

Copper Cycle

Cautions

Nitric and sulfuric acid are toxic and oxidizers and may burn your skin.

Sodium hydroxide is toxic and corrosive and will cause burns to your skin.

Purpose

The purpose of this experiment is to demonstrate a cycle of reactions involving copper. A specific quantity of copper will be transformed through a series of reactions and then recovered as solid copper. A percent recovery will be calculated and sources of loss (or gain) will be identified.

Introduction

Copper is an element that can be found in nature in a variety of different compounds. The most common natural ore is the sulfide, known as chalcocite, Cu_2S . This mineral is an important source of copper metal because it is about 80% copper by weight.

Copper has many important uses due to its chemical and physical properties. Copper is a good conductor of both heat and electricity, hence it can be found in electrical lines or on cooking pots. It is also used in brass and bronze as an alloying agent. Copper oxides are bluish-green in color, making it a common material used for statues, roofs and patina metal siding on houses. Some colorful aqueous copper (II) complexes will be observed in today's experiment.

Chemists use sequences of chemical reactions to obtain a desired product that cannot be prepared in a single step. In a sequence of reactions, the product of an initial reaction is used as a reactant in a second reaction. This process can be repeated until the desired product is obtained.

Just as chemists classify matter based on properties, they also classify reactions based on how they proceed. Different reaction classifications are described in Table 1. A given reaction may belong to more than one category. For example, in the present reaction, copper ions will be transformed into copper metal using zinc metal. This reaction can be classified as a single displacement reaction, but it is also a redox reaction since the copper is gaining electrons from the zinc atoms to produce the copper atoms and zinc ions in solution.

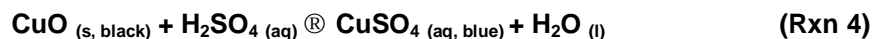
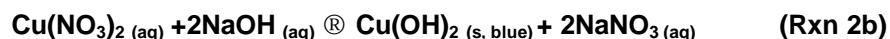
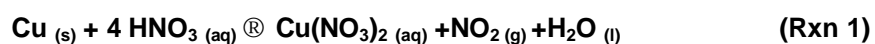
Table 1: Reaction Classifications

Reaction Type	Description
Single displacement	One element replaces a second in a compound
Double Displacement	Cations and anions of two different molecules swap partners
Decomposition	One substance breaks down into two or more simpler substances
Combustion	Reaction between oxygen and another substance, often evolving heat.
Neutralization	combination of an acid and a base
Oxidation/Reduction (redox)	Reaction in which electrons are transferred between two or more substances
Precipitation	Reaction in which two soluble substances combine to form one or more insoluble substances.

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During this experiment copper metal will be transformed into several copper-containing species until solid copper is recovered (Scheme 1). Copper metal will be dissolved in a redox reaction with nitric acid forming a light blue solution containing aqueous copper ions (**Rxn 1**). Once all the copper is dissolved, the excess nitric acid is neutralized using sodium hydroxide (**Rxn 2a**). An excess of hydroxide is added, converting the aqueous copper(II) ions into solid $\text{Cu}(\text{OH})_2$ through a precipitation reaction (**Rxn 2b**). Heating of the precipitate in water decomposes the $\text{Cu}(\text{OH})_2$ into CuO , a black solid (**Rxn 3**). Sulfuric acid is then added to dissolve the copper oxide, forming a light blue solution of Cu(II) ions (**Rxn 4**). Finally, zinc metal participates in a redox reaction with both the copper ions (**Rxn 5a**) and the excess sulfuric acid (**Rxn 5b**) to form solid copper metal and evolve hydrogen gas.

Scheme 1: The series of copper transformation reactions.



Using the initial mass copper and the mass of recovered copper after **Rxn 5** is complete, the percent recovered from this cycle of copper reactions can be calculated using the equation:

$$\% \text{ Recovered} = \left(\frac{\text{Final Mass of Copper}}{\text{Initial Mass of Copper}} \right) * 100$$

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Procedure

Dissolution of Copper

1. Obtain a sample of copper wire or turnings that weighs between 0.25 to 0.35 grams and place in a 250 mL beaker. Record the actual mass of copper used on your data sheet.
2. Obtain 4.0 ml of concentrated nitric acid and **IN THE FUME HOOD** add it drop wise to the copper.
3. Heat the beaker gently—but **NOT** to boiling—under the hood using a hot plate until the copper has completely dissolved and no orange gas is being released.
4. After the copper is completely dissolved slowly add 15.0 mL of distilled water to the beaker and swirl.

Preparation of Copper (II) Hydroxide

5. Add 4 M NaOH with a dropper to the solution containing the dissolved copper ions. Add the NaOH until a precipitate remains in the solution.
6. Once the copper hydroxide has formed allow it to settle.
7. Then add 1 drop of the 4 M NaOH to flow down the side of the flask into the liquid phase while carefully watching to see if any more precipitate is formed. If no more precipitate has formed go ahead but if a precipitate formed continue adding NaOH drop wise until no precipitation occurs and the reaction is complete.
8. Using a piece of red litmus paper test the solution to ensure the solution is basic. Red litmus turns blue in basic solutions.

Conversion of Copper (II) Hydroxide to Copper (II) Oxide

9. Take the solution from Step 8 and add distilled water to obtain a total volume of approximately 75 mL.
10. Boil the solution gently for 7 minutes while stirring. The solid precipitate should change color, which indicates the reaction is proceeding. When the reaction is complete, the liquid containing the will be colorless.
11. Add 7 or 8 drops of phenolphthalein to the solution from Step 10. If the solution becomes red or pink then add 4 M Acetic acid drop wise while stirring until the solution becomes colorless. (Do not add an excess of Acetic Acid or else dissolution of the CuO will occur)
12. Separate the solid and liquid phases by gravity filtration (See figure 1). Rinse the beaker with distilled water using a wash bottle to collect as much of the precipitate as possible.
13. Wash the residue on the filter paper with two separate 3 mL portions of hot distilled water.
14. Leave the solid on the filter paper in the funnel and proceed to step 15. Discard liquid portion down the drain with an excess of water.



Figure 1: Gravity filtration set-up
<http://www.chem.ucalgary.ca/courses/351/laboratory/filtsmall.jpg>

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Conversion of Copper(II) Oxide to Copper(II) Sulfate

15. Obtain two clean 125 mL Erlenmeyer flasks. Place the funnel containing the copper oxide in one flask. Dissolve the copper oxide by adding 8 mL of 4 M Sulfuric acid directly to the residue that remains on the filter paper.
16. Move the filter to the second Erlenmeyer flask and re-circulate the acid solution through the solid on the filter paper. Repeat this step until the entire solid is dissolved.
17. Discard the filter paper in the trash and save the acid solution for the next step.

Recovering Copper Metal

18. **In the hood**, slowly add 0.2 grams of zinc metal to the solution. Swirl the solution to combine. ***At this point, the flasks may be stored until the following week. Consult your instructor. If your flask is colorless the following week, begin with step 20. Otherwise, continue through step 19.***
19. Swirl the solution in the hood until the bubbling stops. If the solution is not colorless, continue adding small 0.1g portions of zinc and swirling after each addition until the bubbling stops. Stop adding zinc once the solution is colorless. Caution: Do not add too much zinc! If excess zinc is present, add HCl.
20. Let the solid copper settle to the bottom of the flask; then slowly decant the liquid portion.
21. Place 15 mL of distilled water in the flask, swirl the flask and allow the solid to settle out of the solution. Carefully decant the liquid portion.
22. Repeat step 21 two more times.
23. Weigh and record the mass of a clean evaporating dish. Transfer the remaining solid copper to this evaporating dish. Allow the solid to settle then slowly remove as much water as possible from the evaporating dish.
24. Obtain a Bunsen burner and beaker that will support the evaporating dish to prepare a boiling water bath. Place the evaporating dish above the boiling water and heat the copper to dryness.
25. Remove the evaporating dish and allow the contents to cool to room temperature. Carefully dry the outside of the evaporating dish.
26. Record the mass of the copper and the evaporating dish.
27. Calculate the mass of copper recovered and the percentage of copper recovered.

Waste Disposal

Dispose of the Copper Metal in the appropriate "RECOVERED COPPER" container.

Clean-Up

Wash all glassware with soap then rinse 3 times with tap water, and once with deionized water.

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Data Sheet

Name: _____

Lab Partner: _____

Procedural Step	Color Observed	Comments and Observations
Dissolution of Copper		
Preparation of Copper (II) Hydroxide		
Conversion of Copper (II) Hydroxide to Copper (II) Oxide		
Conversion of Copper Oxide (II) to Copper Sulfate (II)		
Recovery of Copper Metal		

	TRIAL 1	UNITS
Mass of Initial Copper Sample		
Mass of Copper Recovered		
Percent of Copper Recovered		

