A Low-Cost Quantitative Absorption Spectrophotometer

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Abstract

In an effort to make chemistry and physics instrumentation available to high school chemistry and physics classes, we have designed an inexpensive visible absorption spectrophotometer. The spectrophotometer is constructed using Lego® blocks, a light emitting diode, and optical elements including a lens, slide-mounted diffraction grating, and photodiode detector. The photodiode detector is mounted on a rotatable arm for wavelength selection based on simple laws of diffraction. The design is extremely simple, thereby demonstrating basic physical principles (such as diffraction and absorption of light) that are frequently lost in commercial "black box" instruments. Performance, measured by comparison to a commercial spectrometer, is shown to be sufficiently quantitative to facilitate experiments such as the determination of the pKa of an acid-base indicator.

Key Words

High school, introductory chemistry, Hands-on Learning, UV-Visible Absorption, Spectroscopy, Quantitative Analysis

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Performance of $25 Lego Absorption Spectrometer constructed by Albert, Todt, and Davis (submitted for publication to J. Chem. Ed., Fall 2011).

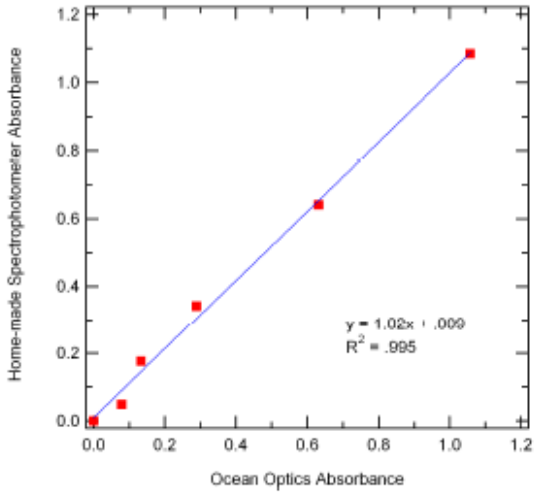

Figure 2: Absorbance measured by Ocean Optics 2000 + vs. Home-made speectrophotometer for the same solutions measured at 590 nm for a basic solution containing various concentrations of Bromothymol blue indicator. Data points represent absorbance measurements, the line represents a least squares fit to the data points.

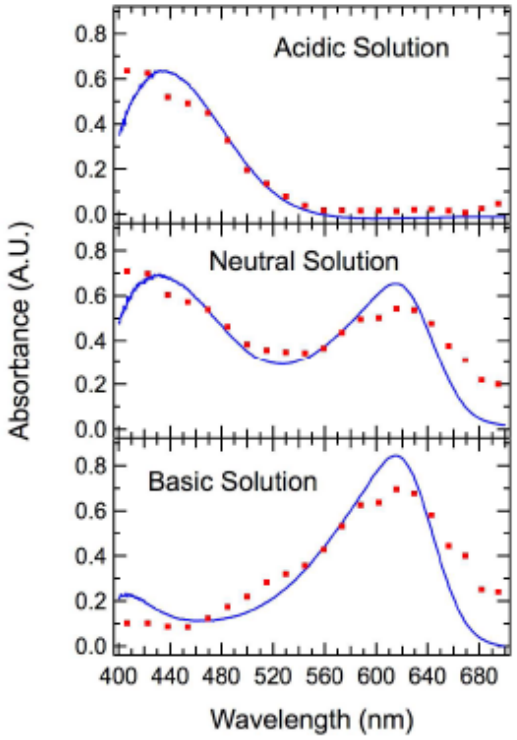

Figure 3: Absorbance of Bromothymol Blue in various pH solutions. Continuous spectra (solid line) were measured using the Ocean Optics 2000+ spectrophotometer. Data points were obtained using our home-made spectrometer

Conclusion

Construction and implementation of quantitative home made spectrophotometers can be a straightforward and inexpensive endevour. For educational purposes it is often desirable to sacrifice a small amount of accuracy in favor of simplicity, reduced cost, and educational value associated with construction of a complete instrument. Our home made spectrophotometer excels in these areas, yielding quantitatively acceptable results while allowing the fundamental scientific principles to be qualitatively apparent. Allowing students to build their own spectrophotometer provides ample opportunity for new variations and improvments in the design. As scientific instruments become more refined, the conceptual aspects of the physical phenomena are often hidden in a box and controlled via a computer, our spectrophotometer aims to eliminate these hidden aspects allowing the user to understand the fundamental qualities of instrument use and design. The low-cost and quantitative results of our spectrophotometer should make hands-on absoroption experiments available to all classroom environments.

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