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The Chemical Kidney

The Ions They Are a Changin'

Introduction

Mix water from a large beaker back and forth into five other beakers. Your students will observe a variety of color changes until at the very end the large beaker contains "lemonade."

Concepts

- Complex ions
- Precipitates

Materials

Ammonium thiocyanate solution, 3 M, NH_4SCN , 1 mL	Beakers, 150-mL, 4
Iron(III) chloride solution, 2 M, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, 2 mL	Beakers, 1000-mL, 6
Oxalic acid solution, saturated, $\text{H}_2\text{C}_2\text{O}_4$, 10 mL	Beral-type pipets, 3
Tannic acid solution, 0.6 M, $\text{C}_{76}\text{H}_{52}\text{O}_{46}$, 1 mL	Cylinder, graduated, 10-mL
Water, distilled	Cylinder, graduated, 100-mL
Balance, 0.01 g	

Safety Precautions

Iron(III) chloride is a skin/tissue irritant. Ammonium thiocyanate is toxic by ingestion and dangerous when heated to decomposition (170 °C) or when in contact with acids since fumes containing cyanides may be produced. Tannic acid is toxic by ingestion and inhalation, and is a suspected carcinogen. Oxalic acid is a skin and eye irritant, and is toxic by ingestion with an LD_{50} of 375 mg/kg. Wear chemical-resistant gloves, a chemical-resistant apron, and chemical splash goggles. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

A. Solution Preparation

1. Prepare each solution in a 150-mL beaker.
2. To prepare a 2 M iron(III) chloride solution, dissolve 10.8 grams of iron(III) chloride hexahydrate in 10 mL of distilled water. Dilute to 20 mL with distilled water. Label the solution.
3. To prepare a 3 M ammonium thiocyanate solution, dissolve 2.3 g of ammonium thiocyanate in 5 mL of distilled water. Dilute to 10 mL with distilled water. Label the solution.
4. To prepare a 0.6 M tannic acid solution, dissolve 10 grams of tannic acid in 10 mL of distilled water. Stir until the solution is uniform. Label the solution.
5. To prepare a saturated oxalic acid solution, dissolve 10 grams of oxalic acid in 50 mL of distilled water. Dilute to 100 mL with distilled water. Stir vigorously for several minutes. Label the solution.

B. Laboratory Setup

1. Arrange five 1000-mL beakers in a row across the demonstration table. Set a sixth beaker behind the row.

- Place 25 drops of iron(III) chloride solution into Beaker 1.
- Place 2 drops of ammonium thiocyanate solution into Beaker 2.
- Place 10 drops of ammonium thiocyanate solution into Beaker 3.
- Place 12 drops of tannic acid solution into Beaker 4.
- Using a 10-mL graduated cylinder, measure out 10 mL of oxalic acid solution and transfer it to Beaker 5.
- Fill the last beaker (Beaker 6) with 600 mL of distilled or deionized water.

Procedure

- Pour the water from Beaker 6 into Beaker 1. Swirl to mix the contents. Pour the solution back into Beaker 6. The solution should be pale yellow, like the color of lemonade.
- Pour the solution from Beaker 6 into Beaker 2. Swirl to mix the contents. Pour the solution back into Beaker 6. The solution should be orange-red, like the color of iced tea.
- Pour the solution from Beaker 6 into Beaker 3. Swirl to mix the contents. Pour the solution back into Beaker 6. The solution should be dark red, like the color of wine.
- Pour the solution from Beaker 6 into Beaker 4. Swirl to mix the contents. Pour the solution back into Beaker 6. The solution should be blue-black, like the color of grape juice.
- Pour the solution from Beaker 6 into Beaker 5. Swirl to mix the contents. Pour the solution back into Beaker 6. The solution should be yellow. Use your imagination to describe the final yellow solution!

Disposal

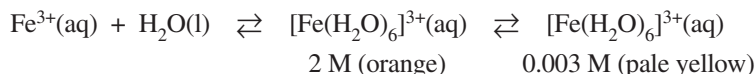
Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The resulting solution may be rinsed down the drain with excess water according to Flinn Suggested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

Tips

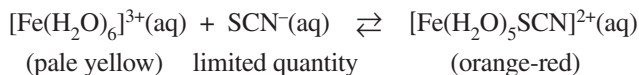
- If the solution in Beaker 1 is too pale, add a few more drops of iron(III) chloride solution.
- Use only distilled or deionized water in order to obtain the best results.
- Be creative when doing this demonstration and make up a funny story to go along with each of the colors. Your story may include a very thirsty person ordering various drinks (lemonade, iced tea, red wine, grape juice) and then because he/she drank too much he/she had to go to the bathroom.
- An alternate idea is to use various types of glasses (i.e., wine glass, beer mug, etc.) in place of the large beakers.

Discussion

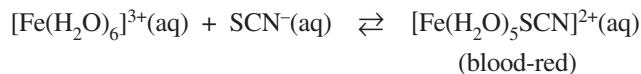
Beaker 1: Hydrated iron(III) ions, $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$, are present in the solution in Beaker 1. The initial solution is orange at a concentration of 2 M. Upon dilution with 600 mL of water from Beaker 6, the solution becomes pale yellow.



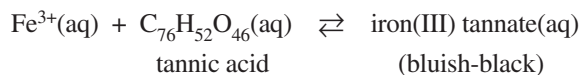
Beaker 2: Thiocyanate ions, SCN^- , are present in Beaker 2 in a limited quantity. When mixed with an excess of hydrated iron(III) ions from Beaker 1, a small amount of iron(III) thiocyanate complex ions are formed.



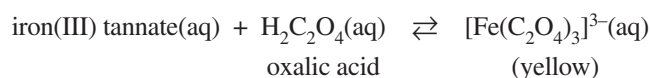
Beaker 3: When additional thiocyanate ions from Beaker 3 are added to Beaker 2, they react with the excess hydrated iron(III) ions from Beaker 2 that did not react in the previous step. The color of the solution becomes a deeper red as more of the iron(III) thiocyanate complex ions are formed.



Beaker 4: When the mixture of iron(III) ions in Beaker 3 is mixed with the tannic acid solution in Beaker 4, iron(III) tannate is formed. The chemical formula of iron(III) tannate is not given because the composition is variable. The formation of iron(III) tannate imparts a bluish-black color to the final solution in Beaker 4.



Beaker 5: An iron(III) oxalate complex is formed when the iron(III) tannate solution in Beaker 4 is mixed with the oxalic acid solution in Beaker 5. This final complex is yellow in color.



Note: The actual formula of this final complex is unknown, but the formula given above is likely. The iron(III) ions may also have waters surrounding them. In fact, by this point, so many components are present in solution that several of them may be contributing to the final yellow color.

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
Evolution and equilibrium

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 of atoms, structure and properties of matter, chemical reactions

References

Rohr, W., Eastchester High School, personal communication.

Shakhashiri, B. Z. *Chemical Demonstrations, A Handbook for Teachers of Chemistry*; University of Wisconsin Press: Madison, WI, 1983; Vol. 1, pp 341–343.

Summerlin, L. R., Ealy J. L. *Chemical Demonstrations, A Sourcebook for Teachers, 1st Ed.*, American Chemical Society, 1985, Vol. 1.

Materials for *The Chemical Kidney* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8461	The Chemical Kidney—Chemical Demonstration Kit
F0006	Iron(III) Chloride, 100 g
A0065	Ammonium Thiocyanate, 100 g
T0002	Tannic Acid, 100 g
Q0005	Oxalic Acid, 100 g
W0001	Water, Distilled, 4 L
GP1040	Beaker, Pyrex, 1000-mL

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