

A Microscale Method To Demonstrate the Belousov–Zhabotinskii Reaction

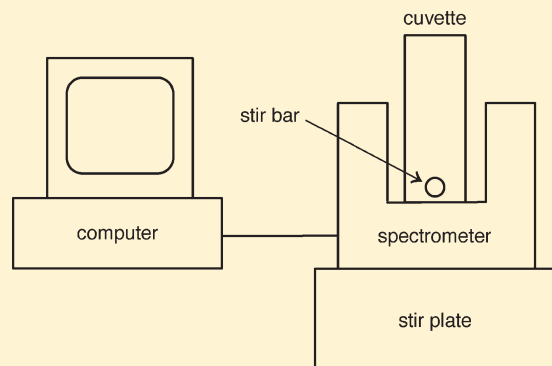
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S Supporting Information

ABSTRACT: A simple method to demonstrate the Belousov–Zhabotinskii reaction using a small volume of solution and a UV–vis spectrophotometer.

KEYWORDS: First-Year Undergraduate/General, High School/Introductory Chemistry, Upper-Division Undergraduate, Curriculum, Demonstrations, Physical Chemistry, Kinetics, UV–Vis Spectroscopy



One of the best known oscillating chemical systems is the Belousov–Zhabotinskii (BZ) reaction, which demonstrates periodic variations in the concentration of intermediates. Oscillations can be observed in a variety of manners from changes in color and pH to redox potential changes. Recently, in a demonstration by Mirholm and Ellervik, an acrylic tank was used to view the color changes on a large scale.¹ Kolb utilized a Petri dish and an overhead projector to demonstrate several oscillating systems.²

The microscale experiment described here follows the chemical oscillations over time by measuring the absorbance using a UV–vis detector. This demonstration gives students the opportunity to actually watch the oscillating profile form. The equipment required is easier to use than the conventional electrochemical method of detection.³ The computer screen can easily be projected onto a larger screen and this demonstration will make the perfect complement to the visible oscillating profiles previously mentioned.^{1,2}

Several articles are available in the literature discussing the mechanism of the BZ reaction.^{4,5} Qualitatively, using this demonstration students will be able to see the induction period of the reaction, the period and amplitude of the profile, and discuss how these features are related to the concentrations of the various chemical species involved in the mechanism.

DESCRIPTION

Oscillating reactions are usually monitored electrochemically. A simpler method, described here, utilizes UV–vis detection. Using a small volume, 3 mL, of solution, the BZ reaction can be monitored with an Ocean Optics spectrophotometer. Students

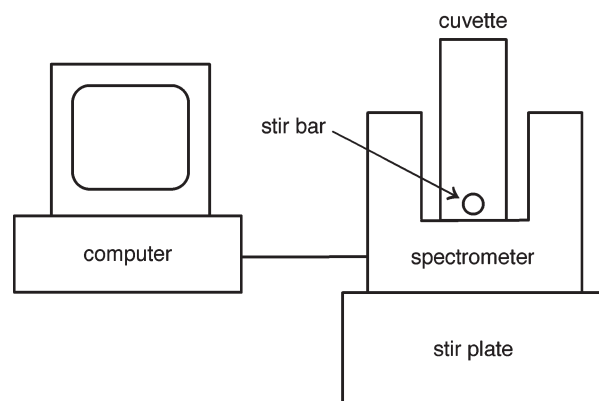


Figure 1. A PC computer interfaced via a USB to the Ocean Optics spectrophotometer.

can see the induction period and several oscillations in a 10 min demonstration. This simple setup requires only an Ocean Optics USB4000 spectrophotometer (model USB-ISS-UV-VIS), Logger Pro 3.7 software, a stir plate, and preparation of three solutions. An apparatus diagram is given in Figure 1. The periodic changes from colorless to yellow observed in this reaction are due to oscillations in the cerium ion concentration between Ce^{3+} and Ce^{4+} . Oscillating profiles are characterized by an initial induction period followed by oscillations with a regular period and amplitude (Figure 2).

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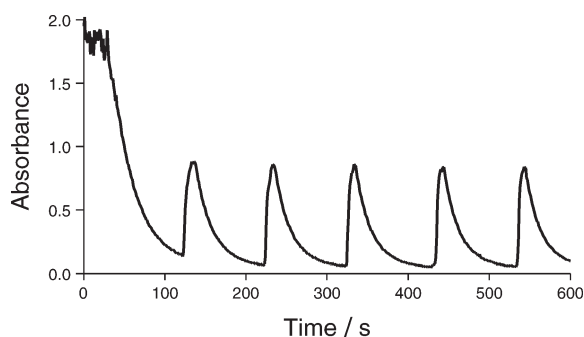


Figure 2. The reaction profile detected at 400.1 nm (0.2 M $\text{CH}_2(\text{COOH})_2$, 0.9 M H_2SO_4 , 0.00553 M $\text{Ce}(\text{NH}_4)_2(\text{NO}_3)_6$, 0.0833 M NaBrO_3 , 0.0197 M KBr).

EXPERIMENTAL DETAILS

The Ocean Optics detector is set up using the Logger Pro software. The detection is set to absorbance versus time. The collection time is set to 600 s, one point per second and the absorbance set to 400.1 nm. The detector is calibrated using deionized water.

Three stock solutions are prepared as follows:

- solution A (0.25 M NaBrO_3): 0.37–0.38 g NaBrO_3 (Alfa Aesar, CAS# 7789-38-0) and deionized water to fill a 10 mL volumetric flask.
- solution B (0.6 M $\text{CH}_2(\text{COOH})_2$, 0.059 M KBr): 0.62 g $\text{CH}_2(\text{COOH})_2$ (Alfa Aesar, CAS# 141-82-2) and 0.07 g KBr (Alfa Aesar, CAS# 7758-02-3) and deionized water to fill a 10 mL volumetric flask.
- solution C (0.0166 M $\text{Ce}(\text{NH}_4)_2(\text{NO}_3)_6$, 2.7 M H_2SO_4): 0.09 g $\text{Ce}(\text{NH}_4)_2(\text{NO}_3)_6$ (Alfa Aesar, CAS# 16774-21-3) and 2.7 M H_2SO_4 (Fisher Scientific, CAS# 7664-93-9) to fill a 10 mL volumetric flask.

One milliliter of solution A and 1 mL of solution B are placed in the cuvette, along with a flea micro stir bar. The sides of the cuvette are wiped with a kimwipe and the cuvette is placed in the detector slot. The stir plate is turned on to a moderate speed, making sure the stir bar is not hitting the sides of the cuvette. One milliliter of solution C is added to the cuvette and data collection is started immediately. The reaction is run undisturbed. Regular oscillations are observed after an induction period of approximately 225 s.

When the reaction is done, the solution is neutralized with baking soda and can be flushed down the drain with copious quantities of water.

HAZARDS

All the chemicals used in this demonstration may cause irritation to the eyes, skin, and other tissue. Particular care should be taken when working with acids. Wear safety goggles at all times. If acid gets on the skin, wash area thoroughly with water. Flush eyes repeatedly if irritated. Potassium bromide may cause upper respiratory tract irritation. Sodium bromate may also be a mucous membrane irritant. Cerium ammonium nitrate is a strong oxidizer and may cause fire in contact with other material. It causes irritation to skin, eyes, and respiratory tract.

ASSOCIATED CONTENT

Supporting Information

A movie of the oscillations. This material is available via the Internet at <http://pubs.acs.org>.

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