Conservation of Mass
A CORE learning cycle lab experiment

This is the third lab of the five-lab experiment sequence. Each of these laboratories will be structured around a learning cycle and an analogical modeling activity.

Experiment A. Making Experimental Observations
Experiment B. Paper Chromatography
Experiment C. Conservation of Mass
Experiment D. Limiting Reagents
Experiment E: Ultraviolet-visible Spectroscopy

Introduction:

Goals:
1. To observe a precipitation reaction.
2. To use an analogical model to think about chemical interactions and the conservation of mass in a precipitation reaction.
3. To design an experiment that supports the conservation of mass.

The Law of Conservation of Mass:
Atoms are conserved in physical or chemical transformations. The number of each type (or species) of atom is the same before the chemical reaction as after the chemical reaction. Each atom has a particular mass associated with it. That means that in a chemical reaction, mass is conserved. The mass of the reactants is equal to the mass of the products.

The conservation of mass seems straightforward, but before atomic theory, the idea that mass is conserved in chemical reactions was not obvious to experimentalists. Different types of chemical reactions, when observed, can appear as if they have created or destroyed matter. Consider a combustion reaction, where a block of wood (made up of a variety of compounds containing hydrogen, oxygen, and carbon atoms) reacts with oxygen. After the wood burns, the resulting pile of ash is lighter than the block of wood. However, in a combustion reaction, atoms in the wood are rearranged to form water (H₂O) and carbon dioxide (CO₂) which are released as gases into the atmosphere. All of the atoms in the original block of wood still exist.

Precipitation reactions can also be misleading. In a precipitation reaction, two solutions containing soluble ions (which are invisible to the eye in the solution) are mixed and react to form a new compound that it no longer soluble. The insoluble compound is a solid that settles out of the solution. The insoluble solid compound is
called a precipitate. It seems as if matter has been created from nowhere.

In this experiment, you will study two precipitation reactions and explore an analogical model for the reaction.

**The CORE Learning Cycle:**

**Phase 1:** We will ask you and a partner to go into the lab, follow a procedure, and make observations.

**Phase 2:** You will then be asked to review material that 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 be asked to 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:**

We will use nuts and bolts and assign them to different types of ions and molecules to model the precipitation reaction. This analogy is useful in accounting for all of the chemical species (atoms, ions, complexes, etc.) present in a solution. In a reaction, when bonds break and new ones form, it is important to have a way to keep track of all of the chemical species. Nuts, bolts, and nails come in different sizes. If you are given a box of nuts, bolts, and nails, you will find some “fit” together securely while others do not. In a similar way, if a solution has a collection of chemical species, some combinations may readily interact, while other combinations do not. In the analogy portion of this lab you will explore how various combinations of nuts, bolts and nails connect, and relate what you learn from the analogy to the behavior of different chemical species in the precipitation reaction.

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**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. Consider a chemical reaction between 5 Zn$^{2+}$ (zinc) and 5 S$^2-$ (sulfide) to form 5 ZnS (zinc sulfide). Write a balanced chemical equation for this reaction.

4. Now imagine that you replace Zn$^{2+}$ with a nut and S$^2-$ with a bolt and draw out a representation for the reaction described above. Is this a type of analogy? Explain by annotating your drawing.
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 have three people.

Your lab work will involve making observations and recording 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:** What are the physical/observable characteristics of each of these solutions?

**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: “we found that both solutions were colorless and of similar viscosity.”

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 the answers would be useful to include in your report.**

**Goggles are required at all times in the lab.** There are no exceptions. Gloves and footwear are available. If you have questions about safety, please do not hesitate to ask your laboratory instructor. This lab has portions of the procedure that must be completed under the hood.

### Equipment and supplies:

<table>
<thead>
<tr>
<th>Filter paper</th>
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<tbody>
<tr>
<td>Long-stem funnel</td>
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<tr>
<td>250 mL Erlenmeyer flasks and beakers</td>
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<tr>
<td>Electric hot plate, wash bottle</td>
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</tbody>
</table>

### Chemicals:

| silver nitrate solution : Ag(NO₃) |
| sodium chloride solution: NaCl |
| calcium chloride solution: CaCl₂ |
| acetone |

![Long-stem funnel](image1)

![Erlenmeyer flask](image2)
Phase 1 of the Learning Cycle: Making observations

The following activities should be completed in the lab.

1. Obtain 0.1 M NaCl and 0.1 M Ag(NO₃) solutions.

   Q: What are the physical/observable characteristics of each of these solutions?

2. Mix together approximately 10 mL of NaCl solution and 10 mL of Ag(NO₃) solution. Record the exact volumes.

   Q: What happens when the solutions are mixed? Is there evidence of a precipitate forming?

3. Allow the solutions to sit for 15 minutes for the reaction to complete. 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.

Thinking about balanced chemical equations:

A balanced chemical equation has a lot of information encoded into it. Consider the example below:

- **Tells you the physical state**
- **A lack of coefficient indicates one mole**
- **Coefficients tell you the number of moles.**
- **Subscripts indicate how many of a particular atom are present in a molecule.** A Cl₂ molecule is composed of two bonded chlorine atoms.

Ultimately, the balanced chemical equation gives you a recipe for a reaction using ratios of moles. In the example above, it takes two moles of sodium atoms and one mole of dichloride molecules to create two moles of sodium chloride. The molar ratio of sodium to dichloride is 2:1. The molar ratio of sodium to sodium chloride in the reaction is 1:1.

However, the ratio in the recipe will still hold for a much smaller number of atoms and molecules. For example, in the reaction above, we can say that 2 sodium atoms will react with 1 Cl₂ molecule to create 2 molecules of sodium chloride. The picture below represents this approach:

In summary, chemical equations provide a general ratio of the amount of each reactant needed to create a certain amount of a particular product. Molar ratios become useful in predicting the mass of product that can be expected.
**The precipitation reaction:**

Now let’s take a look at the chemical equation for the precipitation reaction you performed in Phase 1:

The chemical equation of the reaction of sodium chloride and silver nitrate to produce sodium nitrate and silver chloride:

\[
\text{NaCl}_{(aq)} + \text{Ag(NO}_3\text{)}_{(aq)} \rightarrow \text{Na(NO}_3\text{)}_{(aq)} + \text{AgCl}_{(s)}
\]

Consider all of the information that you can extract from the balanced chemical equation above.

**Q:** What is the precipitate that is formed?

**Q:** What are the molar ratios of the reactants to each other? What is the molar ratio of each reactant to the product silver chloride?

Because we are dealing with ionic compounds, we can write the chemical equation a different way:

Ionic compounds like NaCl and Ag(NO₃) are soluble in aqueous solutions and may separate into positively charged species of ions (cations) and negatively charged species of ions (anions). One way of illustrating the behavior of ionic compounds in solution is a **full ionic equation** like the second equation, below:

\[
\text{NaCl}_{(aq)} + \text{Ag(NO}_3\text{)}_{(aq)} \rightarrow \text{Na(NO}_3\text{)}_{(aq)} + \text{AgCl}_{(s)}
\]

\[
\text{Na}^{+}_{(aq)} + \text{Cl}^{-}_{(aq)} + \text{Ag}^{+}_{(aq)} + (\text{NO}_3\text{)}^{-}_{(aq)} \rightarrow \text{Na}^{+}_{(aq)} + (\text{NO}_3\text{)}^{-}_{(aq)} + \text{AgCl}_{(s)}
\]

Notice that the AgCl is not separated. This is because AgCl is an insoluble compound. It remains a solid and does not separate into a cation and an anion in an aqueous solution.

**Analogical model for the precipitation reaction:**

Now you are going to construct 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. In front of you should be a variety of hardware. There are nails, bolts, and two different sizes of nuts:
1. We would like you to assign each of the types of hardware to each of the different chemical species (see the full ionic equation) involved in this reaction.

As you assign the hardware, consider that some combinations will fit together more tightly than other combinations. The chloride ion has already been assigned as the bolt (see the picture below). The chemical interaction between sodium ions and nitrate ions in an aqueous solution is weak compared to the chemical interaction between silver ions and chloride ions. Make sure your hardware assignments reflect this.

![Diagram of ionic equation]

**Record** which type of hardware you assigned to each chemical species in your notebook.

2. Now, use the hardware to create a representation of sodium cations and chloride anions in a solution. Then, create a representation of silver cations and nitrate anions in a separate solution. These are your reactants.

3. Next, “react” the hardware representations of aqueous sodium chloride and aqueous silver nitrate by rearranging the reactants to form the hardware representation of the precipitate silver chloride and aqueous sodium and nitrate ions.

   **Q:** How do your hardware choices illustrate the differences in solubility of these ionic compounds?

3. Each student should fill out the *Analog to Target worksheet individually* on page 8 (remember, you will each need to scan a legible copy of the worksheet, since your lab report will be electronically submitted). As you fill out the worksheet, please discuss it with your partner, if this helps you think about the chemistry at the atomic scale.

When you have finished, **you have completed Phase 2.**
Analog to Target Worksheet

Fill out this worksheet **individually** as you perform the analogy activity. Work together to discuss similarities and differences. Each student must include a scanned copy of this sheet in their lab report. Make sure your scan is entirely legible. Please **label** the components in your drawings.

<table>
<thead>
<tr>
<th>Analog to Target Comparison</th>
<th>Sodium and chloride ions in an aqueous solution compared to your hardware assignments for these species</th>
<th>Silver and nitrate ions in an aqueous solution compared to your hardware assignments for each of these species</th>
<th>The action of rearranging the hardware compared to the chemical reaction</th>
<th>Silver chloride and sodium nitrate in an aqueous solution compared to the hardware products of the reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Similarities:</strong> What characteristics does the analog share with the target?</td>
<td></td>
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<tr>
<td><strong>Differences:</strong> How does the analog not accurately represent the target?</td>
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<tr>
<td><strong>Draw</strong> a representation of each of the following at the molecular level:</td>
<td>Sodium chloride in an aqueous solution:</td>
<td>Silver nitrate in an aqueous solution:</td>
<td>The chemical reaction:</td>
<td>The products of the reaction in an aqueous solution:</td>
</tr>
</tbody>
</table>
Phase 3: Designing experiments

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

Using the analogical model to make predictions:

Q: Why is mass conserved in chemical reactions? Explain the law of conservation of mass at the molecular level. Use the analogical model to justify your answer.

The experiment:

We would now like you to design an experiment to explore the conservation of mass in a different precipitation reaction between calcium chloride and silver nitrate and answer the following scientific question:

Scientific Question: Is the number of moles of silver chloride produced in the chemical reaction equal to the number of moles of silver and chloride in the reactants?

Use the Designing Experiments worksheet (page 11) 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.

The balanced chemical equation for the reaction of calcium chloride and silver nitrate is:

\[
\text{CaCl}_2(aq) + 2\text{Ag(NO}_3\text{)}(aq) \rightarrow \text{Ca(NO}_3\text{)}_2(aq) + 2\text{AgCl(s)}
\]

Q: Why is it necessary to start your reaction with twice as many moles of silver nitrate (Ag(NO\text{)}_3) as moles of calcium chloride (CaCl\text{)_2})?

In the lab, you will have the following solutions to work with:

\[
\begin{align*}
0.1\text{M Ag(NO}_3\text{)} & \quad 0.1\text{M CaCl}_2 \\
0.2\text{M Ag(NO}_3\text{)} & \quad 0.2\text{M CaCl}_2
\end{align*}
\]

The next page has help with calculations and techniques to help you plan the experiment.

Make sure that you check in with your laboratory instructor before starting your experiment.
How many moles are in an aqueous solution?

The molarity of a solution tells you how many moles of solute, e.g. CaCl$_2$, are in a liter of that solution. Molarity is a measure of concentration. For example, if the bottle says 0.1M on it, that means there would be 0.1 moles of CaCl$_2$ in a liter of that solution. You, of course, rarely will want to use a whole liter of solution.

To figure out how many moles of CaCl$_2$ are in 10mL of a 0.1M solution, here’s what you can do:

remember that 10mL = 0.010L and therefore

\[(0.01 \text{ Liters})(0.1 \text{ moles/Liter}) = 0.001 \text{ moles of CaCl}_2\]

What volume of solution should I use if I want a specific number of moles?

Say you know you want to use 0.002 moles of Ag(NO$_3$)$_2$ in the reaction. How much solution (what volume) should you use? If it’s a 0.1M solution, you can calculate the volume that would contain 0.002 moles this way:

\[(0.002 \text{ moles})/(0.1 \text{ moles/Liter}) = 0.02 \text{ liters or 20 milliliters.}\]

Separating the precipitate:

A technique that will be useful is gravity filtration. Gravity filtration involves using filter paper to separate the insoluble solids (the precipitate) from the liquid 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 the 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.

Drying the precipitate:

Once you have obtained precipitate in the filter paper, it will be wet. The water molecules will add mass, so we need to get rid of them. To do this, we can use acetone and heat to help the water evaporate. Turn on a hot plate. Under the hood, pour acetone into a wash bottle. Carefully fold up the filter paper with precipitate inside and place it on a watch glass. Under the hood, hold the watch glass at an angle over a beaker and use the wash bottle to gently soak the filter paper and precipitate, letting excess acetone drain into the beaker below. Then, remove paper w/precipitate, unfold and place on hot plate to dry. Drying will take 10 - 20 minutes.
Designing Experiments Worksheet

Please use this sheet to summarize your lab group’s experiment and findings. **Before going into lab, have your lab instructor check and initial it. This worksheet is to be scanned and submitted as part of your lab report. Make sure that it is entirely legible!**

<table>
<thead>
<tr>
<th>Please describe your proposed experiment.</th>
<th>(attach extra pages if needed)</th>
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</thead>
<tbody>
<tr>
<td><em>(Check in with your lab instructor before performing experiments)</em></td>
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<tr>
<td>Instructor’s initials:________</td>
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<table>
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<tr>
<th>Describe the data you collected:</th>
<th>(attach extra pages if needed)</th>
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<tr>
<th>What claims can you make?</th>
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Reflections & post-lab discussion (group discussion)

To be completed at the very end of the laboratory session

1. In a group, discuss how the moles of AgCl produced compare to the initial moles of Ag and Cl in the reactants. What are some reasons (e.g., sources of error) that may have impacted your results?

2. In a group, discuss how the analogical model can be used to explain how your experiment supports the conservation of mass to someone who thinks that precipitation reactions create matter.
# 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: (5 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: (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 (Conservation of Mass, 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. Suggestions: Show how you calculated the moles of the reactants. Include the mass of the silver chloride. Show how you calculated the moles of silver chloride produced. |
| Analysis of Evidence (Reasoning): (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): (15 pts total) | **Goal:** To describe what claims or conclusions in response to the question: In the reaction between calcium chloride and silver nitrate, how do the number of moles of silver chloride produced in the chemical reaction compare to the initial number of moles of silver and chloride in the reactants? Can you connect in your claim the evidence that suggests your claim is strong?  
**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](http://generalchemistrywebsite.com) 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).