Mole Ratios
Copper and Silver Nitrate

Introduction

The reaction of copper wire and 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 an products in this chemical reaction?

Background

Stoichiometry is the area 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 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-to-mole* (or simply *mole*) *ratios* that govern the disappearance of the 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:

$$Cu \quad + \quad AgNO_3 \quad \longrightarrow \quad Cu(NO_3)_2 \quad + \quad Ag$$

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

The purpose of this experiment is to determine the number of moles of reactants and products present in the reaction of copper and silver nitrate, and calculate their mole-to-mole ratio. The mole-to-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 left over 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.

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 safety glasses. Wash hands thoroughly with soap and water before leaving the laboratory area.

Materials

Acetone	50 mL beaker
Copper wire	100 or 150 mL beaker
Nitric acid	Toothpick
Silver nitrate	Waste flask

Procedure

1. Obtain a clean, dry 50 mL beaker. Carefully add 1.40-1.60 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 spilled material on the balance or the bench top.*

2. Measure and record the exact mass of silver nitrate to the nearest 0.01 g in your data table.

3. Fill the beaker to the 30 mL mark with distilled water and stir the mixture with a stirring rod until all of the solid has dissolved. Rinse the stirring rod into the beaker with a little distilled water.

4. Take the piece of copper wire and loosely coil it.

5. Find the initial mass of the copper wire to the nearest 0.01 g and record it in the data table.

6. Use a toothpick to suspend the copper wire in the silver nitrate solution. 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 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 or 150 mL beaker with your name and period. Measure and record he mass of this beaker in the data table.

11. After 15 minutes, gently lift the toothpick to remove the copper wire from the solution.

12. Holding the wire with the wooden toothpick, place the copper wire above the 100 or 150 mL beaker. Rinse the wire with a steady stream of distilled water from a 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 another beaker containing acetone. The acetone will clean the wire surface and allow it to dry more quickly. *Note: Several groups can share this same rinse beaker of acetone.*

14. Remove the copper wire from the acetone beaker and allow it to air dry for 3-4 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 water flask as well.

18. Repeat the rinsing and decanting cycle with a second portion of distilled water.

19. Discard the waste water in the large beaker in the fume hood.

20. When all of the water has been decanted, place the labeled beaker containing the silver product on the warming tray in the fume hood.

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 in the data table.

SAMPLE DATA TABLE

Mass of silver nitrate	
Mass of copper wire (initial)	
Observations – Reaction of copper and silver nitrate	
Mass of empty 100 mL beaker	
Mass of leftover copper wire	
Appearance of leftover copper wire	
Mass of beaker plus silver product	

Post-Lab Calculations and Analysis
(Show all work in your lab notebook.)

1. Calculate the mass and moles of copper wire that reacted in this experiment.
2. Calculate the mass and moles of the silver produced in this experiment.
3. Determine the mole ratio – the ratio of the number of moles of silver to the number of moles of copper. Round the result to the nearest whole number.
4. Use the silver/copper mole ratio to write a balanced chemical equation for this reaction of copper and silver nitrate.
5. Did all of the silver nitrate react in this experiment? Show all calculations and explain your answer.
6. Given what you know about copper, silver nitrate and this kind of single replacement reaction, what would you have predicted the balanced chemical equation to be?
7. Explain the possible differences between Question 4 and Question 6.