6E

Using a Reactant in Excess in an Aluminum-Copper Replacement Reaction

Certain metallurgical situations require the addition of a pure metal to an electrolytic solution in order to remove impurities of a different metal. One example is found in the manufacturing process of pure zinc metal. In one stage of the process, zinc dust is added to a $ZnSO_4(aq)$ solution which contains impurities of $CdSO_4(aq)$. This addition of zinc dust causes a single replacement reaction in which the Cd^{2+} ions are replaced by Zn^{2+} ions and metallic Cd is removed as an impurity. In such instances chemists rely on stoichiometry to predict the amount of the zinc metal required.

In this experiment, stoichiometry will be used to predict the required amount of solid copper(II) chloride that should be dissolved in water in order to completely react with a known amount of aluminum metal. It is difficult as well as impractical to combine just the right amounts of each reactant that are required for a particular reaction to occur. Given this fact, this experiment is designed so that the aluminum is the limiting reactant and copper(II) chloride will be used in excess. The skeletal (unbalanced) equation for the resulting single replacement reaction is:

$$Al(s) + CuCl_2(aq) \rightarrow AlCl_3(aq) + Cu(s)$$

You will start with a known mass of aluminum foil and predict an excess amount of copper(II) chloride crystals required for the foil to react completely. In addition, you will be able to weigh the copper produced and determine the mole ratio of copper to aluminum that was involved in the reaction.

OBJECTIVES

1. to observe the reaction between aluminum metal and a solution of copper(II) chloride
2. to predict the mass of copper(II) chloride required to completely react a known amount of aluminum
3. to measure the mass of copper produced
4. to compare the moles of copper produced with the moles of aluminum reacted (as a whole number ratio)

SUPPLIES

Equipment

centigram balance	plastic spoon	filtering apparatus
beaker (100 mL)	stirring rod	lab apron
2 beakers (250 mL)	wash bottle	safety goggles

Chemical Reagents
aluminum foil, Al
copper(II) chloride crystals, $CuCl_2$

PROCEDURE

Part I: Predicting the Required Amount of $CuCl_2(s)$ (Day 1)

1. Obtain a piece of aluminum foil that measures approximately 15 cm × 15 cm. Exact size is not critical.
2. Weigh the aluminum foil and record its mass in your copy of the Experimental Results.
3. Do Prediction Questions 1–5 now. You will need this information in the steps that follow.

Part II: Reacting the Aluminum with the $CuCl_2$

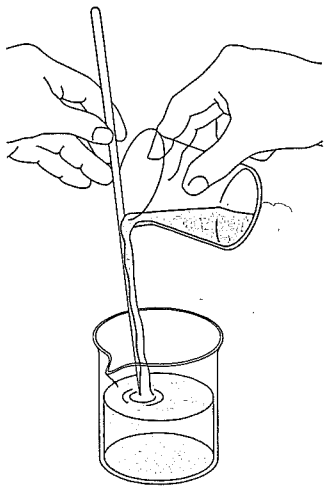
1. Put on your lab apron and safety goggles.
2. Obtain a 100 mL beaker and add one full scoop (plastic teaspoon) of $CuCl_2$ crystals to the beaker.
3. Measure and record the mass of a clean, dry 250 mL beaker. With the 250 mL beaker still on the centigram balance, add $CuCl_2$ crystals until you reach your predicted excess mass. (Refer to your answer to Prediction Question #5.) Return any unused $CuCl_2$ crystals to the designated container provided by your instructor.
4. Carefully add 150 mL of water to the 250 mL beaker containing the $CuCl_2$ crystals and stir until all the crystals are dissolved.
5. Loosely roll the aluminum foil into a tube and place the tube into the solution in the beaker. Make qualitative observations over the next 5 min and record these.
6. Over the next 10 min stir the mixture regularly to ensure that all the aluminum reacts.

$CuCl_2$ is poisonous. Wash any spills with plenty of water then notify your instructor.

Part III: Determining the Mass of Copper Produced

1. *Decant* means to pour off only the liquid and leave the solid behind from a container that is holding both solid and liquid. Carefully decant the liquid from the solid into a second 250 mL beaker. (See Figure 6E-1.)
2. Add 150 mL of water, stir, allow the slurry to settle 2 min, and decant a second time. This is an important step as you attempt to rinse away as much of the $AlCl_3$ residue as possible.
3. Set up a filtering apparatus, then weigh and record the mass of your filter paper. Put your name on the filter paper in pencil.
4. Pour the beaker contents into the filter funnel and use a wash bottle to rinse all particles of copper from the beaker.
5. When the filter has drained, use the wash bottle to gently spray water on the copper residue to rinse it once again.

Figure 6E-1 *Decanting the liquid from the solid*



6. Remove the drained, wet filter paper and copper from the funnel a place it on a folded paper towel. Place all this material in the assign location to dry.

7. Clean up all of your equipment and wash your hands thoroughly befc leaving the lab.

Part IV: Weighing the Dried Copper (Day 2)

1. Obtain your sample of dried filter paper and copper and weigh it. Reco this mass.

2. Clean up all of your equipment and wash your hands thoroughly befo leaving the lab.

REAGENT DISPOSAL

Rinse all solutions down the sink with copious amounts of water. Any soli waste should go into the designated waste container.

POST LAB CONSIDERATIONS

The chemical reaction in this experiment has been:

$$Al(s) + CuCl_2(aq) \rightarrow AlCl_3(aq) + Cu(s)$$

Note that this equation is unbalanced. It will be interesting to see if you ratio of moles of copper produced to moles of aluminum reacted agrees witl the mole ratio in the balanced equation. These mole values will simply be cal culated from the masses (in grams) of the chemicals that have been consumec or produced.

One challenge in reactions such as this is to separate the solid Cu produce from the other product of the reaction. In this case that product is $AlCl_3(aq$ which will add to the mass of the Cu if it is not removed. That was the reasor for the repeated rinsing of the Cu(s) after the reaction.

Sometimes an unexpected secondary chemical reaction occurs. In this experiment, you will have noticed bubbles of a gas forming yet there is no suggestion of a gas being produced in the above equation. Tests show that the gas being produced is hydrogen gas. The explanation for this is beyond the scope of this experiment but this secondary reaction occurs to a small degree so it will not significantly affect your results.

EXPERIMENTAL RESULTS

Mass of aluminum

Mass of empty 250 mL beaker

Qualitative observations of the reaction

Mass of filter paper

Mass of filter paper + copper

ANALYSIS OF RESULTS

Prediction Questions: Predicting the Excess Mass of $CuCl_2(s)$ Required

1. Copy the chemical equation from the introduction and ensure that it is balanced.
2. Use your Results (mass of aluminum) to calculate the moles of aluminum to be reacted.
3. Calculate the moles of $CuCl_2(s)$ required for a complete reaction with the aluminum.
4. Calculate the mass (in grams) of $CuCl_2(s)$ that is required for a complete reaction with the aluminum.
5. Calculate a 50% excess of $CuCl_2(s)$ required. To obtain this, simply take your answer from Analysis 4 and multiply it by a factor of 1.5.

Determining the Moles of Copper Produced

6. Use your Results to determine the mass of copper produced.
7. Calculate the number of moles of copper produced.
8. Calculate the ratio of moles of copper produced to moles of aluminum reacted. Under ideal conditions, what should have been expected? (Hint: Refer to your balanced equation in Analysis 1.)

FOLLOW-UP QUESTIONS

1. In this experiment, what evidence suggests that copper ions were removed from the solution?
2. A student carelessly allows some aluminum tongs to sit in a beaker containing $CuCl_2$ solution overnight and a reaction occurs. In the morning the solution is colorless.

Original mass of tongs	85.1 g
Final mass of tongs	73.2 g

   a. Write the balanced chemical equation for the reaction.
   b. Calculate the moles of aluminum that reacted.
   c. Calculate the mass of $CuCl_2$ that must have reacted.
   d. Which reactant was in excess and by how much?

CONCLUSION

State the results of Objective 4.