Colorful Magic

Introduction

Create a variety of colored solutions by mixing the contents of a few beakers back and forth.

Concepts

- Acid–base indicators
- Complexing agents

Materials

Ammonium hydroxide, NH_4OH, concentrated, 2 drops
Iron(III) chloride, $FeCl_3 \cdot 6H_2O$, 0.2 g
Hydrochloric acid, HCl, concentrated, 15 drops
Phenolphthalein solution, 0.5%, 30 drops
Potassium thiocyanate solution, KSCN, 1 M, 20 drops
Sodium fluoride solution, NaF, saturated, 10 mL
Thymolphthalein solution, 0.04%, 30 drops
Beakers, 250-mL, 4
Beaker, 1-L
Graduated cylinder, 10-mL

Safety Precautions

Phenolphthalein and thymolphthalein solutions are flammable liquids and a fire risk. Ammonium hydroxide and its vapor are extremely irritating—especially to the eyes; toxic by ingestion and inhalation; serious respiratory hazard. Dispense in a hood. Iron(III) chloride is a skin and tissue irritant; corrosive. Hydrochloric acid is highly toxic by ingestion or inhalation; severely corrosive to skin and eyes. Sodium fluoride solution is toxic by ingestion and may be a skin irritant. Potassium thiocyanate solution is toxic by ingestion; emits toxic fumes of cyanide if strongly heated. 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 a saturated sodium fluoride solution by dissolving 4.3 g of sodium fluoride in 100 mL of distilled water. Stir.

Prepare 1 M potassium thiocyanate by dissolving 9.7 g of potassium thiocyanate in 100 mL of water. Stir.

Procedure

1. Place four 250-mL beakers in a row across the demonstration table. Place a 1-L beaker behind the smaller ones.
2. In the first beaker, add 30 drops of phenolphthalein indicator solution.
3. In the second beaker, add 30 drops of thymolphthalein indicator solution and 1 drop of concentrated ammonium hydroxide. Swirl the beaker to mix the contents.
4. Weigh out 0.2 g (approximately 1/8 teaspoon) of iron(III) chloride. Add the iron(III) chloride to the third beaker and then add 5 drops of concentrated hydrochloric acid. Swirl the beaker to mix the contents.
5. Using a 10-mL graduated cylinder, measure out 10 mL of sodium fluoride solution. Add the sodium fluoride solution to the fourth beaker and then add 10 drops of concentrated hydrochloric acid. Swirl the beaker to mix the contents.
6. To the large (1-L) beaker, add 500 mL of distilled or deionized water, 1 drop of concentrated ammonium hydroxide and 20 drops of potassium thiocyanate solution. Carefully swirl the beaker to mix the contents.
7. Pour approximately 125 mL of the contents of the large beaker into each of the four small beakers to produce “strawberry soda,” “blueberry soda,” “red wine,” and “water” respectively.
8. Pour the contents of the first three beakers back into the large beaker to produce “red wine.”
9. Refill the first three beakers with “red wine.”
10. Pour the contents of all four small beakers into the large beaker, ending with beaker 4, to produce “water.”

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Disposal

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

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

Tips

- If the solution produced in the second beaker is clear and not blue like it should be, add an extra drop of concentrated ammonium hydroxide.
- If the final solution produced is yellow and not clear, then decrease the amount of iron(III) chloride initially placed in the third beaker.
- Use distilled or deionized water for the best results.

Discussion

The color changes that occur are a result of several processes. Beakers 1 and 2 contain the acid–base indicators, phenolphthalein and thymolphthalein, respectively. Phenolphthalein is colorless in an acidic solution and the solution starts out clear. Thymolphthalein is blue in a basic solution and therefore the solution is initially blue. Beaker 3 contains Fe^{3+} ions and the solution is a pale orange. Beaker 4 is also colorless and contains F– ions in solution. The large beaker contains OH^- ions and the thiocyanate ion, SCN^-, in a clear solution.

As the contents of the large beaker are added to each 250-mL beaker, the following reactions occur.

In beaker 1, the OH^- ions produce a basic solution that reacts with the phenolphthalein to produce a pink solution.

$$OH^-(aq) + HIn \rightarrow H_2O(l) + In^- \qquad \textit{Equation 1}$$

In beaker 2, the addition of OH^- ions keeps the solution blue.

$$OH^-(aq) + HIn \rightarrow H_2O(l) + In^-$$

In beaker 3, the SCN^- ions react with the Fe^{3+} ions in the beaker to produce the red complex ion, $FeSCN^{2+}$.

$$\underset{\textit{orange}}{SCN^-(aq)} + Fe^{3+} \rightarrow \underset{\textit{red}}{FeSCN^{2+}(aq)}$$

In beaker 4, no reaction occurs between any of the ions present, and the solution remains clear.

When the first three beakers are combined in the large beaker, the resultant solution is acidic. The indicators from beakers 1 and 2 become colorless, leaving the solution the "wine red" color of the $FeSCN^{2+}$ ion.

Finally, the combination of all five beakers produces a colorless solution. The thiocyanate ion (SCN^-) in the "red wine" iron(III) thiocyanate ion, $FeSCN^{2+}$, is exchanged with the flouride ion, F^-, in a single replacement reaction to produce the colorless complex ion, iron(III) flouride, FeF^{2+}.

$$\underset{\textit{red}}{FeSCN^{2+}(aq)} + F^-(aq) \rightarrow \underset{\textit{colorless}}{FeF^{2+}(aq)} + SCN^-(aq)$$

Reference

Britton, W. G., *J. Chem. Educ.*, **1962,** *39*, 8, A589.

Shakhashiri, B. Z. *Chemical Demonstrations: A Handbook for Teachers in Chemistry;* University of Wisconsin: Madison, WI; Vol. 1, p. 342.

Materials for *Colorful Magic* are available from Flinn Scientific, Inc.

Catalog No.	Description
A0174	Ammonium Hydroxide, 14.8 M, 100 mL
F0006	Iron(III) Chloride, 100 g
H0031	Hydrochloric Acid, 12 M, 100 mL
P0115	Phenolphthalein Solution, 0.5%. 100 mL
P0226	Potassium Thiocyanate, 1 M, 500 mL
S0316	Sodium Fluoride, 100 g
T0079	Thymolphthalein Solution, 0.04%, 100 mL

Consult the Flinn Scientific website for current prices.