CHEM FAX!

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The Yellow and Blue Switcheroo

Introduction

Three colorless solutions are mixed to produce a yellow solution that suddenly turns blue, then fades to colorless and turns yellow again. The color of the solution will continue to oscillate between yellow and blue for 10–15 minutes. If you have never performed an oscillating reaction for your students, don't pass this one up—it's a definite show-stopper!

Chemical Concepts

- Oscillating reaction
- Reaction mechanism

Materials

Hydrogen peroxide solution, 30%, H_2O_2, 29 mL

Potassium iodate, KIO_3, 4.3 g

Sulfuric acid, H_2SO_4, 1 M, 10 mL

Soluble starch, 0.1 g

Malonic acid, $CH_2(CO_2H)_2$, 1.5 g

Manganese(II) sulfate, $MnSO_4 \cdot H_2O$, 0.4 g

Water, distilled or dionized, 300 mL

Beaker, 250-mL

Graduated cylinders, 50-mL, 3

Stirring rod or magnetic stirrer with stir bar

Safety Precautions

Hydrogen peroxide solution is an oxidizer and a skin and eye irritant. Potassium iodate is an oxidizer; the solution is acidified and contains sulfuric acid. Sulfuric acid is severely corrosive to eyes, skin and other tissue. Malonic acid solution is moderately toxic and corrosive to eyes, skin and respiratory tract. The reaction produces iodine which is toxic by inhalation and irritating to eyes, skin, and respiratory tract. Perform the demonstration in a well-ventilated room. Avoid all body tissue contact. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Prepare 8.6% hydrogen peroxide solution by adding 29 mL of 30% H_2O_2 to distilled water and diluting to 100 mL.
2. Prepare 0.2 M acidified potassium iodate solution by adding 10 mL of 1 M sulfuric acid, H_2SO_4, to 90 mL distilled water. Add 4.3 g KIO_3 and stir to dissolve.
3. Prepare a starch–malonic acid–manganese(II) sulfate solution by boiling 100 mL of distilled water. Add 0.1 g soluble starch to 5 mL of the boiling water. Stir. Add the starch paste to the remaining boiling water while stirring. Boil for 5 more minutes. Allow the solution to cool. Add 1.5 g malonic acid and stir. Add 0.4 g manganese(II) sulfate, $MnSO_4 \cdot H_2O$. Stir.

Procedure

1. Use a 50-mL graduated cylinder to measure out 40 mL of 8.6% hydrogen peroxide solution and transfer it to a 250-mL beaker.
2. Use a clean 50-mL graduated cylinder to measure out 40 mL of the 0.2 M acidified potassium iodate solution and add it to the beaker. Stir using a stirring rod or magnetic stirrer.
3. Use the third 50-mL graduated cylinder to measure out 40 mL of the starch–malonic acid–manganese(II) sulfate solution. Add this solution to the beaker and stir.
4. Bubbles will begin to appear. In a short period of time, the solution will turn yellow, then blue, and finally colorless. The yellow to blue to colorless oscillations will continue for about 10 minutes.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Dispose of the reaction mixture according to Flinn Suggested Disposal Method #12a.

Tips

- The reaction can also be done using 6% hydrogen peroxide, although the color changes will not be as sharp.
- A magnetic stirrer can be used to stir the solution throughout the entire demonstration or to mix the solutions beforehand. The mixture does not need to be stirred to observe the oscillations.
- Use only distilled or deionized water. Chloride ions from tap water can contaminate the reaction and stop the oscillations.

Discussion

The yellow–blue oscillating reaction is known as the Briggs-Rauscher reaction and was developed by Thomas S. Briggs and Warren C. Rauscher of Galileo High School in San Francisco. The reaction mechanism is very complex. The color changes observed during the reaction are due to oscillations in the concentration of iodine (I_2) and iodide ions (I^-). The yellow color is attributed to an increase in the I_2 concentration. The dark blue color arises from the formation of a starch–iodine complex as both the I^- and I_2 concentrations increase. The colorless solution is caused by the decline in I_2 concentration and the continued rise in I^- concentration.

The dark blue starch–iodine complex consists of amylose–iodine. Amylose is the linear starch fraction which is composed of chains of 1,4-linked α-glucose units (see Figure 1). The color of the complex, blue-black, comes from the pentaiodide anion, I_5^- formed when the I_2 and I^- concentrations are elevated. Though normally an unstable anion, I_5^- becomes stable as a part of the starch complex.

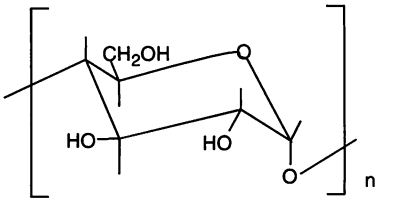

Figure 1.

The overall Briggs–Rauscher reaction is:

$$IO_3^-(aq) + 2H_2O_2(aq) + CH_2(CO_2H)_2(aq) + H^+(aq) \rightarrow ICH(CO_2H)_2(aq) + 2O_2(aq) + 3H_2O(l)$$

The overall reaction may be broken down into two component reactions in which an intermediate compound HOI is generated and then consumed.

$$IO_3^-(aq) + 2H_2O_2(aq) + H^+(aq) \rightarrow HOI(aq) + 2O_2(g) + 2H_2O(l) \qquad \textit{Equation 1}$$

$$HOI(aq) + CH_2(CO_2H)_2(aq) \rightarrow ICH(CO_2H)_2(aq) + H_2O(l) \qquad \textit{Equation 2}$$

The two component reactions are themselves very complex, consisting of ten steps. Iodine and iodide ions are produced as intermediates in various steps of these reactions.

In the proposed reaction mechanism, the concentration of HOI rises and falls, triggering oscillations in the I_2 and I^- concentrations in solution. When the I_2 and I^- concentrations are high, the solution is blue; when I_2 is high and I^- is low, the solution is yellow; and when I_2 is low and I^- is high, the solution is colorless. The oscillations continue until either malonic acid or iodate ions are consumed.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Constancy, change, and measurement

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Materials for *The Yellow and Blue Switcheroo* are available from Flinn Scientific, Inc.

Catalog No.	Description
H0037	Hydrogen Peroxide Solution, 30%, 100 mL
M0091	Malonic Acid, 25 g
M0030	Manganese(II) Sulfate, 100 g
P0063	Potassium Iodate, 25 g
S0122	Starch, Soluble, 100 g
S0228	Sulfuric Acid, 100 mL
AP8660	The Yellow and Blue Switcheroo—Chemical Demonstration Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.