Recovery of Copper
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Introduction

In this lab we are going to start with a sample of copper wire. We will then use a sequence of reactions to chemically transform the copper from its metallic form into a series of ionic copper containing species. At the end of the experiment we will then transform the product back to metallic copper.

Theoretically if all of the reactions go to completion we should end with the same mass of copper that we started with. We will calculate the percent recovery of copper and see how well we did. Notice that we are not calling this percent yield because the product is the same as the main reactant.

The first reaction is an oxidation-reduction reaction shown in equation 1.

\[
(1) \quad \text{Cu} (s) + 4 \text{H}_2\text{O}^+ (aq) + 2 \text{NO}_3^- (aq) \rightarrow [\text{Cu(H}_2\text{O})_6]^{2+} (aq) + 2 \text{NO}_2 (g)
\]

This reaction actually occurs in 2 steps. In the first step, the copper (red-brown) is oxidized to copper(II) ions by nitrate ions that the addition of nitric acid (HNO₃) supplies. At the same time, the Nitrate ions (NO₃⁻) are reduced to nitrogen(IV) oxide (NO₂), a brown gas. When all of the copper has been oxidized we perform the second step by diluting the reaction mixture (RM) with water. The addition of H₂O produces hexaaquocopper(II) ions, [Cu(H₂O)₆]²⁺, a blue solution.

Reaction 2 is a double replacement reaction. This reaction utilizes the addition of sodium hydroxide (NaOH) to change the [Cu(H₂O)₆]²⁺ ions into a light blue solid copper(II)hydroxide, Cu(OH)₂ as seen in equation 2. It is important to note that the NaOH can also neutralize any hydronium ions (H₃O⁺) left in solution by excess HNO₃ as seen in equation 3.

\[
(2) \quad [\text{Cu(H}_2\text{O})_6]^{2+} (aq) + 2 \text{OH}^- (aq) \rightarrow \text{Cu(OH)}_2 (s) + 6 \text{H}_2\text{O} (l)
\]

\[
(3) \quad \text{H}_3\text{O}^+ (aq) + \text{OH}^- (aq) \rightarrow 2 \text{H}_2\text{O} (l)
\]

We will be using red litmus paper to monitor the progress of reaction 2. Litmus paper is an acid-base indicator. In an acidic solution the litmus paper will remain red, but in a basic solution the paper will turn blue. When we add NaOH to the solution the OH⁻ ions will react with any available [Cu(H₂O)₆]²⁺ to form Cu(OH)₂. This means tat as long as we still have unreacted [Cu(H₂O)₆]²⁺ to react with the OH⁻ ions, the solution will not become basic and the litmus paper will remain red. When all of the [Cu(H₂O)₆]²⁺ has been consumed the OH⁻ ions will increase the pH of the solution making it alkaline or basic. When this happens, one drop of the RM will turn the litmus paper blue. To us this means that the Cu(OH)₂ precipitation is complete.
Reaction 3 is a decomposition reaction. We will use heat to decompose the Cu(OH)$_2$ to a black crystalline copper(II)oxide (CuO) as seen in equation (4).

(4) $\text{Cu(OH)}_2(s) + \text{heat} \rightarrow \text{CuO} (s) + \text{H}_2\text{O}(l)$

Reaction 4 is a hydration reaction. We will dissolve the CuO in sulfuric acid (H$_2$SO$_4$), converting the Cu$^{2+}$ ions from CuO back to [Cu(H$_2$O)$_6$]$^{2+}$ ions, as seen in equation 5.

(5) $\text{CuO} (s) + 2 \text{H}_3\text{O}^+ (aq) + 3 \text{H}_2\text{O} (l) \rightarrow [\text{Cu(H}_2\text{O})_6]^{2+} (aq)$

Reaction 5 is an oxidation-reduction reaction that will convert [Cu(H$_2$O)$_6$]$^{2+}$ ions back to metallic Cu (equation 6). To accomplish this we add metallic magnesium (Mg) to the [Cu(H$_2$O)$_6$]$^{2+}$ solution. The Mg will reduce the [Cu(H$_2$O)$_6$]$^{2+}$ forming metallic Cu, Mg$^{2+}$, and H$_2$O. When the blue color from the presence of [Cu(H$_2$O)$_6$]$^{2+}$ is no longer visible the reaction is complete.

(6) $[\text{Cu(H}_2\text{O})_6]^{2+} (aq) + \text{Mg} (s) \rightarrow \text{Cu} (s) + \text{Mg}^{2+} (aq) + 6 \text{H}_2\text{O} (l)$

While the reaction shown in equation 6 is proceeding, H$_3$O$^+$ ions from the excess H$_2$SO$_4$ that was added in reaction 4 will oxidize some of the Mg to Mg$^{2+}$. This will produce hydrogen gas (H$_2$), as seen from the gas bubbles coming from the solution. To make sure that no excess Mg is left as part of our final product we will add Hydrochloric acid dropwise to oxidize any remaining Mg. We will stop adding HCl when gas evolution ceases upon addition of HCl.

After our product has been weighed we will need to calculate the percent recovery. The equation for percent recovery can be seen in equation 7.

(7) $\text{Percent Recovery} = \frac{\text{mass of Cu recovered}}{\text{mass of initial Cu}} \times 100\%$
Procedure

1. Weigh 0.35-0.40 g of copper wire and place into a 250 mL graduated beaker
2. In a fume hood, add 2.5-3.0 mL of concentrated HNO₃ to your beaker
3. Wait until gas evolution ceases before continuing
4. If the Cu has not dissolved gently heat on a hot plate (DO NOT BOIL)
5. In a fume hood, add 10 mL of DI H₂O
6. While stirring your RM slowly add 6M NaOH solution, stop adding NaOH when red litmus paper turns blue on addition of your RM
7. Add enough DI H₂O to the beaker to make a total volume of 70 mL
8. Set up a hot water bath using a Bunsen burner
9. While stirring heat your RM in the hot water bath and let boil for 1-2 minutes
10. Set your RM on the lab bench and let cool to room temp
11. Decant the supernatant liquid, which should be colorless, into the proper waste container
12. While stirring add 40 mL of hot DI H₂O to your RM
13. Decant the supernatant liquid into the proper waste container
14. While stirring add 10 mL of a 3M H₂SO₄ into your RM, stir until dissolved
15. Dilute your RM to 30 mL with DI H₂O
16. Add 0.7-0.9 g Mg granules to your RM, if blue color persists add more Mg
17. Add concentrated HCl dropwise until evolution of gas ceases upon addition of HCl
18. Assemble a vacuum filtration apparatus
19. Place a piece of filter paper on the Buchner funnel and moisten it with DI H₂O
20. Transfer your RM to the filter paper, and wash your product with 15 mL DI H₂O
21. Dispose of the filtrate solution in the filter flask in the proper waste container
22. Weigh your product
## Data Sheet

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<tr>
<td>Mass of initial Cu, g</td>
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<tr>
<td>Mass of Cu recovered, g</td>
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<td>Percent recovery</td>
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Post-Lab Questions

1. What two functions does the NaOH serve?

2. If my initial weight of copper was 5.20 g in this experiment and my percent recovery was 86%, what is the weight of copper recovered?

3. How do you know you have added enough Mg(s)?

4. How do you know if you have oxidized all of the Mg(s)?

5. What color would red litmus paper be in:
   A) HCl(aq)
   B) NaOH(aq)