

Aluminum and Copper

Demonstration and Inquiry



Introduction

There's a lot of pretty chemistry in the reaction of aluminum wire with copper(II) chloride! Burnished copper crystals grow on the wire surface, and the blue color of copper(II) ions slowly fades. What relationships govern the relative amounts of aluminum and copper in this reaction? Can you predict the amount of copper that will be produced and the amount of aluminum that will be used up?

Concepts

- Balanced chemical equation
- Mole ratio
- Stoichiometry
- Single replacement reaction

Background

Stoichiometry—what a strange word! The term is derived from the Greek words *stoicheion*, meaning element, and *metrike*, meaning measure. It is used to describe the mathematical relationships governing the amounts of materials consumed and produced in a chemical reaction. One of the most important lessons in stoichiometry is that the quantities of the reactants and products in a chemical reaction are related to one another on a mole basis. The coefficients in a balanced chemical equation give the relative numbers of moles of each reactant and product involved in the reaction. The ratios of these coefficients represent *mole ratios* that govern the disappearance of reactants and the formation of products.

Inquiry Approach

The purpose of this guided-inquiry activity is to design a graphical method using cooperative class data to compare the amount of aluminum metal that reacts and the amount of copper metal produced in the reaction of aluminum with copper(II) chloride.

Demonstration Questions

1. Observe and record the “signs” of a chemical reaction when aluminum metal is added to a solution of copper(II) chloride. Be as specific as possible!
2. Describe the evidence (observations) supporting the formation of solid copper metal in this reaction. How could the identity of the product be verified?
3. Assuming excess aluminum is used in the demonstration, how can you tell when all of the copper(II) chloride has been consumed?

Inquiry Design and Procedure

1. Form a working group with two other students and discuss the following questions for the reaction of aluminum metal and copper(II) chloride.
 - Write a balanced chemical equation for the reaction of aluminum metal and copper(II) chloride in aqueous solution.
 - What is the relationship between the mass of an element or compound and the corresponding number of moles of the substance?
 - Using the balanced chemical equation for the reaction of aluminum and copper(II) chloride, predict the number of (a) moles and (b) grams of copper solid that should be produced if 27 g (1 mole) of aluminum are used up in the reaction.
2. The demonstration can be modified by dissolving $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ in water and inserting a large piece of aluminum wire. Assuming there is “leftover” wire remaining when all of the copper(II) chloride has reacted, what quantities do you need to measure, calculate, and graph, respectively, to determine the copper/aluminum mole ratio for this reaction?

3. Read the list of *Materials* that may be provided along with the *Safety Precautions* for their use. Write a detailed step-by-step procedure for a cooperative class experiment to determine the mole ratio for the reaction of aluminum and copper(II) chloride. The reaction should be done on a small scale starting with 0.5–3.0 g of $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$, 6–8" of aluminum wire, and 20 mL of water for every gram of copper(II) chloride.
4. What is the advantage of determining the mole ratio graphically using class data rather than calculating it individually for each experiment?
5. Carry out the experiment, record data, and graph the results.

Materials

Aluminum wire, 6–8", 2 pieces

Copper(II) chloride, CuCl_2 , 0.5–3 g

Beakers, 50-mL and 100-mL

Graduated cylinder, 100-mL

Stirring rod

Wooden splint

Safety Precautions

Copper(II) chloride solution is toxic by ingestion. Hydrogen, a flammable gas, may be produced in the reaction. Keep flammable materials away from the reaction. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron, and 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.

Post-Lab Questions

1. Analyze the graph to determine the experimental mole ratio for the amounts of aluminum and copper in the reaction. Compare this value with the predicted mole ratio from the balanced chemical equation, and discuss possible sources of error in the experiment that may have affected the results.
2. Bubbles of gas are often observed in the reaction of aluminum with copper(II) chloride in aqueous solution. (a) What is the gas produced? (b) Write an equation for the formation of the gas from aluminum and water. (c) How would this side reaction affect the experimental mole ratio for the amounts of aluminum and copper?
3. The copper metal produced in the reaction usually turns light green upon drying overnight. (a) What is the likely source of this green color? (b) Based on this observation, explain why the mass of copper may be slightly greater than that predicted based on the mole ratio for the balanced chemical equation.
4. Suggest a possible reason that chemists often use an excess of one or more reactants when trying to make a product rather than combine reactants in the exact stoichiometric mole ratio?
5. The reaction of aluminum with copper(II) chloride is classified as a single replacement reaction. Write a simple, descriptive definition of single replacement reactions based on this example.

Teacher's Notes for Guided Inquiry

Aluminum and Copper

Materials for Demonstration

Aluminum foil, 6" × 12"	Graduated cylinder, 250-mL
Copper(II) chloride solution, 0.5 M, 150 mL	Stirring rod
Beaker, tall-form, borosilicate glass, 600-mL	Thermometer

Safety Precautions

Copper(II) chloride solution is toxic by ingestion. Hydrogen, a flammable gas, is produced in the reaction. Keep flammable materials away from the demonstration area. Avoid contact of all chemicals with eyes and skin. 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.

Demonstration Procedure

1. Measure 150 mL of 0.5 M copper(II) chloride solution in a graduated cylinder and pour the solution into the 600-mL borosilicate glass beaker.
2. Cut a piece of aluminum foil approximately 6" × 12". Loosely roll the foil into a cylinder that will fit into the beaker. (Do not wad up the foil tightly into a ball.)
3. Place the aluminum foil into the beaker, using a stirring rod to push it down into the solution.
4. Observe the “signs” of a chemical reaction (including the temperature).

Disposal

Consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Allow the copper to settle in the bottom of the beaker. If state and local regulations allow, the copper(II) chloride solution may be decanted and washed down the drain with excess water according to Flinn Suggested Disposal Method #26b. Alternatively, copper phosphate may be precipitated from solution by adding excess sodium phosphate. The resulting solid, as well as copper metal and leftover aluminum, may be disposed in the solid trash according to Flinn Suggested Disposal Method #26a.

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

Teaching Tips

- Student preparation is an essential element for success in a student-directed inquiry activity. To ensure a safe lab environment it is critical that the teacher review each group's materials list and their procedure, including any necessary safety precautions, before allowing students to work in the lab.
- In the reaction of aluminum wire with copper(II) chloride, it may be helpful to gently heat the solution at a medium setting or in a hot water bath in order to speed up the reaction. Alternatively, the reaction mixture may be allowed to sit

undisturbed for 24 hours. The aluminum wire should be weighed before and after the reaction.

- The copper metal usually adheres to the aluminum wire and can be scraped or rinsed off. The copper should be washed and then allowed to dry overnight before weighing.

Answers to Demonstration Questions

1. Observe and record the “signs” of a chemical reaction when aluminum metal is added to a solution of copper(II) chloride. Be as specific as possible!

Possible signs of a chemical reaction include color changes, temperature changes, formation of a precipitate, and gas evolution. The reaction of aluminum and copper(II) chloride is very vigorous—the reaction mixture gets very hot as heat is released, the blue color due to the Cu(II) ions fades, the aluminum foil disintegrates, a reddish brown solid appears, and gas bubbles are given off.

2. Describe the evidence (observations) supporting the formation of solid copper metal in this reaction. How could the identity of the product be verified?

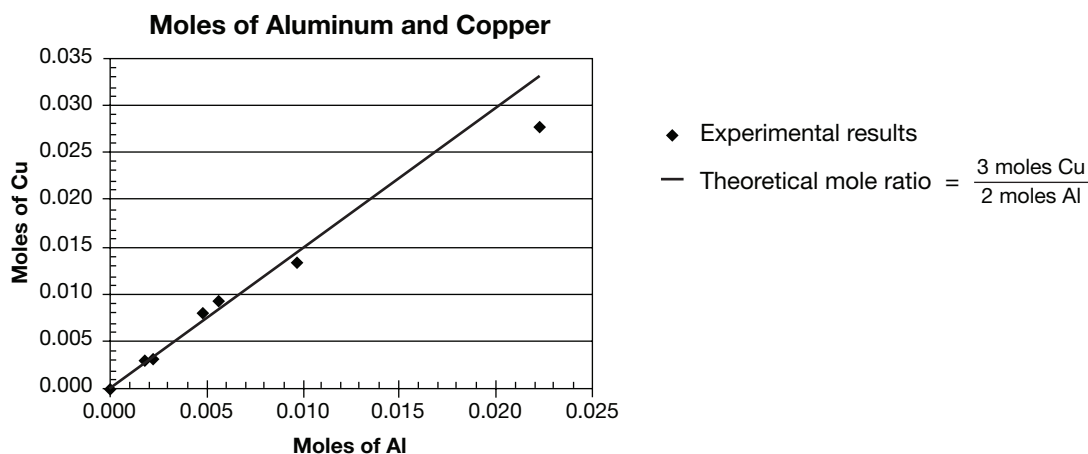
The solid that is formed is reddish brown in color, similar to elemental copper. The identity of the copper could be verified by filtering the solid and determining its density.

3. Assuming excess aluminum is used in the demonstration, how can you tell when all of the copper(II) chloride has been consumed?

The blue color due to Cu²⁺ ions should fade and the solution should turn colorless when all of the copper(II) chloride has reacted.

Sample Data and Results

Mass of CuCl ₂ ·2H ₂ O	Mass of Al	Mass of Cu	Moles of Al	Moles of Cu
0.52 g	0.06 g	0.21 g	0.0022	0.0033
0.52 g	0.05 g	0.19 g	0.0019	0.0030
1.04 g	0.15 g	0.59 g	0.0056	0.0093
1.06 g	0.13 g	0.51 g	0.0048	0.0080
2.52 g	0.26 g	0.85 g	0.0096	0.0134
5.05 g	0.60 g	1.77 g	0.0222	0.0279



The materials for *Aluminum and Copper* are available as a traditional Student Laboratory Kit from Flinn Scientific, Inc.

Catalog No.	Description
AP4678	Leftover Aluminum Wire—Student Laboratory Kit

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