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Chemistry 118 Laboratory
University of Massachusetts, Boston

STOICHIOMETRY - LIMITING REAGENT

LEARNING GOALS

1) Obtain hands on experience with the limiting reagent problem
2) Learn how to use a filter to isolate a solid product
3) Appreciate the importance of drying your sample, to obtain an accurate weight of a product
4) Interpret the meaning of an experimentally measured percent yield.

OBJECTIVE

Solutions of calcium chloride and sodium carbonate will be combined in four different ratios and the amount of calcium carbonate produced will be measured. The limiting reagent in each case will be determined and the percent yield calculated.

INTRODUCTION

This experiment is designed to illustrate the relationship between quantities of reactants and the amount of products produced by a chemical reaction. The principles of stoichiometry and limiting reagents will be used to predict the amount of product that should be produced when mixing two solutions to produce an insoluble product. The reaction to be studied is:

$$CaCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow 2\ NaCl_{(aq)} + CaCO_{3(s)}$$

The balanced chemical equation for this reaction can be expressed in net ionic form as:

$$Ca^{2+}{}_{(aq)} + CO_3{}^{2-}{}_{(aq)} \rightarrow CaCO_{3(s)}$$

Because $CaCl_2$ contains one mole of calcium ions per mole of calcium chloride and Na_2CO_3 contains one mole of carbonate ions per mole of sodium carbonate, the reagent with the fewest number of moles will be limiting. Theoretically, for every mole of limiting reagent, a mole of product, $CaCO_3$, should be formed because there is a 1:1 mol ratio between both reactants and $CaCO_3$ in the balance reaction above. This is called the theoretical yield (in moles). The theoretical yield (in grams) is obtained by multiplying the theoretical yield in moles by the molar mass of calcium carbonate.

The actual yield of product, obtained by weighing the product, can be compared to the theoretical yield. This comparison, called the percent yield, is calculated as follows:

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

PROCEDURE

1. Label four 100 mL beakers which are to hold your reaction mixtures.

2. Using two 250 mL Erlenmeyer flasks, obtain about 100 mL each of the two stock solutions. Label the beakers. Be sure to record the concentrations on the attached data sheet.

3. Rinse a burette with the calcium chloride solution. Fill the burette to between 0.00 and 3.00 mL with the solution. Purging any air bubbles in the tip by draining a small amount of the solution into a beaker. Record the initial burette reading to the hundredths place on the data sheet. Using the approximate volumes listed in Table 1, fill each reaction beaker with solution. Record the actual volume on the data sheet.

4. Rinse the burette with water and then with the sodium carbonate solution. (What happens if you do not first rinse with water?) As above, fill the burette to between 0.00 and 3.00 mL with the solution, purging any air bubbles. Record this value to the hundredths place on the data sheet. Using the approximate volumes listed in Table 1, fill each reaction flask with solution. Record the actual volume on the data sheet. Rinse the burette with water before proceeding.

Table 1

	$CaCl_2$	Na_2CO_3
Reaction #1	25 mL	25 mL
Reaction #2	28 mL	25 mL
Reaction #3	10 mL	25 mL
Reaction #4	25 mL	10 mL

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5. Stir each reaction mixture with a stirring rod. Rinse the rod using a wash bottle containing deionized water, collecting rinsings in the beaker, before transferring to another beaker.

6. The next step will be carried out four times, once for each reaction mixture.

   a) Pre-weigh a piece of filter paper on a watch glass using an analytical balance. Place the watch glasses on a piece of labeled paper so that you can distinguish them. Record the masses on the data sheet.

   b) Using a Buchner funnel and one of your pre-weighed pieces of filter paper, filter the contents of a beaker. Use the spatula and wash bottle to transfer all of the solid into the funnel.

   c) Transfer the filter paper and its contents to the watch glass and dry them under the heat lamp. Place a piece of paper with your name and reaction number under the glass for identification. Check the sample often **making sure the sample doesn't scorch**. While the sample is drying, filter another reaction mixture.

   d) When the contents of the watch glass have dried, weigh the watch glass, paper, and reaction product on the analytical balance previously used. Record all masses on the data sheet. If the product yield exceeds 100%, repeat steps 6c and 6d.

7. Clean all glassware before proceeding with calculations.

8. Complete all calculations and submit them to your laboratory instructor.

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DATA (record units)

for $CaCl_2$	Reaction #1	Reaction #2	Reaction #3	Reaction #4
Concentration **M**				
initial burette reading **mL**				
final burette reading **mL**				
volume delivered **mL**				
for Na_2CO_3	Reaction #1	Reaction #2	Reaction #3	Reaction #4
Concentration **M**				
initial burette reading **mL**				
final burette reading **mL**				
volume delivered **mL**				
	Reaction #1	Reaction #2	Reaction #3	Reaction #4
mass of watchglass + filter paper **(g)**				
mass of watchglass + filter paper + product **(g)**				
mass of product **(g)**				
volumes and masses summary	Reaction #1	Reaction #2	Reaction #3	Reaction #4
Volume of $CaCl_2$				
Volume of Na_2CO_3				
mass of product (actual yield)				

Calculations

	Reaction #1	Reaction #2	Reaction #3	Reaction #4
Moles of Na_2CO_3				
Moles of $CaCl_2$				
Limiting Reagent				
Theoretical Yield (moles)				
Theoretical Yield (mass) **g**				
Percent yield				
Moles of Ca^{2+} in excess				
Moles of CO_3^{2-} in excess				

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DISCUSSION QUESTIONS

1. This reaction goes to completion and there are no undesirable side reactions that form other products. Given this and based on your percent yields and perhaps some observations made during the course of the experiment, postulate the likely sources of errors that had the most significant impact on your results. (5 pts)

2. How could these errors be minimized if you were to repeat the experiment? (5 pts)

LAB REPORT

A written lab report is a common scientific exercise that helps to convey why an experiment was performed, how an experiment was performed, what the results of the experiment were, and why those results are of significance. For this experiment, you are being tasked with writing a complete lab report. A complete lab report consists of:

- **TITLE:** A summation of the experiment in ten words or less. It should describe the main point of the laboratory work. For example: *Effects of Atmospheric* CO_2 *Concentrations on the Global Climate.*
- **ABSTRACT:** A summary of what is contained within a lab report. This allows the author to highlight key information contained in the following sections and provides the reader with key points so they can determine if the lab report contains information they seek. The abstract should be the ***last thing that is written*** for the lab report, as it contains elements of all the other sections. An abstract should be roughly *three to six sentences*. This is more difficult than it sounds, so allow time for several revisions.

- **INTRODUCTION:** In a scientific research article this section of the paper is devoted to making the case for why the work is important and significant and for discussing the previous work reported in the literature that has led up to the work being reported in this paper. In a lab report the nature of the introduction section is a little bit different than in a research article. In a lab report you should focus the introduction on the learning goals of the experiment. Discuss how the experiment is designed to achieve these learning goals and how the experiment fits in with the broader curriculum of the corresponding lecture course.

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- **MATERIALS AND METHODS:** This section should provide the details of how the experiment was carried out. It should not be written as a recipe but more as a journal entry; a fairly detailed account of what was done in lab. A description of how the data was processed should also be part of the Methods section.

- **DATA AND ANALYSIS:** When appropriate you data should be displayed in tables and figures. The figures and tables should have captions that describe what they are illustrating. You should also prepare sentences that introduce the tables and figures and describe what they show. To an extent these sentences and the captions will be and should be somewhat redundant.

- **DISCUSSION:** A description of what the data means. Points of discussion could include: The discussion section will discuss the significance of the findings from the data analysis section. It is also in this section the questions that are being asked are addressed in the context of a well-written paragraph or two.

  (1) Was the goal of the experiment achieved?
  (2) If the results obtained are poor, what could have happened during the experiment to explain this?

- **CONCLUSION:** The conclusion should be a separate paragraph that briefly reiterates what happened in the experiment, what the results are, and what those results mean.

In the upper right hand corner of your first page, be sure to include <u>your name, your TA's name, and the date the experiment was performed</u>.

It is imperative that scientists are able to communicate clearly in their writing. Thus, the lab report will be graded both on the **content of the report** and the **quality of the writing**.