Mole Ratios
Copper and Silver Nitrate

Introduction

The reaction of copper wire with silver nitrate in aqueous solution provides an interesting display of chemistry in action—delicate silver crystals begin to grow on the wire surface and the color of copper(II) ions gradually appears in solution. What relationships govern the relative quantities of reactants and products in this chemical reaction?

Concepts

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

Background

Stoichiometry is the branch of chemistry that deals with the numerical relationships and mathematical proportions of reactants and products in a chemical reaction. One of the most important lessons of stoichiometry is that the amounts of the reactants and products in a chemical reaction are related to one another on a mole basis. Chemical reactions are normally represented by balanced chemical equations. The coefficients in a balanced chemical equation summarize the relative number of moles of each reactant and product involved in the reaction. The ratios of these coefficients represent the *mole ratios* that govern the disappearance of reactants and appearance of products. Knowing the mole ratios in a balanced chemical equation is essential to solving stoichiometry problems.

The reaction of copper metal with silver nitrate solution is a single replacement reaction, represented by the following unbalanced chemical equation.

$$\boldsymbol{a}\ Cu(s) + \boldsymbol{b}\ AgNO_3(aq) \rightarrow \boldsymbol{c}\ Cu(NO_3)_2(aq) + \boldsymbol{d}\ Ag(s)$$

The values of the coefficients a, b, c, and d can be determined experimentally by measuring the mass of copper wire that reacts and the mass of metallic silver that is produced in the above reaction.

Experiment Overview

The purpose of this experiment is to determine the number of moles of reactants and products in the reaction of copper and silver nitrate and calculate their mole ratio. The mole ratio relating the disappearance of copper and the formation of silver metal will be used to write the balanced chemical equation for the reaction.

Pre-Lab Questions

Copper(II) chloride ($CuCl_2$; 0.98 g) was dissolved in water and a piece of aluminum wire (Al; 0.56 g) was placed in the solution. The blue color due to copper(II) chloride soon faded and a red precipitate of solid copper was observed. After the blue color had disappeared completely, the leftover aluminum wire was removed from the solution and weighed. The mass of the leftover aluminum wire was 0.43 g.

1. Calculate the number of moles of copper(II) chloride and of aluminum that reacted.
2. What is the mole ratio of copper(II) chloride to aluminum metal? Express this to the nearest whole number ratio.
3. What happened to the aluminum metal that was consumed in this reaction? Write the formula of the most probable aluminum-containing product.
4. Write a balanced chemical equation for the single replacement reaction of copper(II) chloride with aluminum.

Materials

Acetone, 125-mL, in a 250-mL beaker*
Copper wire, Cu, 25 cm
Nitric acid, HNO_3, 3 M, 3 drops
Silver nitrate, $AgNO_3$, 1.5 g
Balance, centigram (0.01-g precision)
Labeling or marking pen
Beakers, 50- and 100-mL
Erlenmeyer flask, 125-mL
Spatula
Stirring rod
Wash bottle and distilled or deionized water
Wooden splint

*This is an acetone rinse beaker. It should be shared with several groups of students in the classroom. Place the beaker in the hood or in a central location for ease of use.

Safety Precautions

Nitric acid is a corrosive liquid and a strong oxidizer. Silver nitrate is a corrosive solid and is toxic by ingestion; it will stain skin and clothes. Acetone is a flammable liquid; avoid contact with flames and other sources of ignition. Avoid contact of all chemicals with eyes, skin, and clothing. Wear chemical splash goggles and chemical-resistant gloves and apron. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

1. Obtain a clean and dry 50-mL beaker. Zero (tare) the balance with the beaker and carefully add 1.4–1.6 g of silver nitrate crystals to the beaker. *Caution:* Use a spatula to transfer the solid. Do not touch the silver nitrate and carefully clean up any silver nitrate spills in the balance area or on the bench top.
2. Measure and record the exact mass of silver nitrate in the data table.
3. Fill the beaker to the 30-mL mark with distilled water and stir the solution with a stirring rod until all of the solid has dissolved. Rinse the stirring rod with distilled water.
4. Cut a 25-cm piece of copper wire and loosely coil it into the shape shown in Figure 1.
5. Find the initial mass of the copper wire to the nearest 0.01 g and record it in the data table.

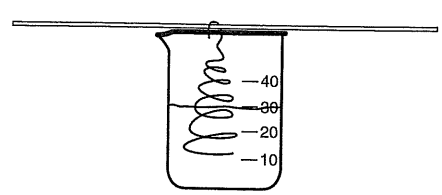

Figure 1.

6. Use a wooden splint to suspend the copper wire in the silver nitrate solution, as shown in Figure 1. The copper wire should not be touching the bottom or sides of the beaker.
7. Carefully add 3 drops of 3 M nitric acid to the beaker. Do NOT stir the solution.
8. Allow the beaker to sit undisturbed on the lab bench for 15 minutes. Try not to jostle or shake the suspended copper wire in any way.
9. Observe the signs of chemical reaction occurring in the beaker and record all observations in the data table.
10. While the reaction is taking place, label a 100-mL beaker with your name and class/period number. Measure and record the mass of this beaker in the data table.
11. After 15 minutes, gently lift the wooden splint to remove the copper wire from the solution.
12. Holding the wire with the wooden splint, place the copper wire above the clean, 100-mL beaker. Rinse the wire with a steady stream of distilled water from the wash bottle. The silver crystals should easily fall off the wire into the beaker. Gently shake the wire and rinse with water until no more silver adheres to the wire. *Note:* Use a total of about 40 mL of distilled water.
13. When all of the silver has been removed, lift the copper wire out of the beaker and place it in the acetone rinse beaker. The acetone will clean the wire surface and allow it to dry more quickly.
14. Remove the copper wire from the acetone rinse beaker and allow it to air dry for 2–3 minutes.
15. Measure and record the final mass of the copper wire. Note the appearance of the leftover wire and record your observations in the data table.
16. Examine the beaker containing the silver product. Most of the silver should have settled into a dense mass at the bottom of the beaker. Carefully decant the liquid into a waste flask to remove most of the water. *Note:* Try not to lose any of the solid in the process.
17. Rinse the solid with 5–10 mL of distilled water from a wash bottle. Decant the rinse water into the waste flask as well.
18. Repeat the rinsing/decanting cycle with a second portion of distilled water.
19. Dispose of the waste solution as directed by your instructor.
20. When all of the liquid has been decanted, place the labeled beaker containing the silver product in a secure location, as directed by your instructor.
21. Allow the solid to dry overnight.
22. When the solid is dry, measure and record the final mass of the beaker plus silver solid.

Name: ____________________

Class/Lab Period: ____________________

Mole Ratios

Data Table

Mass of silver nitrate	
Mass of copper wire (initial)	
Observations—Reaction of copper and silver nitrate	
Mass of empty 100-mL beaker (step 10)	
Mass of leftover copper wire	
Appearance of leftover copper wire	
Mass of beaker plus silver product (step 22)	

Post-Lab Calculations and Analysis

(Show all work on a separate sheet of paper.)

1. Calculate the mass and moles of copper wire that reacted in this experiment.
2. Calculate the mass and moles of silver metal produced in the reaction.
3. Determine the mole ratio—the ratio of the number of moles of silver to the number of moles of copper. *Note:* Round the result to the nearest whole number.
4. Use the silver/copper mole ratio to write the balanced chemical equation for the reaction of copper and silver nitrate.
5. Did all of the silver nitrate react in this experiment? Show all calculations and explain your reasoning.
6. What factors might account for the answer to Question #5?
7. Silver is a precious metal. The price of silver fluctuates daily as it is traded on the open market. Look up the current market value of silver in the financial section of the daily newspaper or on the Internet and record the price. *Note:* The price of metals is usually quoted per Troy ounce, where 1 Troy ounce = 31.0 grams.
8. Calculate the current market value of the silver produced in this experiment.