6D Determining the Limiting Reactant and Percent Yield in a Precipitation Reaction

One example of a double replacement reaction is the mixing of two solutions resulting in the formation of a precipitate. In solution chemistry, the term *precipitate* is used to describe a solid that forms when a positive ion (cation) and a negative ion (anion) are strongly attracted to one another. In this experiment, a precipitation reaction will be studied. Stoichiometry will then be used to investigate the amounts of reactants and products that are involved. The word *stoichiometry* is derived from two Greek words: *stoicheion* (meaning "element") and *metron* (meaning "measure"). Stoichiometry is an important field of chemistry that uses calculations to determine the quantities (masses, volumes) of reactants and products involved in chemical reactions. It is a very mathematical part of chemistry.

In this experiment, you will react a known amount of sodium carbonate solution with a known amount of calcium chloride solution. The skeletal (unbalanced) equation for the resulting double replacement reaction is:

$$Na_2CO_3(aq) + CaCl_2(aq) \rightarrow NaCl(aq) + CaCO_3(s)$$

Note that three of the chemicals have their states or phases designated as (*aq*) and one is designated as (*s*). The (*aq*) represents the term *aqueous* which means that the substance is soluble and dissolved in water. The (*s*) means that the substance is a *solid* (in this case, it is a precipitate). Precipitate formation is easily observed as the mixed solutions turn cloudy and, if desired, the precipitate can be easily separated from the solution by filtering. Since your precipitate will be separated and weighed, this experiment will require a second lab period to allow time for the precipitate to dry. Stoichiometry will then be used to determine the amount of precipitate that should be formed in the reaction.

It is often difficult as well as impractical to combine just the right amount of each reactant that is required for a particular reaction to occur. Given this fact, this experiment is designed so that only one of the reactants will be completely used up. This is called the *limiting reactant* because it limits the amount of products formed. Since the other reactant will have a quantity remaining, it is called the *excess reactant*. One of your tasks will be to determine which of your reactants is limiting and which is in excess.

The two chemical reactants in this experiment have common uses in our lives. In one solid form, sodium carbonate is known as "washing soda" and is used to enhance the effectiveness of laundry soap. Calcium chloride solid can act as a *desiccant* (drying agent) and is used by recreational vehicle owners to remove moisture from the air in the vehicle during winter storage.

OBJECTIVES

1. to observe the reaction between solutions of sodium carbonate and calcium chloride
2. to determine which of the reactants is the limiting reactant and which is the excess reactant
3. to determine the theoretical mass of precipitate that should form
4. to compare the actual mass with the theoretical mass of precipitate and calculate the percent yield

SUPPLIES

Equipment

centigram balance
2 graduated cylinders (25 mL)
beaker (250 mL)
wash bottle
filtering apparatus (ring with stand, Erlenmeyer flask (250 mL) + funnel)
filter paper
lab apron
safety goggles

Chemical Reagents

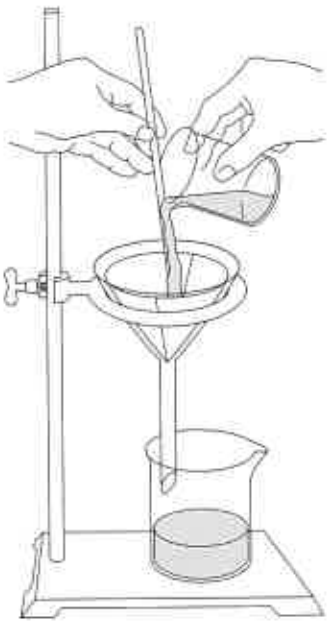
0.70*M* sodium carbonate solution, Na_2CO_3
0.50*M* calcium chloride solution, $CaCl_2$

PROCEDURE

Part I: The Precipitation Reaction (Day 1)

1. Put on your lab apron and safety goggles.
2. Obtain two clean, dry 25 mL graduated cylinders and one 250 mL beaker.
3. In one of the graduated cylinders measure 25 mL of the Na_2CO_3 solution. In the other graduated cylinder measure 25 mL of the $CaCl_2$ solution. Record these volumes in your copy of Experimental Results in your notebook.
4. Pour the contents of both graduated cylinders into the 250 mL beaker and observe the results. Record these qualitative observations in your notebook. Allow the contents of the beaker to sit undisturbed for 5 min to see what happens to the suspended solid particles. Meanwhile, proceed to Step 5.
5. Obtain a piece of filter paper and put your name on it using a pencil. Weigh and record the mass of the filter paper, then use it to set up a filtering apparatus as shown in Figure 6D-1.
6. Use the wash bottle to lightly wet the filter paper in the funnel to keep the filter paper in place. Swirl the beaker and its contents to suspend the precipitate in the solution, then pour it carefully and slowly into the filter funnel. It takes time to complete the filtering process so plan to do it in stages. Use the wash bottle to rinse the remaining precipitate from the beaker.

Figure 6D-1 *Filtering the solid from the liquid*



Wash spills off your skin and clothes with plenty of water.

7. Use the wash bottle one last time to rinse the precipitate in the filter paper. This will remove any residual NaCl(aq) that remains with the precipitate.
8. After the filtering is complete, remove the wet filter paper containing $CaCO_3$ precipitate and place it on a folded paper towel. Put your filter paper in the assigned location to dry.
9. Clean up all your apparatus.
10. Wash your hands thoroughly with soap and water before leaving the laboratory

Part II: Weighing the Dried Precipitate (Day 2)

1. Weigh and record the mass of the dry filter paper containing the $CaCO_3$ precipitate.

REAGENT DISPOSAL

Rinse all solutions down the sink with copious amounts of water. Any solids should go into the designated containers.

POST LAB CONSIDERATIONS

The double replacement reaction in this experiment formed two chemicals which are commonly known to you. The NaCl(aq) is salt water and the $CaCO_3$(s) is a component of some classroom chalks.

Using the data collected, you will be able to calculate the moles of each of the chemicals that are added together to react. Then using the principles of stoichiometry you will be able to determine which chemical is the limiting reactant and thereby predict how much precipitate should form. This stoichiometric determination will then be compared to the actual mass of $CaCO_3$(s) formed.

Chemists are often concerned with optimal yields in manufacturing a certain chemical. One way of measuring this is to calculate the percent yield of that particular chemical by using this formula:

$$\text{Percent yield} = \frac{\text{actual mass produced (grams)}}{\text{theoretical mass produced (grams)}} \times 100\%$$

EXPERIMENTAL RESULTS

Part I: The Precipitation Reaction (Day 1)

Qualitative Observations

Quantitative Observations

Volume of 0.70*M* Na_2CO_3 solution

Volume of 0.50*M* $CaCl_2$ solution

Part II: Weighing the Dried Precipitate (Day 2)

Mass of filter paper + dry solid $CaCO_3$

Mass of filter paper

ANALYSIS OF RESULTS

1. Copy the chemical equation for the reaction from the introduction and balance it.
2. From your Part I Results, calculate the moles of Na_2CO_3 that were added to the beaker.
3. From your Part I Results, calculate the moles of $CaCl_2$ that were added to the beaker.
4. Use your answers from Analysis 1–3 above and stoichiometric principles to determine which chemical is the limiting reactant.
5. Use stoichiometric calculations to determine the theoretical mass of $CaCO_3$ precipitate that should have formed.
6. From your Part II Results, calculate the actual mass of $CaCO_3(s)$ precipitate that formed.
7. Calculate the percent yield of $CaCO_3(s)$.

FOLLOW-UP QUESTIONS

1. If you were to evaporate the filtered solution to dryness, would you be left with only solid NaCl? Explain.
2. What theoretical volume of the Na_2CO_3 solution used in this experiment would result in no excess reactant?
3. A precipitation reaction occurs when 50.0 mL of 0.50*M* $BaCl_2(aq)$ is mixed with 75.0 mL of 0.75*M* $Na_2CO_3(aq)$. The only precipitate is the $BaCO_3(s)$ formed.
   a. Write the balanced equation that describes this reaction.
   b. Which chemical is the limiting reactant?
   c. Predict the theoretical mass of $BaCO_3(s)$ that should form.
   d. This experiment was conducted and the percent yield was found to be 82%. What was the actual mass of $BaCO_3(s)$ that formed?

CONCLUSION

State the results of Objectives 2, 3, and 4.