Mole Ratios
Aluminum and Copper (II) chloride

Introduction

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

Concepts

- Mole ratio
- Stoichiometry
- Balanced chemical equation
- 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 aluminum metal with copper (II) chloride solution is a single replacement reaction, represented by the following unbalanced chemical equation.

$$\boldsymbol{a}\ Al_{(s)} + \boldsymbol{b}\ CuCl_{2(aq)} \rightarrow \boldsymbol{c}\ AlCl_{3(aq)} + \boldsymbol{d}\ Cu_{(s)}$$

The values of the coefficients ***a***, ***b***, ***c***, and ***d*** can be determined experimentally by measuring the mass of aluminum wire that reacts and the mass of metallic copper 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 aluminum and copper (II) chloride and calculate their mole ratio. The mole ratio relating the disappearance of aluminum and the formation of copper metal will be used to write the balanced chemical equation for the reaction.

Pre-Lab Questions

Silver nitrate ($AgNO_3$; 0.98 g) was dissolved in water and a piece of copper wire (Cu; 0.56 g) was placed in the solution. The colorless solution soon began to turn blue and a shiny precipitate of solid silver was observed. After the blue color appeared, the leftover copper wire was removed from the solution and weighed. The mass of the leftover copper wire was 0.43 g.

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

Materials

Acetone in a 250 mL beaker*	50 mL beaker
Aluminum wire	100 mL beaker
Nitric acid, HNO_3	250 mL beaker
Copper (II) chloride, $CuCl_2$	Scoop/spatula
Stirring rod	Electronic balance
Distilled water	

*This is an acetone rinse beaker and will be shared with every group at the table.

Safety Precautions

Nitric acid is a corrosive liquid and a strong oxidizer. Copper (II) chloride is toxic by ingestion. It is an irritant to skin. 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 lab apron. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

1. Obtain a clean and dry 50 mL beaker. Place the beaker on the electronic balance and tare (zero) the balance. Using a scoop/spatula carefully add 1.4-1.6 grams of copper (II) chloride to the beaker.
2. Measure and record the exact mass of copper (II) chloride in the beaker.
3. Fill the beaker to the 30 mL mark with distilled water.
4. Stir the solution with a stirring rod until all of the solid has dissolved. Rinse the stirring rod with distilled water.

5. Loosely coil the piece of aluminum wire into the shape shown in Figure 1.
6. Used the stirring rod to suspend the aluminum wire in the copper (II) chloride solution, as shown in Figure 1. The aluminum wire should not be touching the bottom or sides of the beaker.
7. Carefully add 3 drops of 3.0 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 aluminum wire in any way.

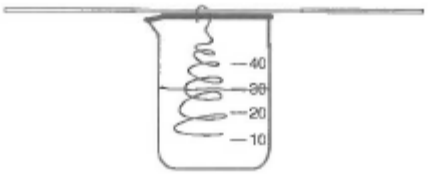

Figure 1.

9. Observe the signs of chemical reaction occurring in the beaker and record all observations.
10. While the reaction is taking place, label a 100 mL beaker with your name and period. Measure and record the mass of this beaker.
11. After 15 minutes, gently lift the stirring rod to remove the aluminum wire from the solution.
12. Hold the wire with the stirring rod, place the aluminum wire above the clean 100 mL beaker. Rinse the wire with a steady stream of distilled water from the wash bottle. The copper crystals should easily fall off the wire into the beaker. Gently shake the wire and rinse with water until no more copper adheres to the wire.
13. When all of the copper has been removed, lift the aluminum 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 aluminum 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 aluminum wire. Note the appearance of the leftover wire and record your observations.
16. Examine the beaker containing the copper product. Most of the copper should have settled into a dense mass at the bottom of the beaker. Carefully decant the liquid into the 250 mL waste beaker to remove most of the water. Try not to lose any of the solid copper in the process.
17. Rinse the solid with 5-10 mL of distilled water from the wash bottle. Decant the rinse water into the 250 mL waste beaker as well.
18. Repeat the rinsing/decanting cycle with a second portion of distilled water.
19. Dispose of the waste solution down the sink with plenty of water.
20. When all of the liquid has been decanted, place the labeled beaker containing the copper product in the drying oven.
21. Allow the solid product to dry overnight.
22. When the solid is dry, measure and record the final mass of the solid copper product.

Post Lab Calculations & Conclusions

1. Calculate the mass and moles of aluminum wire that reacted in this experiment.
2. Calculate the mass and moles of copper metal produced in this experiment.

3. Determine the mole ratio – the ratio of the number of moles of copper to aluminum. Round the result to the nearest whole number.
4. Use the copper/aluminum ratio to write the balanced chemical equation for the reaction of aluminum and copper (II) chloride.
5. Did all of the copper (II) chloride react in this experiment? Explain your reasoning.