Silver "One-Pot" Demonstration

Solubility Equilibria

Introduction

A series of clear, colorless solutions are added to a beaker, each changing the appearance of the reaction mixture as a precipitate is formed or dissolved. This demonstration is one of the more tolerant one-pot reactions and is best performed in a large, well-illuminated beaker with efficient stirring.

Concepts

- Equilibrium
- Chemical reactions

Materials

Ammonium hydroxide, NH_4OH, 5.0 M, 35 mL
Silver nitrate solution, $AgNO_3$, 0.1 M, 10 mL
Sodium carbonate solution, Na_2CO_3, 0.1 M, 2 mL
Sodium hydroxide solution, NaOH, 0.1 M, 10 mL
Sodium chloride solution, NaCl, 0.1 M, 30 mL
Sodium bromide solution, NaBr, 0.1 M, 10 mL
Sodium thiosulfate solution, $Na_2S_2O_3$, 0.1 M, 50 mL
Sodium iodide solution, NaI, 0.1 M, 10 mL
Sodium sulfide solution, Na_2S, 0.1 M, 10 mL
Water, distilled, 200 mL
Graduated cylinder, 10-mL
Graduated cylinder, 50-mL
Graduated cylinder, 250-mL
Beaker, 600-mL
Magnetic stirrer with stirring bar

Safety Precautions

Silver nitrate is moderately toxic by ingestion, irritating to body tissues, and will stain skin and clothing. Sodium hydroxide is severely irritating to body tissues. Ammonia liquid and vapor are strongly irritating to skin, eyes, and mucous membranes. Dispense only in a fume hood. Sodium sulfide is a body tissue irritant and liberates toxic hydrogen sulfide upon contact with acids. Avoid contact of all chemicals with eyes and skin. Wear chemical-resistant goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the lab. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

Prepare 5.0 M ammonium hydroxide by diluting 33.0 mL of concentrated ammonium hydroxide (14.8 M) to 100 mL with distilled water.

Procedure

1. Add 90 mL of distilled water and 10 mL of 0.1 M silver nitrate to a 600-mL beaker. Place the beaker on a magnetic stirrer at a medium setting, add a stir bar, and start stirring.
2. Add 2 mL of 0.1 M sodium carbonate and observe the off-white precipitate.
3. Add 10 mL of 0.1 M sodium hydroxide to form a light brown, *café-au-lait* precipitate.
4. Add 30 mL of 0.1 M sodium chloride to make a curdy-white solid.
5. Add 35 mL of 5.0 M ammonium hydroxide to dissolve the solid.
6. Add 10 mL of 0.1 M sodium bromide to precipitate an off-white solid.
7. Add 50 mL of 0.1 M sodium thiosulfate to dissolve the precipitate.
8. Add 10 mL of 0.1 M sodium iodide and observe the pale yellow precipitate.
9. Add 10 mL of 0.1 M sodium sulfide to precipitate a black solid.

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Disposal

Consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The final reaction mixture should be filtered. The precipitate may be disposed of according to Flinn Suggested Disposal Method #26a. The filtrate may be neutralized and disposed of according to Flinn Suggested Disposal Method #10.

Tips

- This demonstration may be performed to music as a Sing-a-Long One-Pot demonstration, as developed by the partici pants at the Camille and Henry Dreyfus Institute at Princeton University in 1984. Lyrics to the Silver One-Pot song (by William "Flick" Coleman) are provided. As with any demonstration, it is a good idea to practice beforehand to ensure that you can sync your addition of ions with the music. In this case, specific amounts of reagents are not as crucial, so long as sufficient reagent is added to produce the desired visible change.
- Cyanide ions may be added after step 8 to dissolve the silver iodide to yield a clear (but not necessarily colorless) solution, although this step is omitted for safety concerns:

$$AgI(s) + 2CN^-(aq) \rightleftarrows Ag(CN)_2^-(aq) + I^-(aq) \qquad K_{eq} = 7.9 \times 10^{19}$$

Discussion

This demonstration focuses on solubility rules and equilibrium as different ions are added to the silver "one-pot" in succession, precipitating a variety of colorful solids. The silver nitrate itself is clear and colorless, and the addition of carbonate ions forms the off-white silver carbonate solid:

$$2Ag^+(aq) + CO_3^{2-}(aq) \rightleftarrows Ag_2CO_3(s) \qquad K_{eq} = 8.13 \times 10^{-12}$$ *Equation 1*

Hydroxide ions replace the carbonate ions, and precipitate the light brown *café-au-lait* silver oxide:

$$Ag_2CO_3(s) + 2OH^-(aq) \rightleftarrows 2AgOH(s) + CO_3^{2-}(aq) \qquad K_{eq} = 2.0 \times 10^{-8}$$ *Equation 2*

Chloride ions produce curdy-white silver chloride, notable in its different texture from that of the silver oxide:

$$AgOH(s) + Cl^-(aq) \rightleftarrows AgCl(s) + OH^-(aq) \qquad K_{eq} = 1.78 \times 10^{-10}$$ *Equation 3*

Concentrated ammonium hydroxide solution dissolves the silver chloride with the formation of the complex ion:

$$AgCl(s) + 2NH_3(aq) \rightleftarrows Ag(NH_3)_2^+(aq) + Cl^-(aq) \qquad K_{eq} = 1.3 \times 10^7$$ *Equation 4*

Bromide ions precipitate the off-white silver bromide:

$$Ag(NH_3)_2^+(aq) + Br^-(aq) \rightleftarrows AgBr(s) + 2NH_3(aq) \qquad K_{eq} = 4.27 \times 10^{-13}$$ *Equation 5*

Thiosulfate ions dissolve the silver bromide solid, forming the soluble silver thiosulfate complex ion:

$$AgBr(s) + 2S_2O_3^{2-}(aq) \rightleftarrows Ag(S_2O_3)^{3-}(aq) + Br^-(aq) \qquad K_{eq} = 2.5 \times 10^{13}$$ *Equation 6*

Iodide ions produce the pale yellow silver iodide solid:

$$Ag(S_2O_3)^{3-}(aq) + I^-(aq) \rightleftarrows AgI(s) + 2S_2O_3^{2-}(aq) \qquad K_{eq} = 8.30 \times 10^{-17}$$ *Equation 7*

Finally, the addition of sulfide ions forces the precipitation of silver sulfide:

$$2AgI(s) + S^{2-}(aq) \rightleftarrows Ag_2S(s) + 2I^-(aq) \qquad K_{eq} = 5.5 \times 10^{-51}$$ *Equation 8*

The addition of the many different ions to the same beaker may confuse students, so it is important to reinforce the concept

that all of the ions added to the beaker remain in solution after the final step, and that the new ions simply replace the old ions according to the equilibrium and solubility constants of each reaction.

Silver One-Pot Song *(tune: "Silver Bells")*

Silver nitrate, in your one-pot,
You'll agree is crystal clear;
Adding carbonate makes it milky,
Some might call it babies' beer.
While hydroxide, in its base way
Changes this to – café-au-lait
… in our

Silver pot, silver pot,
Chloride then gives curds and whey,
Silver pot, silver pot,
Ammonia takes them away.

Adding bromide, turns it off white,
Thiosulfate makes it clear;
Now some iodide, turns it yellow,
Skip the cyanide, if you fear.
Then the sulfide, scurvy fellow
Gives us tarnish, we must clean off
… in our

Silver pot, silver pot,
All of the ions still are present,
Silver pot, silver pot,
All of the ions are still there.

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
Evolution and equilibrium
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Silver "One-Pot" Demonstration* activity, presented by Annis Hapkiewicz, is available in *Exploring Equilibrium* and in *Solubility Equilibria*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Silver "One-Pot" Demonstration* are available from Flinn Scientific, Inc.

Catalog No.	Description
S0149	Sodium Hydroxide Solution, 0.1 M, 500 mL
S0237	Sodium Chloride Solution, 0.1 M, 500 mL
A0174	Ammonium Hydroxide, 14.8 M, 100 mL
S0269	Sodium Bromide Solution, 0.1 M, 500 mL
S0150	Sodium Thiosulfate Solution, 0.1 M, 500 mL
S0245	Sodium Iodide Solution, 0.1 M, 500 mL
S0252	Sodium Sulfide Solution, 0.1 M, 500 mL
AP7235	Magnetic Stirrer, Flinn
S0235	Sodium Carbonate Solution, 0.1 M, 500 mL
S0305	Silver Nitrate Solution, 0.1 M, 100 mL

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