



The Yellow and Blue Switcheroo

Introduction

Your students will think you are the King or Queen of Chemistry when you do this amazing demonstration. Three colorless solutions are mixed to produce a yellow solution which suddenly turns blue and then yellow again. The solution will oscillate between yellow and blue for several minutes. If you've never seen or done an oscillating reaction, don't pass this one up—it's fit for a king or a queen!

Chemical Concepts

- Oscillating reactions
- Reaction mechanisms

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, $\text{CH}_2(\text{CO}_2\text{H})_2$, 1.5 g

Manganese(II) sulfate, $\text{MnSO}_4 \cdot \text{H}_2\text{O}$, 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 potassium iodate acidified 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, $\text{MnSO}_4 \cdot \text{H}_2\text{O}$. 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 potassium iodate acidified 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 to yellow and then to blue and then to colorless. The yellow to blue to colorless oscillations will continue for about 10 minutes.

Disposal

Dispose of the reaction mixture according to Flinn Suggested Disposal Method #12a. Consult your current *Flinn Scientific Catalog/Reference Manual* for proper disposal procedures.

Tips

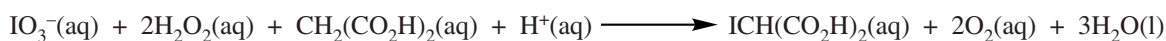
- The reaction can also be done using 6% hydrogen peroxide, although the color changes will not be as sharp. Therefore an 8–9% solution is recommended for this demonstration.
- A magnetic stirrer can be used to stir the solution throughout the entire demonstration or used to simply mix the solutions well at the beginning and then simply enjoy the oscillations. No mixing is required during the oscillations.
- Use only distilled or deionized water. Chloride ions from tap water can contaminate the reaction and stop the oscillations.
- This demonstration can be scaled up but be careful of the iodine vapors.

Discussion

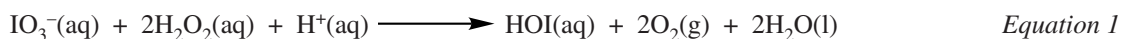
This oscillating reaction is known as the Briggs-Rauscher (BR) reaction and was developed by Thomas S. Briggs and Warren C. Rauscher of Galileo High School in San Francisco. The reaction mechanism is very complex. During the reaction, oscillations occur in the concentrations of iodine and iodide ions. The yellowish color is attributed to the rise in I_2 concentration; the blue-black color of the starch-iodine complex results from the rise in both I^- and I_2 concentrations. 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 is amylose-iodine. The dark blue color of the complex comes from the pentaiodide anion, I_5^- formed when I_2 and I^- concentration are elevated. Though normally an unstable anion, it becomes stable as a part of the starch complex.

The overall BR reaction is:



This reaction consists of two component reactions in which an intermediate molecule HOI is generated and then consumed.



The two reactions are themselves very complex, consisting of ten steps. Iodine (I_2) and iodide ions (I^-) are produced as intermediates in various steps along the reaction pathway.

In the proposed reaction mechanism, the concentration of HOI rises and falls, triggering oscillations in the I^- and I_2 concentrations in solution. When 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 clear. The oscillations continue until either malonic acid or iodate ions are consumed. A detailed explanation of the reaction is included in the attachment.

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.