Limiting Reactants

OBJECTIVES: To determine the limiting reactant in a chemical reaction

SKILLS: weighing, filtering, stoichiometric calculations

EQUIPMENT: Filter flask, crucible holder

REFERENCE: Chemistry: The Molecular Nature of Matter, Jespersen et al., 7th edition, Sections 3.4–3.6, 4.1, 4.7

SAFETY AND DISPOSAL: All waste can be disposed of in the laboratory sink

INTRODUCTION: A balanced chemical equation shows the mole ratio by which the reactants will combine to form the products. If there is not enough of one reactant and too much of another, then the first is called "limiting" (because it limits the amount of product formed) and the second is called "excess" (because some of it is left over after the reaction is complete).

In this experiment you will study the system:

$$CaCl_{2\,(aq)} + K_2C_2O_4{\bullet}H_2O_{\,(aq)} \Rightarrow CaC_2O_4{\bullet}H_2O_{\,(s)} + 2\ KCl_{\,(aq)}$$

This equation shows that for every 1 mole of calcium chloride that reacts, 1 mole of potassium oxalate (monohydrate, MW = 184.24 g/mol) will also react producing one mole of calcium oxalate (monohydrate, MW = 146.12 g/mol) and 2 moles of potassium chloride. This ratio will hold true no matter how much material is available. If there are more moles of potassium oxalate than calcium chloride, then all of the calcium chloride will react along with some of the potassium oxalate. Some potassium oxalate will be left over as excess. The same concept holds if there are more moles of calcium chloride than of potassium oxalate.

In this experiment you will dissolve a given amount of potassium oxalate in water and combine it with a solution of calcium chloride. A precipitate will form, which will be filtered, dried and weighed. The liquid filtrate will be tested to see which of the reactants was in excess. By calculating the number of moles of each reactant, you will be able to predict the amount of product formed and compare your prediction with your experimental result. Different students in the class will use different amounts of potassium oxalate. You will plot the class data to visualize the role of the limiting reactant in chemical reactions.

EXPERIMENTAL PROCEDURES

1. Reaction: Obtain approximately 50 mL of distilled water in a 125 mL Erlenmeyer flask. Adjust the pH of the water by adding 3 M NH_3 dropwise until the litmus or pH paper shows that the solution is just basic. To test, obtain a piece of either red/neutral litmus or pH paper. Using a stirring rod, touch a drop of the distilled water to the paper. If the paper turns blue, the solution is already basic. If the paper stays red, add 1-3 drops of the 3 M NH_3, stir and check the color of the paper. Continue this until the solutions turns the paper blue.

Your instructor will assign you a mass of potassium oxalate. Weigh out the assigned mass of potassium oxalate to within $\pm$ 0.005 g of your assigned mass. Dissolve the potassium oxalate in the 50 ml of the pH adjusted distilled water. Use a small quantity of distilled water to rinse the weighing boat into the beaker in order to transfer ALL of the potassium oxalate. Next, while stirring, use a volumetric pipette to carefully add 15 mL of the 0.0750 M calcium chloride solution to your flask to form the calcium oxalate precipitate. Note your observations.

Using a hot plate, gently heat the solution to 75°C for 15 minutes. Do not let the temperature go over 75°C. When removing your thermometer from the flask, be sure to wash it carefully with distilled water into the flask in order to limit the amount of precipitate lost. After 15 minutes, remove the solution from the heat and allow the precipitate to settle. You can immerse the beaker in an ice bath to help cool the mixture. While the precipitate is settling, warm approximately 30 mL of distilled water to 70–80°C. This warm water will be used later to wash the filtered precipitate.

2. Filtering: Prepare to filter the calcium oxalate precipitate by locating your fritted (Gooch) crucible and obtaining a crucible holder, filter paper/pad and filtering flask. Place the filter in the crucible and record the mass. Set-up the filtration apparatus as demonstrated by your laboratory instructor. Apply suction, and slowly pour approximately 10 mL of distilled water through the crucible. Use a stirring rod to help seat the filter in the crucible. Be sure that the filter covers all of the holes and that it is properly seated onto the crucible so that no solid can pass around the outside edges of the filter.

While the suction remains on, carefully filter the precipitate by pouring it slowly from the Erlenmeyer flask into the crucible. Use small portions of distilled water to wash your Erlenmeyer flask to ensure your have transferred all of the solid to the crucible. Wash the precipitate in the crucible, by slowly adding three 10 mL portions of the warm distilled water. Allow the suction to pull through the crucible for at least 5 minutes after the last amount of solution was filtered.

3. Testing: Break the vacuum at the flask by disconnecting the tubing from the flask while the vacuum is still running. Obtain two test tubes from your locker. Fill each tube half way using the filtrate from the filtering flask. Test the filtrate to determine the excess reagent using the following instructions:

Testing for the excess reactant: Test the solutions in test tube 1 and test tube 2 as follows:

Testing for excess $CaCl_2$: Add 2 drops of 0.50 M potassium oxalate to the solution in test tube 1. If a precipitate forms calcium chloride is in excess and potassium oxalate is the limiting reactant.

Testing for excess $K_2C_2O_4$: Add 2 drops of 0.50 M calcium chloride to the solution in test tube 2. If a precipitate forms, potassium oxalate is in excess and $CaCl_2$ is the limiting reactant.

4. Drying and weighing: Place the crucible in your locker on top of some paper towels and allow the solid to dry until the next lab period. **When you return the following week, determine the weight of your crucible with your filter and precipitate. Record this mass in your notebook and be sure to enter your results on the lab computer as well.**

NOTEBOOK TEMPLATE INFORMATION

The following experimental data should appear in your lab notebook:

Assigned mass of potassium oxalate and actual mass of potassium oxalate used
Concentration and volume of the calcium chloride solution used
Mass of crucible with filter
Mass of crucible with filter and precipitate

In addition, your lab notebook should contain observations of what you saw and what happened.

As part of the calculations for this experiment, you will need to determine the following quantities:

the number of moles of potassium oxalate that you used.
the number of moles of calcium chloride that you used.
the mass and the number of moles of calcium oxalate precipitate that you recovered