

Lightstick Kinetics

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Articles on the use of lightsticks to investigate the temperature dependence of the rate of reaction (k) and the decay in light intensity (I) have appeared in recent issues of this *Journal* and have proven to be interesting experiments at our schools. The chemistry of lightsticks and an additional value for the energy of activation have been described by Shakhshiri (*3*). The following article describes an adaptation of this experiment to use the Calculator Based Laboratory (CBL)¹ interface, a TI-82/83 graphing calculator, and an easily manufactured wooden block as the support system (Fig. 1). The light intensity and temperature of the heated luminescent mixture from the lightstick are simultaneously measured, graphed, and stored by the calculator using the CHEMBIO program from Vernier Software.² Data analysis, consisting of reexpressing the data and graphs and a regression analysis, can be completed on the calculator. Alternatively, the data can be transferred from the calculator to a computer using the Graphical Analysis² software package for analysis and printing of the graphs.

A film canister acts as a light shield to prevent room light from reaching the light sensor. The wooden block is a $5 \times 5 \times 1.5$ " piece of pine cut from commercially available 2×6 building lumber. A $3/4$ " diameter hole 4.5 " deep is drilled in the center of the top 1.5 " edge to hold an 18×150 -mm test tube. A $5/8$ " diameter hole 3 " deep is drilled 1.5 " from the bottom of the adjacent 1.5 " edge to hold the light sensor. A $9/32$ " hole drilled in the center of the bottom of the film canister and in the center of the syringe cap accommodates the temperature probe. A small one-hole stopper with a slit cut in the side can be used in place of the syringe cap. A metal Vernier temperature probe is used, since it does not seem to be affected by the components of the lightstick. A typical lightstick provides enough material for two students. By reheating, the sample can be used for additional trials during the same lab period. If the sample is stoppered and stored in ice or in a freezer, it can be used during other class periods on the same day.

Experimental Procedure

CAUTION: Wear gloves and lab aprons during the sample preparation to protect your hands and clothes. The dye in the lightstick will stain. Safety glasses must be worn.

The light sensor is attached to channel 1 and the temperature sensor to channel 2 of a CBL using Vernier DIN adapters for Vernier sensors with round 5-pin plugs. The CBL is attached to the calculator using the calculator link cable. The light sensor is set at 0-600 lux and the program CHEMBIO is run using the stored calibration for the light sensor. The

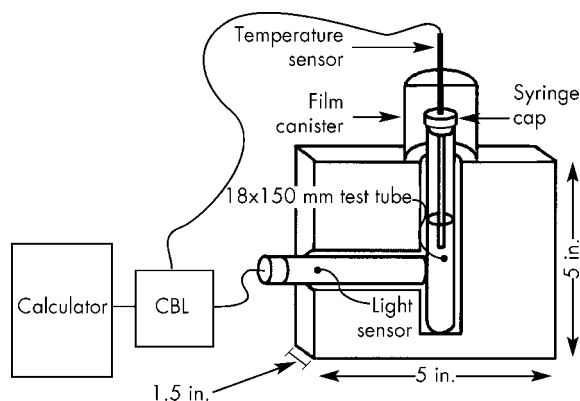


Figure 1. Diagram of the experimental setup using the Calculator Based Laboratory (CBL) interface, a TI-82/83 graphing calculator, and an easily manufactured wooden block as the support system.

temperature sensor must be calibrated using two water baths at different temperatures. The slope and intercept of the temperature calibration line should be recorded, since they can be reentered in the program if the calibration is lost. A 45 °C water bath is prepared for the lightstick. The lightstick is snapped and the contents mixed. Wait 5–10 min. for the short-term light-emitting reaction to finish so only the long-term reaction is being measured. The top is cut off the lightstick and some of the contents are transferred to the test tube using a long-stem Pasteur pipet. Transfer enough liquid to bring the level just above the height of the light sensor hole in the wooden block. This can easily be judged by placing the tube in the block and looking through the light sensor hole. The temperature sensor is placed through the hole in the film canister and syringe cap and adjusted so that it is in the center of the liquid. The test tube is placed in the water bath for a few minutes until the liquid and sensor reach the bath temperature. The test tube is removed from the water bath and the outside is quickly dried. The test tube assembly and the light sensor are inserted into the block with the light sensor against the wall of the tube. A time graph is selected with a data collection of 20 samples at 30-s intervals. Data collection is started. No graphs will be displayed on the calculator during the data collection. At the end of the time period, the CBL transfers the data to the calculator and graphs of light intensity versus time and temperature versus time can be viewed. The data are analyzed on the calculator while the test tube is removed and reheated for additional trials.

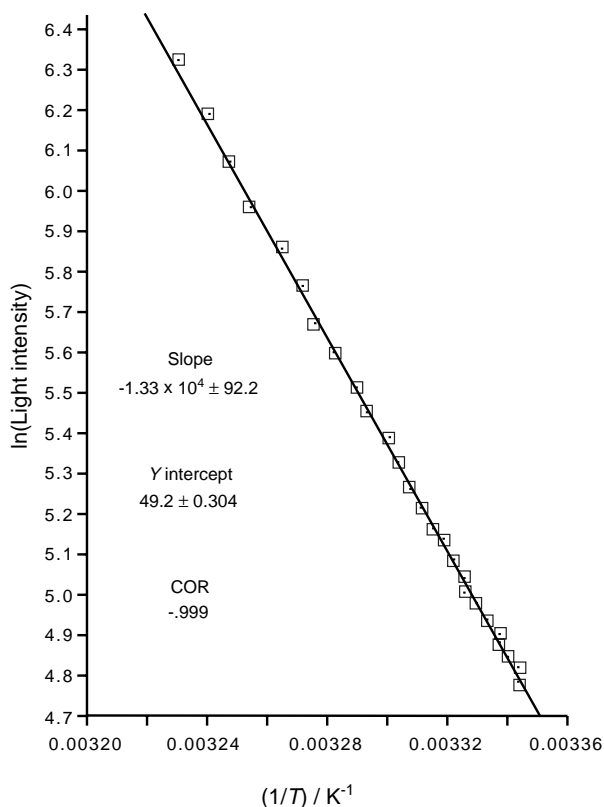


Figure 2. Plot of light intensity vs $1/T$ using an Illumistick in the experiment.

Data Analysis

Additional data lists of the natural logarithm of the light intensity and $1/T$ in K^{-1} are generated. A graph of the natural logarithm of the light intensity versus $1/T$ in K^{-1} is plotted and a linear regression analysis is performed on the data. The slope of the regression line equals $-E_a/R$, allowing the energy of activation to be calculated.

Discussion and Results

Using an Illumistick³ in the experiment gave a good correlation to a straight line (Fig. 2), and a value of 110 kJ/mol for the energy of activation was obtained. Green Ozark Trail⁴ lightsticks and green Snaplight GlowStick⁵ gave values of 69 kJ/mol and 105 kJ/mol, respectively. These values are higher than the 56 kJ/mol reported by Bindel and Shakhshiri for the Cyalume lightstick⁶, but the same reaction system may not be present in these brands. Because of the number of

brands of lightsticks on the market and the difficulty of determining the reaction system being used, it is better to look for agreement in the values from the same brand than to compare the results from different brands.

The value of the experiment lies in its intrinsic interest to students and its incorporation of technology in the high school laboratory. Students readily see that the light intensity, and hence the rate of reaction, decreases with decreasing temperature. The graphical presentation of the relationship between light intensity and temperature may be sufficient for an introductory laboratory, reserving the data analysis to determine the energy of activation for an intermediate or advanced course. The experiment can be performed in the 90-minute period of a typical block schedule or shortened to fit a 50-minute period by precalibrating the temperature probes, preheating the water baths, and having the lightstick mixture transferred to the test tubes.

Acknowledgments

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Notes

^WNotes for the instructor and a student handout including data sheets, explanatory material, and detailed instructions are available on *JCE Online* at <http://jchemed.chem.wisc.edu/Journal/issues/1999/Nov/abs1514.html>.

1. Texas Instruments Customer Support Line, P.O. Box 6118, MS3268, Temple, TX 76503-6118; 1-800/842-2737; www.ti.com/calc.
2. Vernier Software, 8565 S.W. Beaverton-Hillsdale Hwy, Portland, OR 97225-2429; 503/297-5317; www.vernier.com.
3. Illumistick is a trademark of the Coleman Company and is available at sporting goods stores.
4. Ozark Trail is a trademark of the Wal-Mart Company and is available at their stores.
5. Snaplight GlowStick is a trademark of the Omniglow Corporation and is available in different colors from Educational Innovations Inc., 151 River Road, Cos Cob, CT 06807; 203/629-6049. This lightstick uses the Cyalume system.
6. Cyalume is a trademark of Cytec Technology Corp.

Literature Cited

1. Bindel, T. H. *J. Chem. Educ.* **1996**, *73*, 356.
2. Estell, J. K. *J. Chem. Educ.* **1991**, *68*, 225.
3. Shakhshiri, B. Z. *Chemical Demonstrations*, Vol. 1; The University of Wisconsin Press: Madison, 1983; pp 146–152.