EXPERIMENT 1: Reactions of Copper and the Copper (II) ion

Ira Remsen, eminent nineteenth century chemist (and Professor of Physics and Chemistry at Williams College from 1872-76) described his introduction to chemistry in the following passage.

> "While reading a textbook of chemistry, I came upon the statement 'nitric acid acts upon copper'. I was getting tired of reading such absurd stuff, and I determined to see what this meant...I was even willing to sacrifice one of the few copper cents then in my possession. I put one of them on the table; opened the bottle marked 'nitric acid'; poured some of the liquid on the copper and prepared to make an observation. But what was this wonderful thing which I beheld? The cent was already changed, and it was no small change either. A greenish blue liquid foamed and fumed over the cent and over the table. The air in the neighborhood of the performance became colored dark red. A great colored cloud arose. This was disagreeable and suffocating -- how should I stop this? I tried to get rid of the objectionable mess by picking it up and throwing it out of the window. I learned another fact -- nitric acid not only acts upon copper but it acts upon fingers. The pain led to another unpremeditated experiment. I drew my fingers across my trousers and discovered the nitric acid acts upon trousers...(This) resulted in a desire on my part to learn more about that remarkable kind of action. Plainly the only way to learn about it was to see its results, to experiment, to work in a laboratory."

Chemical reactions are at the heart of chemistry. We care not only about what things are, but also about how they can be changed. In this first experiment, you will go through a series of reactions in sequence, beginning with the reaction between copper and nitric acid that caught the attention of Ira Remsen. You will then use the product from this first reaction as the starting material for the second reaction, and the product from the second reaction as the starting material for the third, and so on. When you have finished, you will have carried out a "cycle" of reactions; in chemical terms, you will be exactly where you started, having regenerated copper solid.

For each of the reactions, you are given the chemical equation and the nature of the materials to be used. You will need to calculate (**before** coming to lab) how much of a given substance you should use. You should also consider how you will determine when the reaction is complete. One of the goals of this experiment is to regenerate as much copper as possible. In each of the step in this reaction sequence, copper is the limiting reagent; you will therefore want to use a large excess (ten-fold) of other reagents in each step in order to ensure that the reactions occur as completely as possible.

As you carry out each reaction, you will generate a variety of solids, gases, and solutions. You should record your observations carefully and take time to consider their underlying causes: what causes the fizzing in a given step? what causes the colors you see? are there other reactions occurring besides the ones specified below? You should also pay careful attention to your own experimental technique, as well as to the general procedures used: are there any mistakes that you made? are there procedures that seem to result in a significant loss of material, or that seem to be relatively imprecise or inaccurate? You will be asked to evaluate all of these questions in your lab report for this experiment.

Step 1:

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu^{2+}(aq) + 2NO(g) + 4H_2O(l) + 6NO_3^-(aq) \quad (1)$$

Do this reaction in the hood! Please label your beaker in order to avoid confusing it with other students' reactions. Your starting materials will be a piece of copper weighing about 0.5 g (weigh it and record the weight before starting) and concentrated nitric acid (16 M). After the reaction is complete, dilute the solution to about 100 mL with distilled water.

Step 2:

$$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s) \quad (2)$$

You will be given 3.0 M NaOH. In deciding whether this reaction is complete, remember that some of the NaOH will be used to neutralize the excess acid from step 1.

Step 3:

$$Cu(OH)_2(s) \rightarrow CuO(s) + H_2O(l) \quad (3)$$

This reaction will proceed simply by heating the solution and the precipitated copper hydroxide to boiling. To prevent "bumping", add two or three boiling chips and stir while heating. When the reaction is complete, allow the CuO to settle, decant (pour off) the liquid (do not attempt to filter the solution) and wash with very hot distilled water. Pour off the wash water as well, so that the volume of the solution is minimal before going on to the next step.

Step 4:

$$CuO(s) + H_2SO_4(aq) \rightarrow Cu^{2+}(aq) + H_2O(l) + SO_4^{2-}(aq) \quad (4)$$

You will be given 6 M sulfuric acid.

Step 5:

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq) \quad (5)$$

Add zinc metal powder (use only a fivefold excess in this step). Stir constantly. Avoid breathing the gas evolved (what is it?). When the reaction with the zinc is complete, the excess zinc can be dissolved with hydrochloric acid. After completing both reactions, wash and dry the product, and weigh.

Lab Report

Your report for this experiment will be relatively brief (approximately 3-5 pages, double spaced), but should contain all of the sections described in the section on writing lab reports presented earlier in this lab manual. Specifically for this experiment you should give the details of each reaction, including amount of reagents and type of reaction. Quantify, to the best of your ability, each possible source of error that would account for any differences between your final weight of recovered copper and the initial weight. You should also include sources of error that cannot be quantified. Consider which source is most significant and therefore which step(s) in your reaction sequence led to the greatest error.