Lab 4: Stoichiometry II

Percent Copper and Formula Weight of a Copper Compound

Introduction

In this lab you will be given an unknown, copper-containing compound for which you must determine the percent copper (Cu) and formula weight. In the “Chemical Compositions of Compounds” lab, you were asked to determine the percent copper in an unknown sample of copper(II) carbonate hydroxide by heating the sample in a crucible and decomposing it to form copper(II) oxide, carbon dioxide, and water. You then used the amount of CuO produced to determine the % Cu in your sample. Since this approach will only work for compounds containing carbonates (CO$_3^{2-}$) or hydroxides (OH$^-$), we will have to use a different method.

In this experiment, the Cu unknowns provided are salts that readily dissolve to form aqueous solutions of the constituent ions. For example, copper(II) sulfate pentahydrate (CuSO$_4$·5H$_2$O) and copper(II) chloride, anhydrous, will dissolve according to the following reactions:

\[
\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(s) \rightarrow \text{Cu}^{2+}(aq) + \text{SO}_4^{2-}(aq)
\]

\[
\text{CuCl}_2(s) \rightarrow \text{Cu}^{2+}(aq) + 2\text{Cl}^-(aq)
\]

In each case, we can use the oxidation-reduction reaction between copper ions and solid magnesium (Mg) to convert Cu$^{2+}$ to Cu(s):

\[
\text{Cu}^{2+}(aq) + \text{Mg}(s) \rightarrow \text{Cu}(s) + \text{Mg}^{2+}(aq)
\]

This is an oxidation-reduction (or REDOX) reaction because it involves the transfer of electrons from the Mg atom to the Cu$^{2+}$ ion, forming solid Cu and Mg$^{2+}$ ions. (REDOX reactions are covered in Chapter 4 of the Zumdahl textbook.) If we ensure that all the Cu$^{2+}$ ions are removed from the solution by adding an excess of solid Mg, we can use the mass of the metallic copper formed to determine the % Cu in the original sample:

\[
\% \text{Cu} = \frac{\text{mass of copper formed}}{\text{mass of copper compound weighed out}} \times 100\%
\]

If the number of Cu atoms in one formula unit of the compound and the % mass of Cu in the compound are both known, then the formula weight of the compound can be calculated:

\[
\% \text{Cu} = \frac{n \text{ (atomic mass of Cu)}}{\text{formula weight of compound}} \times 100\%
\]
where \( n \) is the number of Cu atoms in one formula unit of the compound. For example, the value of \( n \) would be 1 for copper(II) chloride (\( \text{CuCl}_2 \)) and 2 for copper(I) oxide (\( \text{Cu}_2\text{O} \)). You will be told what the value of \( n \) is for your unknown. The atomic mass of Cu can be found on the periodic table and the % Cu is calculated using the mass of your metallic copper and the starting mass of your copper-containing sample, as described above.

Once you have calculated the formula weight of your compound, you can compare your value with the known formula weights for a list of possible compounds and determine the identity of your sample.

The prelab assignment on WebAssign addresses the following:

- \( \text{Cu}^{2+} \text{(aq)} \) is the limiting reagent, so how would you determine what quantity of Mg would be required to ensure an excess if you are given information about the mass and identity of your starting compound?

- What happens to the excess Mg(s) after all of the \( \text{Cu}^{2+} \text{(aq)} \) has been reduced?

- What calculations will you perform using the mass of copper compound weighed out, the mass of metallic copper produced, and the number of copper atoms per formula unit in order to calculate the formula weight of your compound and identify it from a list of possible compounds?

**Helpful information**

- Percent composition and limiting reagents are covered in Zumdahl, Ch 3.

- Oxidation-reduction reactions are introduced in Zumdahl, Ch 4.

- In order to choose the correct answer for question 2c on the prelab, you will need to calculate the formula weight for each of the possible compounds on the list. Naming of compounds is covered in Zumdahl, Ch 2. Additionally, when compounds contain waters of hydration, the mass of those water molecules must be included when calculating the formula weight of the compound. The number of water molecules attached to the compound is named according to the Greek prefixes shown in Table 2.6 in the Zumdahl text. If something is labeled “anhydrous,” that means that there are no waters of hydration on the compound.

For example: Copper(II) acetate pentahydrate is \( \text{Cu} (\text{C}_2\text{H}_3\text{O}_2)_{2} \cdot 5\text{H}_2\text{O} \). When calculating the formula weight for this compound, you would include 1 Cu, 4 C, 16 H, and 9 O.
Safety Considerations

- 6 M HCl is a highly corrosive acid. Use extreme caution when handling this reagent. If you get some acid on you, wash areas of contact with large amounts of water.

- H₂ gas is highly flammable. Small amounts of H₂ will be produced during the reaction between Mg(s) and HCl. Be sure to keep the beaker containing the reaction away from any flames or sparks.

- Be firm, but gentle when using the glass stirring rod to break up the pieces of Mg during the reaction between Mg(s) and Cu²+. Leave the beaker firmly on the countertop rather than holding it in your hand while you perform this step. Not only is broken glass dangerous, but the solution in the beaker contains acid that will spill all over if the beaker is broken.

- Acetone and ethanol are both highly flammable. Be sure to keep away from flames and sparks.

- Acetone is a hazardous chemical, so any solutions containing acetone must be disposed of properly.