Limiting Reactants

An analogy and learning cycle approach

Introduction

This lab builds on the previous one on conservation of mass by looking at a chemical reaction in which there is a limiting reactant. In phase 2, we will use the same nuts and bolts analogy but will apply it differently and there will be a different type of Analog to Target Worksheet. We will also explore other types of analogies using examples of foods. The scientific question to explore in phase 3 involves identification of the limiting reactant.

Goals:

1. To observe a precipitation reaction where there are limiting and excess reactants.
2. To use an analogical model to gain insight about reactions with limiting reactants.
3. To design an experiment to discover which of two reactants is the limiting reactant in a precipitation reaction.

Limiting Reactants

When a chemical reaction occurs between two or more reactants, the reaction will continue as long as one of the reactants doesn't run out. When one reactant is used up, no more products can form. If one reactant gets used up before another reactant in a chemical reaction, we call the reactant, which is used up the **limiting reactant**. The reactant that is left over is called the **excess reactant**. When there is an imbalance of reactants, the total amount of product that can form is determined by the amount of the limiting reactant.

Balanced chemical equations typically show the molar ratio of reactants that will result in all of the reactants being converted into products. If you are given two quantities of reactants, you can determine which reactant will limit the amount of product that can be formed by comparing the molar ratio of reactants that you actually have to the molar ratio from the balanced equation. You can also compare the total amount of product you can make with each reactant separately, in order to determine which one limits the reaction.

The CORE Learning Cycle

Phase 1: You and a partner will go into the lab, follow a procedure, and make observations.

Phase 2: You will then review material, which provides an explanation about what you observed in lab and create an analogical model of the chemical reaction.

Phase 3: Before going back into the lab, you will apply your understanding by designing an experiment. You and your partner will then go back into the lab to conduct your experiment and gather experimental results.

An analogical model for thinking about limiting reactants.

In last week's lab, we used nuts and bolts to explore an analogy to account for all of the chemical species present in a solution, before and after a chemical reaction took place. As a continuation of the analogy activity, we will use the same assignments made last week of different nuts and bolts to represent different types of ions. This week, we will consider what happens if we limit the amount of some nuts and bolts. We will again "run" a precipitation reaction, but this time, we will focus on the consequences of having an imbalance in reactants.

Pre-lab Assignment

In your lab notebook, please prepare the following information and answer the questions. You must complete the pre-lab before coming to the lab meeting or you will not be permitted to go into the laboratory.

1. Please write a 2-3 sentence introduction to the lab.

2. Please create a safety information table including the chemicals used in the lab, the hazards associated with them, and any safety handling precautions. (See example.)

3. Given a bicycle which has 1 frame and 2 wheels:

   a. How many bicycles can be assembled with 22 frames and 41 wheels? Explain you answer.

   b. Which component limits how many bicycles can be made?

4. What is an example of a molecule that requires 2 of one type of atom and 1 atom of a different species? Try to write a balanced chemical equation for the formation of this molecule.

Laboratory Guide

On the following pages you will find instructions for doing an experiment. In this experiment, you are asked to pair up with another student when doing lab work. If there is an odd number of participants in lab, one group may be permitted to have three people.

Your lab work will involve simultaneously being asked to individually make observations and record these in your own lab notebook, and working in partnership on certain activities which may involve answering questions, discussing observations, analyzing results, or designing your own procedures in response to scientific questions.

As you go through the experimental guide, you will notice there are questions that are set off in the guide (i.e. "**Q:**"). For example:

> **Q:** Can you tell by visually comparing each solution that one is more concentrated?

You are required to respond to these questions in your lab notebook. Our expectation is that you write enough to give an indication of what you were thinking about. You do not have to write down the question AND answer, but you must address the answer, for example: "by looking at the solutions we found …."

Part of the purpose of making an entry into your notebook is to allow you to remember later what you were thinking at this part of the lab, which can be very useful when writing your lab report. It is also evidence for your lab instructor of your thinking process. **Please note that you are not required to provide any particular question and answer in your lab report. However, you may find that some of your answers and thought process involved would be useful to include in your report.**

Goggles are required at all times in the lab. There are no exceptions. Gloves and aprons are available. If you have questions about safety, please do not hesitate to ask your laboratory instructor.

Equipment and supplies:
Filter paper
Long-stem funnel
250 mL Erlenmeyer flasks and beakers

Chemicals:
silver nitrate : $Ag(NO_3)$
sodium chloride : NaCl
Solution pair A & B **OR** 1 & 2 (pairs consist of silver nitrate and sodium chloride where one reactant is more concentrated)

Phase 1 of the Learning Cycle: Making observations

The following activities should be completed in the lab.

Choose a pair of solutions labeled A and B **OR** 1 and 2. Each set consists of a solution of sodium chloride and one of silver nitrate. One of the solutions in each pair is more concentrated than the other. If equal volumes are mixed, one of these reactants will limit the amount of silver chloride that is formed.

1. Record which solution pair you chose (A & B **OR** 1 & 2).

2. Measure 10.0 mL of each of your assigned solutions in a graduated cylinder. Record the exact volumes you used for each solution in your notebook.

> **Q:** Can you tell by visually comparing each solution that one is more concentrated?

3. Now, mix the two solutions in a labeled beaker.

> **Q:** Does the precipitate that forms look any different than it did in last week's reaction? Why or why not? (Recall that last week, equal amounts of reactants with equal concentrations were used.)

4. Allow the mixture to sit for 15 minutes for the reaction to complete (It can sit for longer.) During this time, you should move on to Phase 2 in the breakout room.

This is the end of Phase 1.

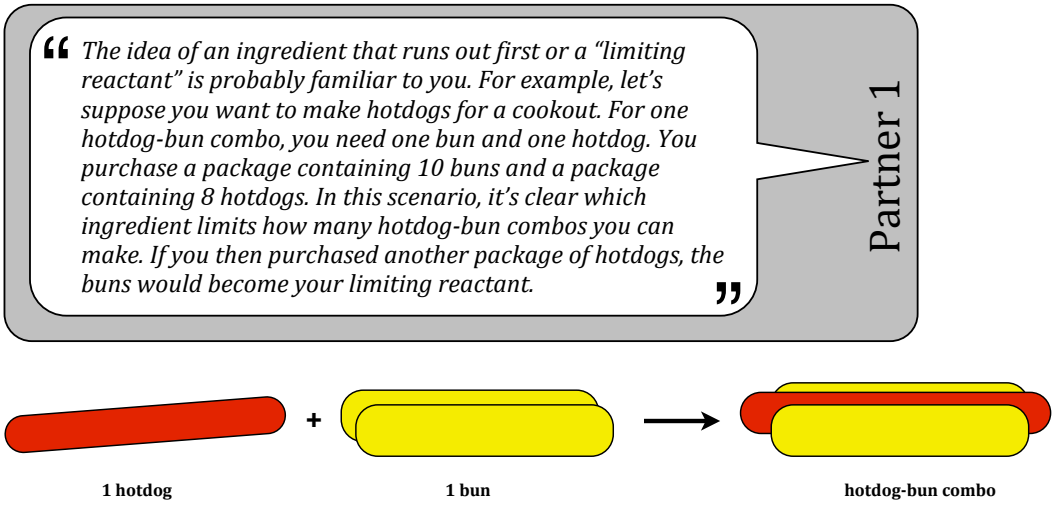
Phase 2 of the Learning Cycle: Exploring the Analogy

The following activities should be completed in the breakout room.

Round robin reading and thinking out loud

Take turns reading these examples out loud to each other. When finished, please ask the person listening to answer the questions, responding out loud also. Reading and thinking together out loud has been shown to be beneficial to thinking about complex problems[1].

1. The first person in the group should read the following passage out loud:



2. After listening, partner 1 should ask partner 2 to answer the following questions, while explaining their thinking process out loud:

a. How could we write a balanced equation for combining hotdogs and buns into a hotdog-bun combo?

b. What would the limiting reactant be if we purchased 4 packages of hotdogs and 3 packages of buns?

c. Think of another example where the limiting reactant is straightforward to determine and explain it to me.

[1] Berardi-Coletta, B., Buyer, L. S., Dominowski, R. L., & Rellinger, E. R. (1995). Metacognition and problem solving: A process-oriented approach. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(1), 205.

3. Now, partner 2 should read the following passage out loud to partner 1:

Partner 2

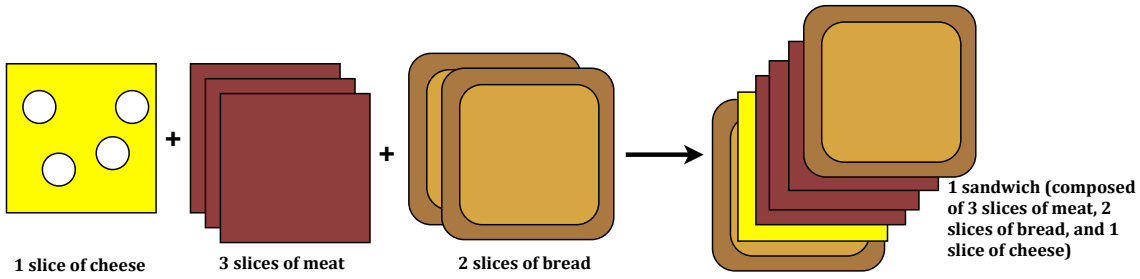
"The idea of a limiting reactant is more complicated when different numbers of items compose what you need to assemble. For example, let's suppose we want to assemble sandwiches composed of 2 pieces of bread, 3 slices of meat, and 1 slice of cheese. If we purchase a loaf of bread with 18 slices, a package of meat with 22 slices, and a package of cheese with 10 slices, it becomes a little harder to keep everything straight in order to determine what ingredient limits the number of complete sandwiches that can be made. One way to make it easier to calculate the "limiting reactant" is to think about how many sandwiches can be made with each ingredient separately and then compare the totals:

1 loaf of bread with 18 slices of bread could make a total of 9 sandwiches (18 pieces of bread divided by 2 slices per sandwich).

1 package of meat slices with 22 slices could make a total of 7 sandwiches (22 slices of meat divided by 3 slices per sandwich. is 7 with a remainder of 1 slice).

1 package of cheese with 10 slices could make a total of 10 sandwiches (1 slice per sandwich).

Surprisingly, the package with the most items (i.e. the 22 meat slices) is the limiting reactant!"



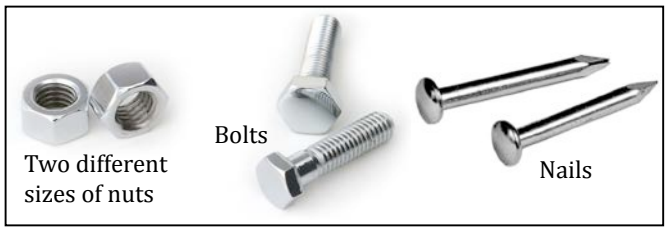
4. Next, partner 2 should ask partner 1 to answer the following questions while explaining their thinking out loud:

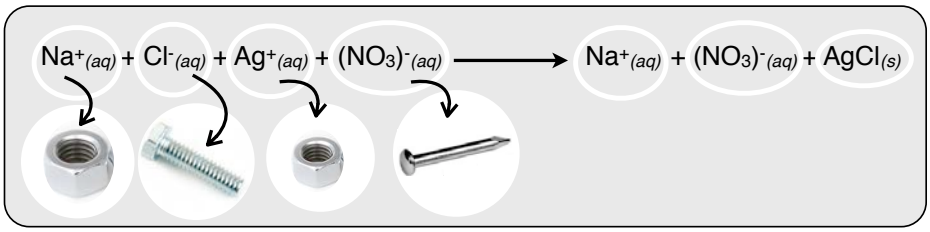
a. Why are the meat slices the limiting reactant? Please explain.

b. Think of another example where the limiting reactant is difficult to determine and explain it.

Analogical model for a limiting reactant in a precipitation reaction

Last week, you constructed an analogical model for the reaction of sodium chloride and silver nitrate that results in the formation of the precipitate silver chloride and aqueous sodium nitrate. Now we would like you to use the same analogical model to illustrate the case of a limiting reactant in the same reaction.





1. Using the above hardware assignments, run a reaction to form silver chloride with the hardware using different amounts of sodium chloride and silver nitrate. (For example: You could start out with 5 sodium ions and 5 chloride ions and react that with 3 silver ions and 3 nitrate ions.)

2. Use the ***Analog to Target worksheet*** (page 8) to record the results of the reaction when one of the reactants is limiting. Work with your partner to answer the questions. Remember, you will need to each individually hand in a copy of this sheet with your laboratory report.

Extra Credit - Extra Challenge: Limiting Reactant

Extra Credit: if this analogy seems simplistic, you may want to consider extending the analogy for extra credit. This might involve thinking about additional aspects at the atomic scale and extending them back to the analog.

You might consider developing a new analogy and using it in place of nuts and bolts. If a new analogy is used, you should create your own analogy to target worksheet that considers similarities and limitations between the macro and atomic level domain.

Remember: you are not constrained to the examples above.

In order to receive extra credit, your pair should describe your modified analogy in your lab report in a separate section called Extra Credit, Extra Challenge. In this section you should identify how the modified analogy strengthened your understanding or insight of the chemical phenomena under examination. You should also identify explicitly where in the analog-to-target worksheet these modifications revealed themselves. Extra credit will be worth up to 10% on your entire grade for the experiment.

This is the end of Phase 2.

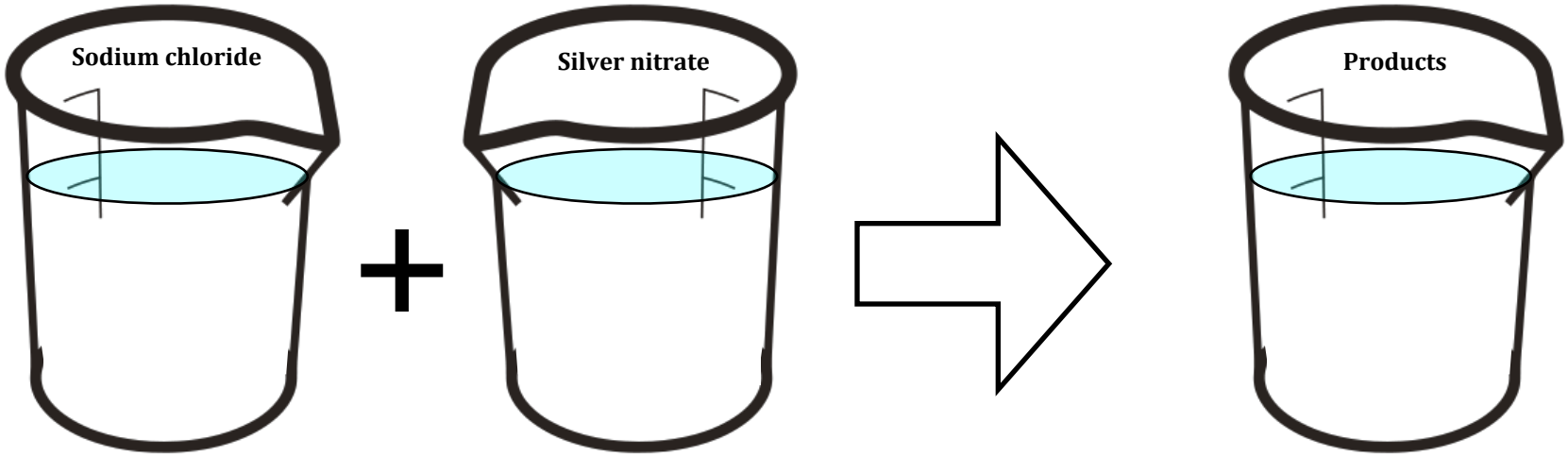
Analog to Target Worksheet

Name: _____

Fill out this worksheet individually but you can work together to discuss any aspect of it. Each student must include a scanned copy of this sheet with their lab report. Make sure your scan is entirely legible. Please label the components in your drawings.

As you run your reaction with the hardware, fill in the information in this chemical equation that models the reaction:

$$\_\_\_\_NaCl_{(aq)} + \_\_\_\_Ag(NO_3)_{(aq)} \longrightarrow \_\_\_\_Na(NO_3)_{(aq)} + \_\_\_\_AgCl_{(s)} + \_\_\_\_ \square_{(aq)}$$



In the beakers above, draw a molecular-level representation of aqueous sodium chloride and aqueous silver nitrate solutions in the proportions that you have chosen.

Draw the products that result. Be sure to represent that some products will be soluble and some will not.

What is the molar ratio of sodium chloride to silver nitrate in this reaction?

What is the molar ratio of each reactant to the product silver chloride in the balanced chemical equation when there is not a limiting reactant or excess reactant?

Which species was the limiting reactant in this reaction?

Which reactant was in excess?

Which species remain in solution after the reaction? Why?

Phase 3 of the Learning Cycle: Designing experiments

Plan your experiments in the breakout room before proceeding to lab to complete them.

Using the analogical model to make predictions:

> **Q:** What chemical species will be present in the filtrate after a precipitation reaction occurs if there is an excess of one reactant in the reaction? Use the analogy to justify your response.

The experiment:

Design an experiment to determine the identity of the solutions you worked with in Phase 1 and decide which of these solutions is the limiting reactant.

Scientific Question: In the reaction between your pair of solutions, is sodium chloride or silver nitrate the limiting reactant?

You will have **labeled solutions** of silver nitrate and sodium chloride to use in your experiment. Use the ***Designing Experiments*** worksheet (page 10) to summarize this process. You will hand in one copy of this sheet as a lab group at the end of lab. Make sure to also take careful notes of the process in your laboratory notebook. **Check in** with your laboratory instructor before starting your experiment.

Designing Experiments Worksheet

Names:	Experiment #:
Signatures:	Section:

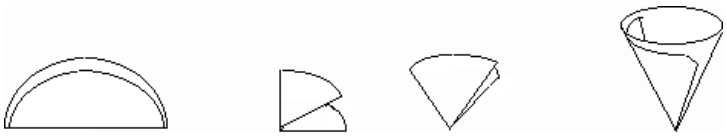
Please use this sheet to summarize your lab group's experiment and findings. ***Before going into lab, have your lab instructor <u>check and initial it</u>. This worksheet is to be scanned and included as part of your lab report. Make sure that the scan is entirely legible!***

Describe your proposed experiment. *(Check in with your lab instructor before performing experiments)* Instructor's initials:_____	(attach extra pages if needed)
Describe the data you collected:	(attach extra pages if needed)
What claims can you make?	

Separating a precipitate:

A technique that will be useful is **gravity filtration**. Gravity filtration involves using filter paper to separate the insoluble solids (the precipitate) from a solution to obtain a clear solution (the **filtrate**) in a new beaker.

Obtain a piece of 12.5 or 15 cm ashless filter paper. Fold the circle in half to form a semicircle. Then fold the semicircle in half. Open it into a cone and tear off a small piece of the upper, outside corner. This will improve the seal between the filter paper and the funnel. The figure below demonstrates the folding of filter paper:



Place the folded filter paper in **a long-stem funnel** that is attached to a ring stand. Place a beaker underneath to collect filtrate. Pour liquid from the reaction into the funnel to wet the filter paper. Then, slowly pour the rest of the reaction through the funnel. The solids will be trapped in the filter paper.

Reflections & post-lab discussion (group discussion)

To be completed at the very end of the laboratory session

1. Find another group that used the same pair of unknown solutions as you. Compare procedures. Did you obtain similar results?

2. In a group, discuss how the analogical model can be used to explain how your experiment allowed you to determine the limiting reactant to someone unfamiliar with the chemical principles in this lab.

Rubric for laboratory reports* (due next lab meeting)

The purpose of lab reporting is clear communication of your data and observations, analysis, and claims.

Introduction: **(10 pts)**	**Goal:** To provide a short introduction. **Content:** The summary presents the title of your report, the date that the lab work was done, your partners, if any, and a couple overview sentences about what the lab experiment was about.
Data, Results, Evidence: Scientific data that supports the claim. Submission of the Analog to Target and Designing Experiments Worksheets are required. **(25 pts total)**	**Goal:** To describe what you did and what data was collected and observed **Downloaded Procedure:** Reference the laboratory procedure that was downloaded and the date it was accessed (Limiting Reactant, InterChemNet, accessed: 10/8/2014). Any changes in procedures should be noted. **Analogy:** The Analog to Target Worksheet should be included. **Student Developed Procedure:** The Designing Experiments Worksheet should be included. If insufficient details are present on the worksheet, provide further details in your lab report. **Data, Results, and Evidence:** Carefully organize and present the data you collected. Observations can be important data to use in your analysis. Since patterns are often critical to understanding data, present data in Tables as well as Figures.
Analysis of Evidence (Reasoning): Scientific explanations that use evidence and appropriate chemistry concepts to construct claims. **(30 pts total)**	**Goal:** To provide the logic to evaluate your data and observations **Discussion:** Explain why the evidence you presented supports your claim. This will include a discussion of the Analog to Target and Design your Experiment worksheets. How did you analyze the evidence? Data from outside sources goes here rather than in the Data section because you were not involved in obtaining the data. The "thinking" work involved in analyzing what you did in lab belongs here. Hints for writing this lab report: Are any patterns evident? Discuss the phenomena at both the submicroscopic (molecular) level & macroscopic (visible to your eyes) level. **Use the analogical model to further develop your explanations of results and underlying chemical concepts in your discussion.**
Claim(s): Statement(s), derived from evidence, using scientific reasoning. **(15 pts total)**	**Goal:** To describe what claims or conclusions in response to the question: In the reaction between your pair of solutions, is sodium chloride or silver nitrate the limiting reactant? Remember your data and reasoning are key to your claim, not just the answer! **Claims:** Clearly state what claims or conclusions you can make. The logic of your claims builds from the evidence and reasoning presented in your previous sections. What reasoning can you provide to make meaning of the experiments you conducted (along with outside references). **A good claim will include a short summary of the major pieces of evidence and analysis.** Please write your claims clearly in order for them to be assessed reasonably. Hints for writing this lab report: Think about your experimental procedure and how it allows you to understand how to analyze an unknown solution.

*Lab Course Guidelines and Sample Lab Report, see the general chemistry website for more information

Items to incorporate into your laboratory report:

1. The Analog to Target Worksheet (legible scan).
2. The Designing Experiments Worksheet (legible scan).