The Reversible Orange and Blue Reaction

Introduction

Fascinating reaction has it all—bubbling and effervescence, and reversible orange and blue color changes as a precipitate appears and then disappears. Many concepts come into play in this colorful demonstration of competing redox reactions, catalysis, and transition metal complex ions. A great demo all around, especially if your school colors are orange or gold and blue!

Concepts

- Redox reactions
- Catalysis
- Complex ions

Materials

Copper(II) sulfate solution, $CuSO_4$, 1 M, 1 mL
Hydrogen peroxide, H_2O_2, 3%, 240 mL
Potassium sodium tartrate solution, $KNaC_4H_4O_6$, 1 M, 60 mL
Beaker, 1-L (a tall form beaker works nicely)
Graduated cylinders, 10-mL and 100-mL
Hot plate/magnetic stirrer (or hot plate and stirring rod)
Thermometer, –10 to 100 °C

Safety Precautions

Dilute (3%) hydrogen peroxide solution is a weak oxidizing agent and a skin and eye irritant. Copper(II) sulfate is a skin and respiratory tract irritant and is toxic by ingestion. 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.

Procedure

1. Using a 100-mL graduated cylinder, measure 60 mL of potassium sodium tartrate solution into a 1-L beaker.
2. Using a clean 100-mL graduated cylinder, measure 40 mL of 3% hydrogen peroxide. Add the hydrogen peroxide to the beaker while stirring the solution. Continue stirring throughout the rest of the demonstration.
3. Heat the beaker until the solution temperature reaches 50 °C. Turn off the heat. Very little reaction will be apparent at this point.
4. Using a 10-mL graduated cylinder, measure 1 mL of copper(II) sulfate solution and add it to the beaker. Observe the following:
   a. Light blue color due to the copper(II) tartrate complex ion
   b. The reaction starting, indicated by bubbling
   c. The temperature rising to about 80 °C
   d. Vigorous bubbling as additional gas is formed
   e. The color suddenly changing to an opaque orange-gold due to the precipitation of copper(I) oxide (Cu_2O).
5. Add another 40 mL of 3% hydrogen peroxide to the beaker and watch as the orange precipitate dissolves, the blue color returns, and then the reaction suddenly repeats itself (the orange precipitate returns).
6. The sequence of color changes can be repeated about six times by adding more hydrogen peroxide (step 5). The solution must be kept hot, at 70 °C or higher. The reaction can no longer be repeated when the solution becomes too dilute or the tartrate ion is depleted.

Disposal

Please consult your current *Flinn Science Catalog Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The final solution may be disposed of down the drain with plenty of water according to Flinn Suggested Disposal Method #26b.

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Tips

- A 600-mL beaker or 500-mL tall form beaker may be used if a 1-L tall-form beaker is not available.
- A good discussion time is while the solution is heating. Heating the solution takes several minutes—this is a good time to initiate a discussion of the relevant chemistry concepts.

Discussion

The reversible orange and blue reaction demonstrates several fundamental principles in chemistry. It also reveals that "typical" chemistry may be quite unusual! The catalytic decomposition of hydrogen peroxide to produce oxygen gas and water is well known, and many substances, including metals and metal ions, will catalyze the reaction. The decomposition reaction is an example of disproportionation in which hydrogen peroxide is both oxidized, to give oxygen gas, and reduced, to give water. Hydrogen peroxide can act therefore as either a reducing agent or an oxidizing agent, depending on reaction conditions and the substrates involved.

The intense blue color observed when Cu(II) ions are added to the solution containing hydrogen peroxide and tartrate ions signals the formation of copper(II)–tartrate complex ions (Equation 1). As the solution is heated these Cu(II) ions catalyze the decomposition of hydrogen peroxide, resulting in gas bubbles and the liberation of heat. The gas bubbles are a mixture of oxygen and carbon dioxide, suggesting that two competing redox reactions occur simultaneously. In one reaction, hydrogen peroxide is oxidized by copper(II), giving oxygen gas and a bright orange precipitate of copper(I) oxide (Equation 2). In an accompanying reaction, tartrate ions are oxidized by hydrogen peroxide to give carbon dioxide, formate ions, and water (Equation 3). Cu(II) ions catalyze this reaction as well—the oxidation of tartrate by hydrogen peroxide is slow in the absence of a transition metal catalyst. Adding more hydrogen peroxide when these initial reactions have subsided re-oxidizes copper(I) oxide, resulting in the disappearance of the orange precipitate and the return of the blue color of the copper(II) complex ions (Equation 4). The entire cycle then repeats itself until the tartrate ion concentration has been depleted. All of the redox equations given below are written in basic form since it is known that the pH of the reaction mixture increases over the course of the demonstration.

$$Cu^{2+} + 2C_4H_4O_6^{2-} \rightarrow [Cu(C_4H_4O_6)_2]^{2-} \qquad \textit{Equation 1}$$

$$2Cu^{2+} + H2O_2 + 4OH^- \rightarrow Cu_2O(s) + O_2 + 3H_2O \qquad \textit{Equation 2}$$

$$C_4H_4O_6^{2-} + 3H_2O_2 \xrightarrow{Cu(II)} 2CO_2 + 2HCO_2^- + 4H_2O \qquad \textit{Equation 3}$$

$$Cu_2O + H_2O_2 + H_2O \rightarrow 2Cu^{2+} + 4OH^- \qquad \textit{Equation 4}$$

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12

Evidence, models, and explanation
Constancy, change, and measurement

Content Standards: Grades 9–12

Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Acknowledgments

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Reference

Sherman, Marie C. and Deborah Weil, "A Reversible Blue-and-Gold Reaction." *J. Chem. Educ.*, **1991,** *68*, 1037.

Chemicals for *The Reversible Orange and Blue Reaction* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8684	The Reversible Orange and Blue Reaction
P0084	Potassium Sodium Tartrate, 100 g
P0085	Potassium Sodium Tartrate, 500 g
C0246	Cupric Sulfate Solution, 1 M, 500 mL
H0009	Hydrogen Peroxide, 3%, 473 mL

Consult the Flinn Scientific website for current prices.