Development and Calibration of a Low Cost Visible Spectrometer

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Introduction

- Visible spectrometers collect both quantitative and qualitative data in the range of visible light on the electromagnetic spectrum~ 380 -760 nm.
- These instruments measure intensity of radiation of a source as a function of wavelength (or frequency)
- The absorbance of light at each wavelength correlates to concentration according to Beer's Law (Fig. 1) (Robinson, 1995)
- The long term goal - to develop a visible spectrometer accessible to students with readily available and inexpensive components, including Microsoft Excel as software.
- Prototype instrument needs calibration of intensity and wavelength.

Method

- Calibration of the independent variable, wavelength (nm), from the previously existing unit-less pixels.
  - Thymol blue (TB) was used to provide a range of colors with maxima at known wavelengths. (Fig.4)
  - TB is a diprotic acid, with three protonation states. The diprotic acid is red (pH <2), the monoprotic acid is yellow (pH 4-5), and the conjugate base is blue (pH > 8.0).
  - Other intermediate pH-dependent colors are shown in Fig 2.
- Calibration of the dependent variable, intensity of absorbance, uses solutions of water and ethylene glycol as indicated below.

Solution	A	B	C	D	E	F	G
Vol EG (mg)	0	1	2	3	4	5	6
Vol H_2O (mg)	6	5	4	3	2	1	0
% EG	0	16 67	33 33	50	66 67	83 33	100

- Linear correlation of absorbance and concentration from Beer's Law (Fig. 3)

Figure 1. Beer Lambert Equation

$$A = \varepsilon bc$$

- A is the absorbance
- ε is the extinction coefficient
- b is the path length
- c is the concentration

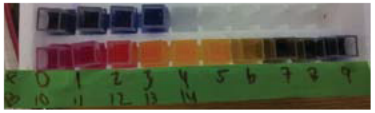

Figure 2. Photograph of Cuvets of pH adjusted Thymol Blue

Photographs of Spectrometer

Figure 5a. MBED Microcontroller, Attached to Visible Spectrometer

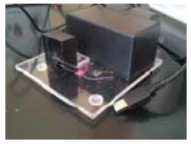

Figure 5b. Source, Sample Holder, and Slit of Spectrometer

Figure 5c. Layout of Spectrometer Components Viewed Through Clear Base

Results

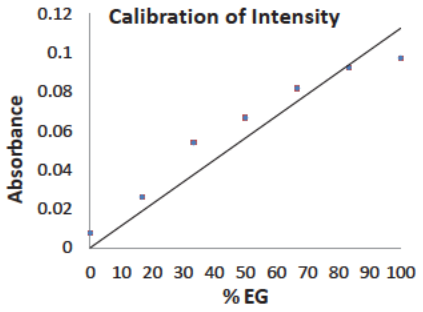

Figure 3. Absorbance of % Ethylene Glycol (EG) in water. Symbols indicate a non-linear correlation. Straight line represents hypothetical Beer's Law relationship.

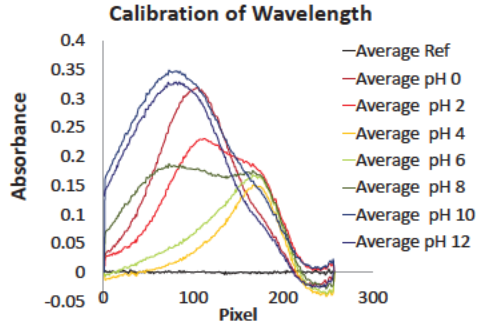

Figure 4. Peak Absorbance of pH Adjusted Thymol Blue

Discussion

- Intensity Calibration
  - Data suggests that absorbance is non-linear (i.e. There is a deviation from Beer's Law)
    - This observation is l kely due to physical properties of instrument, including size of slit width
    - Issues of a shifting baseline were observed, which were likely due to LED source or sensor
- Wavelength Calibration:
  - Pixels associated with peak maxima of Thymol Blue are consistent with expected wavelengths, but further studies are needed
  - Problem of shifting baseline is apparent from spectra in Fig. 4 at pixels greater than 200.
  - The grating position on the spectrometer is adjustable, and it's position needs to be fixed to obtain consistent results.

References

Smith, Eugene T. *Instrumental Methods for Undergraduates*. 10-14. Print.

Robinson, James W. *Undergraduate Instrumental Analysis*. 5th ed. Marcel Dekker, Inc., 1995. 262-263. Print.