Lab 12-Copper Cycle Lab

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, Cu2S. 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. It is also an alloy agent in brass and bronze as an. Copper oxides are bluish-green in color, making it a common material used for statues, roofs and patina metal siding on houses. 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

- **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.

During this experiment copper metal will be transformed into several copper-containing species until solid copper is recovered.

1. Measure mass of the copper metal in grams _____ grams Cu^o and mass of the Erlenmeyer flask _____ grams

Watch a teacher led demonstration of copper metal reacting with Nitric acid

Balanced Equation #1 - Determine a balanced chemical reaction between copper metal and concentrated nitric acid:

__ $Cu^o_{(s)}$ + __ $HNO_{3\ (aq)}$ → _____ (aq) + _____ (g) + _____ (l)

********Get your balanced equation signed off by your teacher before you go any further* _____ ********
Teacher Signature

Stoichiometry #1a - Determine how many milliliters of 12M nitric acid are needed to react completely with the copper

_____g Cu^o

Stoichiometry #1b- Determine how many moles of aqueous copper(II) nitrate were produced

_____g Cu^o

******Get your stoichiometric calculations signed off by your teacher before you go any further* _____ *******
Teacher Signature

Complete Reaction #1- *Wear Safety Googles, perform experiment in the fume hood, wash hands when finished.*

Copper metal, in a 250mL Erlenmeyer flask, will be dissolved in a redox reaction with excess nitric acid in the burette forming a light blue solution containing aqueous copper ions (Rxn 1). Once all of the copper is dissolved proceed to Reaction #2. If any copper metal still remains then add a small amount of excess nitric acid before continuing.

How many mls of excess nitric acid were there left in the beaker after the reaction stopped?

_____ mL nitric acid added - ____ mL nitric acid needed to react with copper = _____ mL excess nitric acid

Stoichiometry #1c- Determine how many moles of excess nitric acid were leftover

_____excess mL HNO_3

******Get your stoichiometric calculations signed off by your teacher before you go any further* _____ *******
Teacher Signature

2. React any remaining nitric acid with the base sodium hydroxide to neutralize the acid

Balanced Reaction #2a- neutralize the excess nitric acid with sodium hydroxide in a double replacement reaction

__ HNO_3 (aq) + __ NaOH (aq) → _____ (aq) + _____ (l)

Balanced Reaction #2b- React the copper (II) nitrate with sodium hydroxide in a double replacement reaction

_____ (aq) + __ NaOH (aq) → _____ (aq) + _____ (l)

*******Get your balanced equations signed off by your teacher before you go any further* _____ ********
Teacher Signature

Stoichiometry #2a - Determine how many ml of sodium hydroxide need to be added in excess to react with the acid

_____ mols excess HNO_3

Stoichiometry #2b - Determine how many ml of sodium hydroxide to react with copper (II) nitrate

_____ mols $Cu(NO_3)_2$

What is the total minimum number of mL of sodium hydroxide needed? _____

******Get your stoichiometric calculation signed off by your teacher before you go any further* _____ *******
Teacher Signature

Complete Reaction #2- Wear Safety Googles, wash hands when done, add sodium hydroxide slowly until fizzing stops and a light blue solid precipitate forms and settles on the bottom. The solution should be clear, if the solution is still blue then add an additional amount of sodium hydroxide until the final solution is clear.

Stoichiometry #2c - Determine how many mols of copper (II) hydroxide were produced

_____ mols $Cu(NO_3)_2$

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 $Cu(OH)_2$ through a precipitation reaction (Rxn 2b).

3. Copper(II)hydroxide solid precipitate is heated to cause a decomposition reaction to occur

Balanced Reaction #3

_____ (s) → _____ ( ) + _____ ( )

Stoichiometry #3- Determine how many moles of solid product were produced

**Get your balanced equation and stoichiometry signed off by your teacher before you go any further* _____*

Teacher Signature

Complete Reaction #3 Add 100mL of water to the flask and heat solution until all blue turns to black then use a pipette to remove most of the excess aqueous solution but be sure not to lose any of the solid black compound

4. Add excess sulfuric acid to the black solid

Balanced Reaction #4

Stoichiometry #4a- Determine how many mL of 3.0M sulfuric acid needs to be added

Stoichiometry #4b- Determine how many moles of copper (II) sulfate formed

***Get your balanced equation and stoichiometry signed off by your teacher before you go any further* _____*

Teacher Signature

Complete Reaction #4 add sulfuric acid until all of the black solid turns to blue aqueous solution

5. React blue solution with zinc metal

Balanced Reaction #5a react with zinc metal

Balanced Reaction #5b react excess zinc metal with sulfuric acid until fizzing stops

Stoichiometry #5a- how many grams of zinc need to be added? (add zinc in slight excess)

Stoichiometry #5b- how many grams of copper metal should be produced?

**Get your balanced equation and stoichiometry signed off by your teacher before you go any further* _____ **

Teacher Signature

Complete Reaction #5- 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.

Rinse the copper metal several times then drain most of remaining water being careful not to lose any copper. Slowly heat the flask until dry.

Mass of flask and copper _____grams – mass of flask = mass of copper metal _____ grams

Determine percent yield of copper metal recovered:

$$\frac{\text{mass of recovered copper}}{\text{mass of starting copper}} \times 100 = \text{percent yield}$$

If yield is less than or more than 100% account for reasons as to why this may have occurred.

Follow up Questions:

1. What volume of nitrous oxide gas was produced in Reaction #1? Assume @STP _____
2. How many milliliters of water were produced in Reaction #1? _____

The series of copper transformation reactions.

$Cu_{(s)} + 4\ HNO_{3\ (aq)} \rightarrow Cu(NO_3)_{2\ (aq)} + NO_{2\ (g)} + H_2O_{(l)}$ **(Rxn 1)**

$HNO_{3\ (aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaNO_{3\ (aq)}$ **(Rxn 2a)**

$Cu(NO_3)_{2\ (aq)} + 2NaOH_{(aq)} \rightarrow Cu(OH)_{2\ (s,\ blue)} + 2NaNO_{3\ (aq)}$ **(Rxn 2b)**

$Cu(OH)_{2\ (s,\ blue)} + heat \rightarrow CuO_{(s,\ black)} + H_2O_{(g)}$ **(Rxn 3)**

$CuO_{(s,\ black)} + H_2SO_{4\ (aq)} \rightarrow CuSO_{4\ (aq,\ blue)} + H_2O_{(l)}$ **(Rxn 4)**

$CuSO_{4\ (aq,\ blue)} + Zn_{(s)} \rightarrow Cu_{(s)} + ZnSO_{4\ (aq)}$ **(Rxn 5a)**

$H_2SO_{4\ (aq,\ blue)} + Zn_{(s)} \rightarrow H_{2\ (g)} + ZnSO_{4\ (aq)}$ **(Rxn 5b)**