Honors Chemistry Lab 29: Stoichiometry and Percentage Yield

Stoichiometry calculations are about calculating the amounts of substances that react and form in a chemical reaction. Based on the balanced chemical equation, we can calculate the amount of a product substance that will form if we begin with a specific amount of one or more reactants. Or, you may have a target amount of product to prepare. How much starting compounds are needed to prepare this amount? These are practical calculations that are done frequently by chemists. In this experiment, you will prepare copper metal from the reaction of aluminum metal with a solution of copper(II) sulfate. From the amounts of the reactants, you will determine which reactant is the limiting reactant, and from this amount, calculate the theoretical yield of copper metal. From the actual amount of copper obtained, you can then calculate your percent yield of copper.

ASK: How can I experimentally determine the percentage yield of copper metal in a single replacement reaction?

Materials: analytical balance, weigh boat, $CuSO_4 \cdot 5H_2O$, HCL (6 M), DI H_2O, beaker (150 mL), stirring rod, Al metal (foil), CH_3OH

Pre- lab Questions:

P1. Write and balance the reaction of aluminum in copper(II) sulfate pentahydrate.
P2. Determine which of the reactants is limiting and which is in excess.
P2. Calculate the theoretical yield of copper.

RESEARCH:

1) Weigh a clean, dry 150 mL beaker and record its weight on the report form.

2) Carefully add copper(II) sulfate pentahydrate, CuSO4 •5H2O, until 2.00 g have been added.

3) Measure 10 mL of deionized water in a small graduated cylinder and add the water to the beaker to dissolve the copper(II) sulfate pentahydrate with the aid of a glass stirring rod. Record the color of the solution on the report sheet.

4) Measure 2.0 mL of 6 M HCl in your graduated cylinder, add it to the solution, and mix well. **Note: 6 M HCl is caustic and must be handled with extreme caution.**

5) Weigh 0.25 g of dry aluminum foil in small pieces and record the weight in your STEM journal.

6) Add the pieces of Al foil a little at a time. Use the stirring rod to mix the solution during the reaction. (CAUTION: Exothermic reaction!) Note the color of the solution after the added piece of aluminum no longer darkens on its surface. Add the remaining few pieces of aluminum foil and add an additional 5 mL of 6 M HCl to facilitate the reaction of any excess aluminum with the hydrochloric acid.

7) After all of the aluminum foil has reacted, allow the solid particles of copper product to settle, and carefully decant the solution from the solid (leaving the copper behind in the beaker). Add 20 mL of deionized water to the solid, stir well with the stirring rod, and decant again. Repeat this washing with 20 mL of water once more. Finally, add 10 mL of methanol to the solid, stir, and decant. **Note: methanol is extremely flammable and should be nowhere near a flame.**

8) Heat the beaker on an electric hot plate at medium heat (a setting of about 4 out of 10) until the solid and beaker are thoroughly dry. Allow the beaker and its contents to cool, and then weigh and record the weight on the report form. If time allows, you may re-heat the beaker for an additional 10 minutes and re-weigh the beaker and contents to ensure that drying is complete (heating to constant weight). **Do not overheat**.

9) On the report sheet, record the moles of Al and $CuSO_4 \cdot 5H_2O$ used, and determine which is the limiting reactant. Based on the limiting reactant, calculate the theoretical yield of copper metal product. From your actual yield of copper, calculate the percent yield of copper product obtained from the reaction.

10) Place your copper metal in the collection container on the front desk (do not wash it down the sink!), rinse your glassware well, and return it and your other equipment to their proper storage locations.

MAKE your claim and SUMMARIZE: (include the following questions in your summary).

Q1. Calculate the percentage yield for the reaction. Include this one in your data analysis section and show all work.

Q2. List three reasons why your percent yield might be less than the theoretical yield.

Q3. In step 8 of the research procedure, you are told not to overheat the copper. Explain why overheating should be avoided using your knowledge from Lab 3 (part 1).

Q4. Propose an explanation for the use of 6 M HCl in this protocol.

Q5. Propose an explanation for the use of methanol (CH_3OH) in this protocol.

Please self-assess your STEM journal using the rubric/checklist