Cost-Effective Teacher

A Film Canister Colorimeter

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With the increasing need to use technology in the classroom and laboratory, it is all the more necessary that students understand what the technology is doing. This need has been addressed in a variety of ways (*1–8*). In this experiment, students constructed a very simple colorimeter using a typical black film canister that was slightly modified. A diagram of the apparatus is seen in Figure 1. A green light-emitting diode (LED) served as the combination light source and filter monochromator. An LED was chosen as the light source because of the inherent long life, low cost, and low operating expense of LEDs. Galan et al. have shown a novel design of the coupling of an LED with fiber optics in the construction of a colorimeter (*10*).

With all their advantages, LEDs are polychromatic light sources, which results in deviations from Beer's law (*11*). Compensation for these deviations can be achieved by using a calibration curve if concentration determinations are desired. In this work it is noted that these deviations introduced error into the measurement of the molar absorptivity of permanganate.

A voltage divider circuit composed of a photoresistor in series with a fixed resistor functioned as the detector. The construction and application of this colorimeter is suitable for introductory chemistry, quantitative analysis, and instrumental analysis courses that explore the basic components of spectrometers or colorimeters. The incorporation of the basic voltage divider circuit also makes this experiment applicable for introductory physics courses.

Procedure

A typical black film canister was modified by attaching two 1-in. spacer arms made from ³⁄₈-in. i.d. PVC tubing opposite one another. Without the spacer arms, the light source and detector were too close to one another to reveal changes in absorbance for reasonable concentrations of permanganate. The LED (Radio Shack, 5 mm, V_F = 2.1 V) was secured into one of the arms with a cork stopper and powered by a 9-V battery. A potentiometer (Radio Shack, Bourns 3006P 103 15-turn, 10-kΩ Trimpot) maintained the voltage to the LED at 2.0 V. The photoresistor (Radio Shack, cadmium sulfide photocell) was secured in another cork stopper on the opposite side of the canister. It was placed in series with a 1-kΩ resistor and a 9-V battery. The resistors in series acted as a voltage divider circuit. As light struck the photoresistor, its resistance decreased, which led to an increase in the voltage across the fixed resistor. Therefore the measured voltage followed changes in transmittance in the cuvette. The cuvette was secured in the film canister compartment in a holder constructed from Super Sculpey (Polyform Products Company), a clay-like material that can be formed and heat hardened.

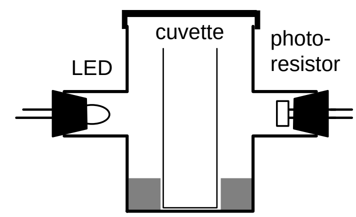

Figure 1. A film canister colorimeter.

Measurements of voltage were substituted for transmittance. To obtain a background signal, a measure of the "dark" voltage (V_{dark}) was made with the canister closed and with the LED off. A voltage measurement corresponding to the 100% transmittance value (V_{water}) was made with the LED on and the cuvette filled with water. Solutions of varying concentration (6.25×10^{-5} M to 5.00×10^{-4} M) were added to the cuvette. After the addition of each solution, the cap was placed onto the canister to provide a stable dark background and the voltage across the fixed resistor was recorded using a multimeter. To calculate the absorbance the following relationship was used:

$$A = -\log\left(\frac{V_{sample} - V_{dark}}{V_{water} - V_{dark}}\right)$$

Hazards

The only potentially hazardous materials used were the oxidizing solutions of permanganate, which should be handled with care and disposed of properly.

Results and Discussion

An Ocean Optics Chem2000 spectrometer was used to determine the maximum emission wavelength of the LED of 565 nm, which corresponds with a wavelength of significant absorbance for permanganate as seen in Figure 2. Figure 3 is a plot of absorbance versus concentration of permanganate solution using the film canister colorimeter. As expected, there is a linear relationship between absorbance and concentration. From these data, the value of molar absorptivity (ε) of the permanganate ion at 565 nm was calculated to be 1014 M^{-1} cm^{-1}. Table 1 is a comparison of the results of the student-constructed colorimeter to those of several commercial models.

The Texas Instruments Calculator-Based Laboratory interface and Vernier colorimeter system was used because it contains a green LED as one of its light sources. The results of this experiment were also compared to results from a commonly

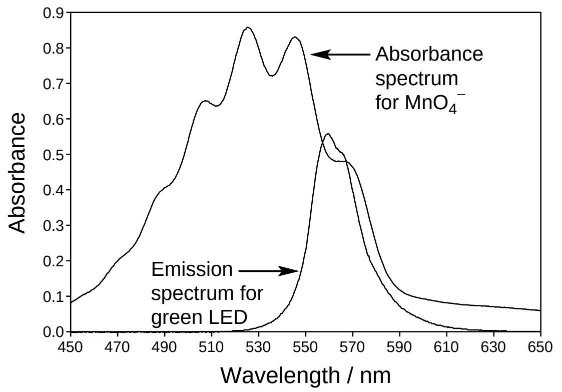

Figure 2. Comparison plot between the absorbance spectrum for permanganate ion and emission of the green LED. NOTE: The emission spectrum was scaled to fit on this plot.

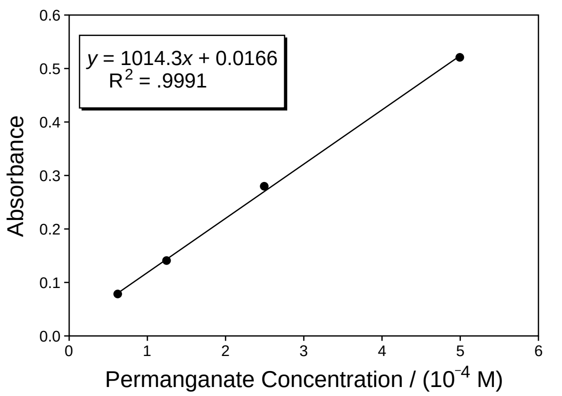

Figure 3. Calibration curve for permanganate using the film canister colorimeter.

Table 1. Molar Absorptivity of Permanganate Ion at 565 nm

Instrument	$\varepsilon/(M^{-1}\ cm^{-1})$	n
Student spectrophotometer	1010 ± 71	6
TI–CBL system	1031 ± 94	6
Spectronic 21	1419 ± 52	4
Ocean Optics Chem2000	1328 ± 27	6

used Spectronic 21 spectrometer. The Ocean Optics Chem2000 spectrometer was used to determine a "standard" value for ε (at 565 nm) because of its superior monochromator having a bandpass of about 1.5 nm. Typical LEDs have FWHM values of about 25 nm, and the spectral slit width for the Spectronic 21 is 10 nm. The differences in the values of molar absorptivity, especially between the two instruments with LED light sources and the other two instruments, is attributed to the LED's polychromatic character (*11*).

Conclusion

This experiment involves constructing a low-cost, low-tech colorimeter that is able to show students all of a colorimeter's elementary components and a fundamental application of spectroscopy. Its incorporation of elementary concepts of electronics makes it an easily accomplished, explained, and understood experiment for chemistry or physics courses.

Acknowledgment

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WSupplemental Material

Detailed instructions for constructing the film canister colorimeter are available in this issue of *JCE Online*.

Literature Cited

1. Wendlandt, W. W. *J. Chem. Educ*. **1976,** *53*, 134.
2. Atkinson, G. F. *J. Chem. Educ.* **1977**, *54*, 66.
3. Delumye, R. D. *J. Chem. Educ*. **1987**, *64*, 630–634.
4. Martin, J. D. *J. Chem. Educ*. **1990**, *67*, 1061–1062.
5. Berka, L. H.; Clark, W. J.; White, D. C. *J. Chem. Educ*. **1992,** *69*, 891.
6. Vitz, E. J. *J. Chem. Educ.* **1994**, *71*, 879–885.
7. Pharr, C. M.; Maimberg, B. J.; Jegla, J. D.; Gammon, S. D. *J. Chem. Educ*. **1996**, *73*, 238.
8. Hamilton, J. R.; White, J. S.; Nakhleh, M. B. *J. Chem. Educ*. **1996**, *73*, 1052.
9. Shiowatana, J. *J. Chem. Educ*. **1997**, *74*, 730–731.
10. Galan, M.; Roldan, E.; Mozo, J. *J. Chem. Educ*. **2001**, *78*, 355–357.
11. Skoog, D. A.; Leary J. J. *Principles of Instrumental Analysis*, 4th ed.; Harcourt Brace: Orlando, FL, 1992; pp 129–131.