A Dry Complex

Transition Metal Complex Ions

Introduction

Show the formation and color of coordination compounds of copper with ammonia and water.

Concepts

- Transition metal complexes
- Reversible chemical reactions
- Lewis acids and bases

Materials

Ammonia gas supply
Copper(II) sulfate, anhydrous, $CuSO_4$, 30g
Copper(II) sulfate, pentahydrate, $CuSO_4 \cdot 5H_2O$, 30g
Water
Beaker, 50-mL
Pipet, thin-stem
Stopper, solid, #2
Syringe with stopcock valve
Test tube holder
Test tube rack
Test tubes, 20 × 150 mm, 4

Safety Precautions

Ammonia is toxic and irritating or fatal by inhalation as well as a moderate fire risk. Use ammonia gas only under an operating fume hood. Be aware of the hot test tubes and only use borosilicate glass test tubes. Be aware of the heat that can be generated by the addition of water to anhydrous $CuSO_4$. Wear chemical splash goggles, a chemical-resistant apron, and chemical-resistant gloves. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Fill two test tubes about ⅓ full with anhydrous $CuSO_4$.
2. Fill two test tubes about ⅓ full with $CuSO_4$ pentahydrate.

Procedure

1. Using a thin-stem pipet, add several drops of water using a thin stem pipet to the anhydrous $CuSO_4$. Observe the temperature and color changes in the test tube.
2. While under a fume hood, use a syringe with a stopcock valve to obtain some ammonia gas. Slowly add the gas to the other test tube with anhydrous $CuSO_4$. Stopper and gently shake the test tube. Observe the formation of the tetraammine copper(II) ion at the top of the test tube. A second sample of ammonia gas may need to be added.
3. As a control, add several drops of water using a thin-stem pipet to the $CuSO_4$ pentahydrate and observe the lack of temperature and color change. Instead a solution is formed.
4. Add ammonia gas to the remaining test tube with $CuSO_4$ pentahydrate. Observe how the top of the $CuSO_4$ is a darker blue than the bottom.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Dispose of the excess copper(II) sulfate according to Flinn Suggested Disposal Method #26a.

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Tip

- If anhydrous copper(II) sulfate is not readily available, it may be prepared by following these steps:
  1. Fill several 20 × 150 mm test tubes about ⅓ full of $CuSO_4 \cdot 5H_2O$.
  2. Hold the test tube at about a 45° angle and gently heat over a Bunsen burner to drive off the water. Be careful—overheating will cause decomposition of the $CuSO_4$.
  3. Use a paper towel to wick off the water that may have formed in the upper portions of the test tube.
  4. Loosely stopper with a #2 solid stopper and allow to cool.

Discussion

Normally the formation of the tetraammine copper(II) ion is done by adding aqueous ammonia to a water solution containing the hexaaquo copper(II) ion. After an initial precipitation of $Cu(OH)_2(s)$ from the basic ammonia solution, further addition of ammonia solution causes the solid to dissolve and the formation of the dark blue tetraammine copper(II) ion (ammonia is a stronger ligand than water). The addition of ammonia gas to anhydrous $CuSO_4$ shows that the formation of the copper(II) ammonia complex ions, $Cu(NH_3)_4^{2+}$, formally known as tetraammine copper(II) +ions, can occur outside of a water solution.

$$CuSO_4(s) + NH_3 \rightarrow CuSO_4(s) \cdot xNH_3 \text{ or } Cu(NH_3)_4^{2+}$$

$$CuSO_4(s) + H_2O \rightarrow CuSO_4 \cdot 5H_2O$$

$$CuSO_4 \cdot 5H_2O(s) + NH_3 \rightarrow CuSO_4 \cdot 5H_2O(s) + CuSO_4 \cdot xH_2O \cdot yNH_3$$

$$CuSO_4 \cdot 5H_2O(s) + H_2O \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq)$$

The reactions can also be used as an example of Lewis acid-base reaction. The Cu^{2+} serves as the Lewis acid and H_2O and NH_3 serve as Lewis bases.

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, interactions of energy and matter

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *A Dry Complex* activity, presented by Jesse Bernstein, is available in *Transition Metal Complex Ions*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *A Dry Complex* are available from Flinn Scientific, Inc.

Catalog No.	Description
C0102	Copper(II) Sulfate, Pentahydrate, 100 g
C0107	Copper(II) Sulfate, Anhydrous, 100 g
GP1005	Beaker, 50 mL
AP1718	Pipet, Thin-Stem, Pkg/20
AP2224	Rubber Stopper, solid, #2, Pound
GP6030	Test Tubes, 20 × 150 mm

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