Thionin — The Two-Faced Solution

Light Energy and Chemical Energy Demonstration

Introduction

A large beaker contains a bright purple solution. The beaker is placed on an overhead projector that is half-covered with aluminum foil—half of the purple solution is sitting on the piece of aluminum foil, the other half is sitting directly on the overhead stage. Switch on the overhead lamp and, in seconds, the solution on the side of the beaker exposed to light turns colorless, while the unexposed side remains purple. The result is sharp and stunning—a two-faced solution! The solution appears to be divided by an invisible line running vertically through the solution. Amazing enough, but switch off the overhead light and the entire process can be reversed.

Concepts

- Reversible reactions
- Oxidation–reduction
- Photochemistry

Materials (for each demonstration)

Aluminum foil
Iron(II) sulfate, $FeSO_4 \cdot 7H_2O$, 2.0 g
Sulfuric acid solution, H_2SO_4, 1 M, 100 mL
Thionin solution, 0.001 M, 10 mL
Water, distilled or deionized, 500 mL
Beaker, glass, 1-L
Balance, 0.001 g
Cylinder, graduated, 10-mL
Overhead projector
Stirring rod, glass

Safety Precautions

Sulfuric acid solution is corrosive to eyes and skin. Iron(II) sulfate is slightly 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.

Preparation

Prepare 0.001 M thionin solution by adding 100 mL distilled water to 0.023 g of thionin. Stir to dissolve. The thionin solution has a poor shelf life; use within one week.

Procedure

1. Mix together the following chemicals in a 1-L beaker: 10 mL of freshly prepared 0.001 M thionin solution, 100 mL of 1 M sulfuric acid, and sufficient distilled water to bring the final volume to about 600 mL. Mix thoroughly.
2. Turn off the room lights and add 2.0 grams of iron(II) sulfate. Stir to dissolve.
3. Place the beaker on the overhead projector stage. Turn on the lamp. Observe that the solution changes from purple to colorless in a matter of seconds.
4. Turn off the lamp and allow the purple color to return.
5. On the overhead projector stage, place a piece of aluminum foil several layers thick. The foil should not cover the entire projector stage.
6. When the solution is purple, place the beaker on the projector stage so that half of the beaker is sitting on the piece of aluminum foil. *(The students should be in direct line with the bisecting line so they can observe the vertical division.)*
7. Turn on the projector lamp, and observe the solution. A distinct vertical division between the purple side and colorless side should be clearly visible. *(The vertical division indicates that the reaction is initiated by light and not heat.)*
8. The reaction can be reversed by turning off the light. The reaction is reversible for several days.

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Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The two-faced solution may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

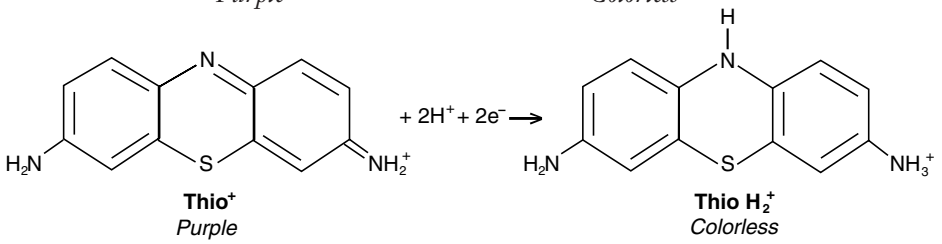
- Prepare the thionin solution fresh. The thionin solution will lose its activity if stored for a long period of time.
- The color change will fade over time from bright purple to a paler shade of blue or purple. This color change may still be effective after one week.
- Direct, bright sunlight may also be used as the light source.

Discussion

Thionin is an organic compound that can exist in two forms, an oxidized form which is purple and a reduced form which is colorless. When a reducing agent such as iron(II) ion (Fe^{2+}) is added to an acidic thionin solution, the protonated thionin molecule ($thio^+$) accepts two hydrogen atoms and is reduced to its colorless form—but only in the presence of an intense light source. The reduction is a photochemical reaction that is catalyzed by light. This demonstration is a dramatic example of the conversion of light energy to chemical energy. The reaction can also be reversed; when the light source is removed the purple color due to the oxidized form of thionin returns.

The demonstration also provides a vivid example of a reversible reaction and equilibrium. The equilibrium is represented by the following chemical equation:

$$\underset{\textit{Purple}}{Thio^+ + 2Fe^{2+} + 2H^+} \rightleftarrows \underset{\textit{Colorless}}{ThioH_2^+ + 2Fe^{3+}}$$



Thio$^+$ *Purple* **Thio H_2^+** *Colorless*

Remember that if one reactant in a balanced chemical equation is oxidized, another reactant must be reduced. Fe^{2+} is oxidized to Fe^{3+} in the forward reaction, while in the reverse reaction Fe^{3+} is reduced to Fe^{2+}. $Thio^+$ represents the monoprotonated form of thionin in acidic solution.

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.

Reference

Flinn ChemTopic™ Labs, Volume 15, Equilibrium; Cesa, I., Editor; Flinn Scientific: Batavia IL (2003).

Materials for *Thionin—The Two-Faced Solution* are available from Flinn Scientific, Inc.

Catalog No.	Description
T0095	Thionin, 1 g
S0202	Sulfuric Acid Solution, 1 M, 500 mL
F0016	Iron(II) Sulfate, 500 g
A0019	Aluminum Foil, 25-ft. roll
AP8845	Thionin–The Two-Faced Solution—Chemical Demonstration Kit

Consult the Flinn Scientific website for current prices.