength, and a detector to measure the amount of light.

The Need

Commercial grade visible light absorption spectrometers are often built for efficiency of use in commercial settings which hides many of the working principles that allow the spectrometer to function and how the data is extrapolated from the sample. At their cheapest, commercial spectrometers cost about $500, with many costing much more than this. The high price prohibits certain schools from utilizing spectrometers in the classroom, but the spectrometer that is being designed in this research project will cost between $50 and $100. Making an affordable spectrometer that also teach the students the basics of spectrometry is the goal of this project because seeing how the instrument works is often lost in “black box” commercial grade spectrometers. Often, students place a sample into the instruments without knowing how the data appears on the screen, which is considered a “black box” instrument, but that is not helpful when it comes to teaching students about the basic principles behind the instrument. With the Lego spectrometer, the workings of the instrument are visible to the student; therefore, they can easily see and understand how the instrument is able to take a sample and extrapolate the data from the sample.

Proof of Concept

Building a spectrometer out of low-cost, readily available materials, LEGOs, has already been done before; therefore, establishing that the concept works. The previous design used a hand operated rotatable arm for mounting the detector (Albert, Todt, & Davis, 2012). In previous implementations, the operator had to use a protractor to set the desired angle in order to acquire the desired wavelength to pass through the detector, and the readings had to be recorded by hand. This process is time consuming, introduced human error into the system, and makes the instrument difficult to use.

The proposed project will use a microcomputer and accompanying software to control a servo motor that sets the desired wavelength and records the data. This streamlines the process and it eliminates human error introduced to the system from misreading the protractor. The microcomputer allows the angle to be set with more accurate measurement, resulting in more accurate data. Also, the microcomputer will control of powering the light emitting diode and reading the voltage across the detector.

After the LEGO spectrometer is constructed, the data from the low-cost spectrometer will be compared to that of commercial grade spectrometers to evaluate the performance of the low-cost instrument. Once the performance of the low-cost spectrometer is satisfactory, several labs will be developed that utilize the spectrometer. The first experiment that could use the new spectrometer would be to quantify iron concentrations in various cereals (Adams, 1995). Another lab could be determining the kinetics of crystal violet fading (Adams, 1995). Finally, the more complex experiment that can use the low-cost spectrometer is Pump-probe spectroscopy of methyl red (Cooksey, 2006). All of these experiments cover a range of chemistry, from analytical to physical chemistry, showing just how important spectroscopy is to the field of chemistry.

Final Product

The beginning steps of this project were learning how to read and write code for the microcomputer open source. Once the software was understood, the instrument was mapped out and constructed using LEGOS and the components necessary for the spectrometer to operate. With the spectrometer constructed and the software understood, the microcomputer software was integrated into the spectrometer, making the spectrometer fully functional. This included writing the appropriate code needed to be able to power the light source, adjust the detector via the servo motor, and power the photodiode detector to collect the data. With the spectrometer, fully functional, a series of diluted dyes were analyzed via the LEGO spectrometer and a commercial grade spectrometer. The comparison of the two spectrometers allowed for adjustments of the LEGO spectrometer to be made, allowing for more accurate data to be collected from the LEGO spectrometer.

References

Albert, D., Todt, M., Davis, H. F. (2012) *Journal of Chemical Education* 89, 1432- 1435.

Adams, P. (1995) *Journal of Chemical Education* 72, 649- 651.

Cooksey, C. (2006) *Journal of Chemical Education* 110, 8613- 8622.