Moles Lab Activities

Strand Molar Relationships

Topic Investigating stoichiometry

Primary SOL CH.4 The student will investigate and understand that chemical quantities are based on molar relationships. Key concepts include
a) Avogadro's principle and molar volume;
b) stoichiometric relationships;
c) solution concentrations;
d) acid/base theory; strong electrolytes, weak electrolytes, and nonelectrolytes; dissociation and ionization; pH and pOH; and the titration process.

Related SOL CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include
a) designated laboratory techniques;
b) safe use of chemicals and equipment;
c) proper response to emergency situations;
g) mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis.

Background Information

The mole is the basic counting unit used in chemistry and is used to keep track of the amount of matter being measured or transferred. Performing calculations using molar relationships is essential to understanding chemistry. Because of its importance, the concept of the mole, its value, and basic conversions should be introduced very early in the course and revisited often, ideally in every unit, in order for students to understand the concept completely and become proficient with its use.

This lesson offers a wide variety of lab activities in which students practice mole conversions at varying levels of difficulty. These conversions have applications to various content areas so that students can practice these concepts throughout a chemistry course, not just when studying stoichiometry. The common theme of these activities is to have students do simple lab measurements of various substances encountered in everyday life and then perform simple mole calculations and respond to conceptual questions related to the concept. If students approach the idea of the mole both conceptually and mathematically, then they will be able to handle the wide variety of problems that rely on the mole. The idea is to provide a solid conceptual and analytical understanding of the mole concept.

Although the first activity is designed to give students a solid understanding of a counting unit and relative masses as a foundation for understanding the mole, students should be introduced to the quantity of the mole and its role as a counting unit before starting these activities. A review of basic scientific notation and rules for significant figures is also recommended. The activities start with conversions involving elements followed by compounds and then by simple reactions.

Doing one or more moles lab activities in each unit you teach will give students plenty of practice and time to become proficient with all of the basic conversions and calculations. While these activities could be done together in one discrete unit, it will prove more effective to students' long-term retention to have them do these activities throughout the course.

Teacher notes for each activity are found in the list below. Among other things, these notes indicate the recommended unit in which the activity should take place and an estimated time for students to complete the work.

Materials

- Moles Lab Activity 1: PCU (Popcorn Counting Units)
- Moles Lab Activity 2: Elements—Aluminum, Elements—Carbon, Elements—Copper, Elements—Iron, Elements—Silicon, Elements—Sodium
- Moles Lab Activity 3: Compounds—Water, Compounds—Sodium Chloride, Compounds—Chalk Compounds—The Fictitious Compound "Cambium"
- Moles Lab Activity 4: Solutions—Aqueous Copper (II) Sulfate Pent hydrate, Solutions—Alum
- Moles Lab Activity 5: Synthesis of an Oxide of Copper
- Moles Lab Activity 6: Single Replacement and Percent Yield
- Moles Lab Activity 7: Alka-Seltzer
- Moles Lab Activity 8: Conservation of Mass—Reaction of Vinegar and Baking Soda
- Moles Lab Activity 9: Percent Water in a Hydrate

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Procedure

(Found on the attached lab activity sheets)

Assessment

- **Questions**
  (Embedded in each lab activity)
- **Journal/Writing Prompts**
  - Design and describe your own investigation related to a moles lab activity.
- **Other**
  - Design your own Moles Lab Activity Sheets for other students to complete. This can be done experimentally, if time permits, or with mock data provided with the sheets. Submit a grading rubric for the activity.

Extensions and Connections (for all students)

(Listed with the various moles lab activities)

Strategies for Differentiation

- Have students color-code lab procedures and questions, using colored pencils/markers.
- Invite a local nutrition expert from a clinic, grocery store, or hospital to discuss the interpretation of nutritional labels.

- Have students work in groups to create a graph that illustrates the sodium content of snacks. Students can report findings orally or in a group report.
- Have students pick a favorite snack and, using the nutrition label, calculate the number of sodium atoms per serving. Have them share their findings in class. Provide a graph or table to record information.
- Pair students for this activity. It is important to consider students' abilities to complete the extensive written portion of this assignment. Give students with written-language-skill deficits opportunities to record their observations in pictures or on a computer in order to focus on the observations themselves rather than on the written reporting of observations.
- Have students write the general equation for converting moles to atoms and keep it in their vocabulary journals for reference.

Teacher Notes for Moles Lab Activities

Moles Lab Activity 1: PCU (Popcorn Counting Units)

Time: Students will need 20–30 minutes to do initial calculations and collect data. Part 3 could be completed outside of class.

Application: This activity should be used when introducing <u>isotopes</u> and <u>relative atomic masses</u>, which requires the simultaneous introduction of the concept of the mole as a counting unit. The activity also provides reinforcement of scientific notation.

Helpful Hints/Suggestions: Samples can be placed in small plastic containers or baggies. Students may have difficulty understanding that for the data table in Part 2, the PCU is the *number* determined in Part 1 and should be the same for each type of bean. Students may also have difficulty in completing the extension table unless you either explain in advance what they are to do or have them practice such calculations previous to the activity. Some of the confusion comes from not understanding that the tables in Parts 1 and 3 are actually worksheets, not data tables. Not everyone will get the exact same value for a PCU, but this is correct. For honors classes, this fact may be an interesting discussion topic involving lab errors and differences among the kernels and balances.

Answers to Selected Questions: The answers to question #9 need to be recorded in a class data table so that question #10 can be answered. The answer to each part of question #13 should be the same and equal to answer #2. Question #19 should relate to the small size of the atom and the need for a large number of them in order for them to be seen and measured. The answer to question #19 is C-12, the reference isotope for atomic masses.

Moles Lab Activity 2: Elements

Time: Students will need about 5–10 minutes at each lab station to do initial calculations and measurements. They will need a total of 15–20 minutes to complete all questions, some of which could be completed at home.

Application: This activity should be used when introducing <u>elements</u>, <u>chemical symbols</u>, and <u>moles-to-atoms calculations</u>.

Helpful Hints/Suggestions: This activity is actually a set of six activities dealing with six different elements—one for each lab station. It is easy to make additional activities, as the format of each is consistent. Also, if you do not have one or more of these elements on hand, it is easy to substitute others, using the same format. Setting up each sample at a lab station and having students rotate between them works best. Make sure each sample is clearly labeled and stays that way.

These activities go quickly once students get through the first two. It helps if the first group at each station has to get your signature, confirming that their calculations are correct, before they move on. They then become that element's "experts," a role they will like. This will help insure they really do know what they are doing and will allow for other students to have more than one person to verify their work and/or answer questions. It also allows you to determine quickly who is having difficulty with the concept and to whom to offer additional help.

The extension for the aluminum activity requires students to weigh out one mole of aluminum foil and make a creative sculpture. Students don't always understand this from the directions, so it may need some further explanation. They can make a mole, but they should realize that it can be formed into anything.

Answers to Selected Questions: None of the questions should give students any great difficulty. It may help for you to do the extension questions ahead of time so you have an answer key.

Moles Lab Activity 3: Compounds

Time: Students will need about 5–10 minutes at each lab station to do initial calculations and measurements. They will need a total of 15–20 minutes to complete all questions, some of which could be completed at home.

Application: This activity should be used when introducing formulas of compounds, molecular masses, and percent composition.

Helpful Hints/Suggestions: This activity is actually a set of four activities. Directions on the handouts have been intentionally kept short so students will focus on the concept rather than the directions. Samples can be placed in small plastic containers or baggies.

Water: When doing water, remind them about keeping the balance pans dry. You need to tell them ahead of time that the water is going to be weighed directly in the graduated cylinder, so if they are not using an electronic balance that has a tare function, they will need to find the mass of the cylinder as well. You will need to alter the directions on the handout accordingly.

Chalk: If it is difficult to go outside for use of the sidewalk chalk, then use the blackboard or large pieces of paper on the floor. Students really seem to enjoy and remember this activity. Encourage them to be stylistic and artistic in drawing their names. If you do go outside, clearly state limits as to where and what they write. Depending on the nature of your group, you may need to remind them that this is very public so they need to keep it "clean." Be certain that students copy what they draw into their data books.

"Candium": This lab needs to be done with great cleanliness. If you use store-bought cups for samples and measuring, then a reward to students when they finish the activity is that they may eat their "compound" or "element" as long as it has not been contaminated (touched anything in the lab). If you do permit this, you should make it very clear that you are using nonstandard lab materials and that this is *not* a standard practice in a chemistry lab!

Answers to Selected Questions: The answers to most questions require basic conversions. The extension for NaCl deals with colligative properties that will probably not have been covered at this point. You can either require them (honors students) to look it up on their own, or talk about deicing and antifreeze as the questions come up. Introducing in extensions topics that will be covered later in the course helps students put things in context and drives home the point about interconnectedness and cumulative knowledge. The extension for sidewalk chalk requires students to differentiate between ionic and covalent bonds. This topic should be covered if you are working on compounds and their formulas.

Moles Lab Activity 4: Solutions

Time: Students will need about 5–10 minutes at each lab station to do initial calculations and measurements. They will need a total of 15–20 minutes to complete all questions, some of which could be completed at home.

Application: This activity should be used when introducing chemical formulas, dissociation, mass-to-molecules/ions calculations, and solutions.

Helpful Hints/Suggestions: This activity is actually a set of two activities. Some students will need help with adding molar masses of these hydrated salts. Alum can be purchased at the store. One solution is supposed to be saturated, and the other is not—a concept that is also being introduced at this time. You should also reinforce the concept of the smallness of ions/particles that pass through the filter paper. It is helpful to use the copper solution to reinforce the concept of dissociation and that the particles do not disappear but are simply too small to be seen.

Answers to Selected Questions: The questions in the extensions concerning what is left on the filter paper and what is in the filtrate aim at having students identify the species present and the form that they are in—i.e., atoms, ions, or molecules.

Moles Lab Activity 5: Synthesis of a Compound

Time: Students will need about 5–10 minutes at each lab station to do initial calculations and measurements. They will need a total of 15–20 minutes to complete all questions, some of which could be completed at home.

Application: This activity should be used when introducing chemical formulas, percent composition, and empirical formulas.

Helpful Hints/Suggestions: The copper has an interesting series of color changes before it turns black, but students may miss it if they are not paying attention. This reaction is not efficient, and errors will be high. You should get enough conversion that the percent oxygen will be less than the first oxide so that that should be their choice for their product. The high error in this lab is actually a good teaching opportunity, not only for sources of error (incomplete reactions), but also for ways reactions really occur. The oxidation is not instantaneous and is greatly dependent on surface area and amount of heat. This leads into a discussion of collision theory. Because students' data will vary, this lab is good for having a discussion of class-data accuracy and precision. You get a little better data with copper powder than granules, but not enough to offset the safety issue, if that is a concern. Either way, a lot of the copper will not react, which can be seen if the product is stirred after it cools. If you have metal rods for stirring, students can stir while the copper is heating. However, this can lead to problems of sample loss and possible burns if students are not careful, and it decreases error only a little bit. Another way to decrease error is to use Bunsen burners/clay triangles and heat for a longer period of time. However, the reduction of error may not be worth the added time when the focus should be on the reaction and calculations. Remind students of the safety rules for working with very hot materials.

Answers to Selected Questions: Weaker students might have a little trouble with predicting the possible oxides and with the Roman numeral naming system; they often remain confused about the Roman numeral indicating the number of metal atoms. This is a good reaction to try to clear up this confusion. Some students may have trouble figuring out the equation for Pre-Lab #4; they need to start with the oxide produced in #3 (Cu_2O) and react it with O_2 again to form CuO. For question #3 after the analysis, some students have a hard time with the concept that Cu_2O is less fully oxidized than CuO; therefore, focus on the theoretical percent O to help them understand this.

Moles Lab Activity 6: Single Replacement and Percent Yield

Time: Students will need about 30 minutes at each lab station to do initial calculations and measurements. They will need a total of 15–20 minutes to complete all questions, some of which could be completed at home.

Application: This activity should be used when introducing <u>chemical equations/types</u>, <u>mass-to-mass conversions</u>, and <u>percent yield</u>.

Helpful Hints/Suggestions: Copper(II) chloride is expensive, and shipping the solid can be hazardous. You can either buy the solution premixed, or you can substitute an acidified copper(II) sulfate solution of the same molarity (the solution needs to be made in 0.5–1.0 *M* HCl). All copper solutions should be handled carefully by students, and you must be sure that the necessary safety procedures are followed. Students should get a measurable temperature change during this lab. If you do the extension to recover the copper, there are problems that occur. The copper on the filter paper needs to be washed thoroughly with water, especially if you are using acidified copper(II) sulfate. As the copper dries, it tends to form hydroxides from the exposure to moisture and the air. This could mean you will end up with more than a 100% yield. For an honors class, this is a good teaching point about experimental errors and unwanted secondary reactions. In a regular class, however, it may distract them from focusing on the mass-to-mass conversions that they learning. It may be possible to reduce this error by washing with acetone before drying, but this might not be worth the effort. In any case, it is important to demonstrate to students that science is not perfect!

Answers to Selected Questions: Weaker students will have some difficulty justifying the reaction from experimental evidence. It is surprising that they may not realize that the solution still having some blue color is proof that the copper solution is not the limiting reactant and that the color of the product matches the color of copper. Students also tend to confuse theoretical and experimental yields.

Moles Lab Activity 7: Alka-Seltzer

Time: Students will need about 15–20 minutes to do initial calculations and measurements. They will need a total of 15–20 minutes to complete all questions, some of which could be completed at home.

Application: This activity should be used when introducing <u>Gas Laws</u>.

Helpful Hints/Suggestions: In this lab, you are ignoring the role of the citric acid in Alka-Seltzer to simplify the reaction so that students can focus on the gas conversions. It is a good idea to acknowledge this up front to avoid questions later that will distract weaker students. Students may forget to put the weighing dish back on the balance after adding the tablet to the water. If you do not have a barometer, then access the weather information online, and use the reported pressure; it will be close enough. (Students will have errors anyway.) The weather service gives pressure in inches of Hg, so students may need help with the conversion to atm. The extension questions in this lab could actually be turned into a student investigation. Students could vary amounts of Mg or acid and see the effect on yield and/or limiting reactant.

Answers to Selected Questions: The conversion described in the last bullet under "Analysis" can be done in several ways. You can leave it up to the students, or for weaker students, you may want to specify which way to do it. Another possibility is to have one partner do it one way and the other partner do it the other way to prove that both ways yield the same answer.

Moles Lab Activity 8: Conservation of Mass

Time: Students will need about 15–20 minutes to do initial calculations and measurements. They will need a total of 15–20 minutes to complete all questions, some of which could be completed at home.

Application: This activity should be used when introducing balancing equations and conservation of mass.

Helpful Hints/Suggestions: This lab is very straightforward. Some students will have trouble with loss of mass because they do not seal the bag correctly or they spill some vinegar before they get the bag sealed. You may want to model sealing up the bag while keeping the beaker upright. If students do not measure out the reactants correctly, they may generate enough gas to pop the bag open; deal with this as a lab-safety and carelessness issue.

Answers to Selected Questions: If this is the first time students have been asked to calculate percent error, they will need help. They will confuse theoretical and experimental values. They may also have some calculator-entry issues with order of operations.

Moles Lab Activity 9: Percent Water in a Hydrate

Time: Students will need about 30 minutes to do initial calculations and measurements. They will need a total of 15–20 minutes to complete all questions, some of which could be completed at home.

Application: This activity should be used when introducing chemical formulas, percent composition, and hydrated salts.

Helpful Hints/Suggestions: Weaker students will need help with adding molar masses of these hydrated salts. A desiccator will reduce errors, but it is not absolutely required. Be sure to include this in your discussion of errors, if you do not use one. Other hydrated salts can be used, but copper(II) sulfate has a good color change. [Cobalt(II) chloride also has a good color change and is a good substitute, if you are allowed to order it.] It is good for students to get visual confirmation of the dehydration. You will need to demonstrate how to transfer the hot evaporating dish. This lab usually calls for heating in a crucible, but we have found that the increase in errors when using this method is offset by students' being able to see the process. It also gives you more to talk about when analyzing errors and suggestions for improvement when students are asked to design their own procedures. Be sure to go over the necessary lab safety procedures. The extension in this activity can be used as an assessment as well.

Answers to Selected Questions: Analysis bullet 4: Students often have difficulty with precision versus accuracy in class data. You might want to review this in the pre- or post-lab discussion. Analysis bullet 6: Students often have misconceptions about whether this is a chemical or physical change. Reviewing this would be helpful. Extension bullet 4: If students do not realize that heating the salt to dehydrate is endothermic, they may not realize that the reverse process must be exothermic.

Moles Lab Activity 1:
PCU (Popcorn Counting Units)

Materials

A container of each of the following:

- Popcorn kernels
- Kidney beans
- Pinto beans
- Peas
- Lima beans
- Navy beans
- A large unopened bag of popcorn
- Kernels
- Balance
- Safety goggles

Objective

To devise a new counting unit, use it in calculations, and compare it to the use of a mole.

Procedure

Part 1

1. Weigh out 5.0 grams of popcorn kernels on the balance, and count the number of kernels there are in 5.0 grams. This *number* will be called **"1 PCU"** (1 popcorn counting unit).
2. Complete the following equation in your data record:
   1 PCU = _____ kernels = 5.0 g of kernels
3. Show how you would calculate the number of kernels in 3 PCUs:
4. Show how you would calculate the number of kernels in 20.0 grams of popcorn:
5. Show how you would calculate the mass, in grams, of 100 popcorn kernels:

6. Complete the table at right.

7. Use the balance to find the mass, in grams, of the unopened bag of popcorn kernels. Mass:

8. Use the mass of the popcorn bag and your PCU to determine how many kernels are in the bag. Show your work here, and record your answer on the class data table.

9. Based on the class data table, what is the average number of kernels in the popcorn bag?

Number of popcorn kernels	Number of PCUs	Mass of popcorn kernels (g)
	2	
	10	
	500	
		10.0
		650.0
		5.0×10^5
1		
498		
7,000		
5.0×10^8		

10. How close to the class average number is the number you found?

11. Explain what could account for the different numbers of kernels calculated by each student.

12. We can use a PCU just like a dozen is used. When we count out a dozen eggs, bagels, and marbles, we know that the mass of each dozen will not be the same. Would you expect 1 PCU of lima beans to weigh the same as 1 PCU of popcorn kernels? ______ Explain you answer.

13. How many popcorn kernels have you determined to be equal to 1 PCU? If you were counting out 1 PCU of marbles, how many marbles would you count out? ______ If you were counting out 1 PCU of each type of bean, how many of each would you count out?

14. Count out 1 PCU of pinto beans. This will be the number of pinto beans equal to the number of kernels in one PCU. Use a balance to determine the mass of 1 PCU of pinto beans and record in the table below.

Part 2

1. Complete the data table at right, keeping in mind that the number of particles in a PCU is always the same.
2. Is the number of kidney beans in 1 PCU more than, less than, or equal to the number of navy beans in 1 PCU?

Type of particle	Number of particles in 1 PCU	Mass of 1 PCU
Pinto bean		
Kidney bean		
Lima bean		
Pea		
Navy bean		

3. How does the mass of 1 PCU of kidney beans compare to the mass of 1 PCU of navy beans? ____________
   How can you account for the differences in mass that you observed?

4. Would 5.0 grams of kidney beans be more than, less than, or equal to the mass of 1 PCU of kidney beans? _____________
   Would 10.5 grams of peas be more than, less than, or equal to the mass of 1 PCU of peas? ________________
5. Why is a mole a better unit than a PCU for counting atoms?
6. How many particles are in a mole? ________

Extension

1. Fill in the table at right.
2. Explain how the mass of one mole of magnesium atoms compares to the mass of one mole of iron atoms.
3. Just as our masses in this lab can be based on popcorn kernels, the atomic masses of each element on the periodic table can be (and are) based on one element. What element is it?

Element	Symbol	Mass of 1 mole	Number of particles	Number of moles	Mass of sample (g)
Carbon			6.02×10^{23}	1	12
Carbon			1.2×10^{24}	2	
Carbon				3	36
Carbon				0.5	
Carbon					3
Magnesium					24.3
Silicon					14
Neon			6.02×10^{22}		
Iron				3	

Moles Lab Activity 2: Elements—Aluminum

Materials

- Empty aluminum can
- Balance
- Aluminum foil
- Safety goggles

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Find and record the mass of one mole of aluminum.

2. Find and record the mass of the aluminum can.

3. Answer the following questions:
   - Does the aluminum sample contain more than, less than, or exactly one mole of aluminum?

   - How many moles of aluminum atoms are in one aluminum can?

   - How many individual atoms of aluminum are in one aluminum can?

4. Check your answers with the student aluminum experts, and ask them to initial your original data to certify that they are correct.

Extension

1. How many cans would you need to have one mole of aluminum?

2. Make a “sculpture” out of aluminum foil, using exactly one mole of the foil.

Moles Lab Activity 2: Elements—Carbon

Materials

- Sample of carbon
- Balance
- Safety goggles

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Find and record the molar mass of carbon.

2. Find and record the mass of the carbon sample.

3. Answer the following questions:
   - Does the carbon sample contain more than, less than, or exactly one mole of carbon?
   - How many moles of carbon atoms are in the carbon sample?
   - How many individual atoms of carbon are in the carbon sample?

4. Check your answers with the student carbon experts, and ask them to initial your original data to certify that they are correct.

Extension

1. A person weighing about 78 kg is about 18% carbon by mass. What is the mass (in grams) of carbon in this person? How many moles of carbon are in this person?

2. Graphite is one allotropic form of the element carbon. Do some research to define *allotrope,* and describe the structure and properties of graphite and of other carbon allotropes.

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Moles Lab Activity 2: Elements—Copper

Materials

- Sample of copper
- Balance
- Pre-1982 penny

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Find and record the molar mass of copper.
2. Find and record the mass of the copper sample.
3. Answer the following questions:
   - Does the copper sample contain more than, less than, or exactly one mole of copper?
   - How many moles of copper atoms are in the copper sample?
   - How many individual atoms of copper are in the copper sample?
4. Check your answers with the student copper experts, and ask them to initial your original data to certify that they are correct.

Extension

1. Determine the mass of a pre-1982 penny.
2. Answer the following questions:
   - How many moles of copper are in the penny?
   - How many atoms of copper are in the penny?
   - How many pennies are needed to make a mole of copper?

- Why would these calculations be invalid for post-1982 pennies?

Moles Lab Activity 2: Elements—Iron

Materials
- 10 iron nails
- Balance
- Iron filings
- Small cup
- Magnetic retriever

Procedure
Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Find and record the molar mass of iron.
2. Find and record the mass of 10 iron nails.
3. Answer the following questions:
   - Do 10 nails contain more than, less than, or exactly one mole of iron?
   - How many moles of iron atoms are in the 10 nails?
   - How many individual atoms of iron are in the 10 nails?
4. Check your answers with the student iron experts, and ask them to initial your original data to certify that they are correct.

Extension
1. How many iron nails are needed to get one mole of iron atoms?
2. Pick up some iron filings with the magnet. Scrape these off into a weighing cup, and determine the mass of the collected iron filings. Calculate how many moles of iron filings were collected.
3. Estimate the volume of one mole of iron filings, and describe how you determined this.

Moles Lab Activity 2:
Elements—Silicon

Materials
- Sample of silicon
- Balance

Procedure
Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Find and record the molar mass of silicon.

2. Find and record the mass of the silicon sample.

3. Answer the following questions:
   - Does the silicon sample contain more than, less than, or exactly one mole of silicon?
   - How many moles of silicon atoms are in the silicon sample?
   - How many individual atoms of silicon are in the silicon sample?

4. Check your answers with the student silicon experts, and ask them to initial your original data to certify that they are correct.

Extension
Silicon is to geologists what carbon is to biologists. It makes up 28% of Earth's crust and is found in many minerals. Sand, quartz, and glass are all made up of silicon dioxide (SiO_2).

1. Answer the following questions:
   - Is silicon dioxide an element or a compound?
   - How many moles of silicon are in one mole of silicon dioxide?
   - How many moles of oxygen are in one mole of silicon dioxide?
   - How many atoms of silicon are in one mole of silicon dioxide?
   - How many atoms of oxygen are in one mole of silicon dioxide?
2. Silicon is a *metalloid*. Look up the properties of a metalloid, and explain why metalloids are so useful in making semiconductors for computers and other electronics.

Moles Lab Activity 2: Elements—Sodium

Materials

- Small bag of snack food
- Balance

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Find and record the molar mass of sodium.

2. Answer the following questions:
   - How many mg of sodium are in one serving of snack crackers?
   - How many g of sodium are in one serving of snack crackers?
   - How many moles of sodium are in one serving of snack crackers?
   - How many individual atoms of sodium are in one serving of snack crackers?

3. Check your answers with the student sodium experts, and ask them to initial your original data to certify that they are correct.

Extension

Healthy American adults should restrict their sodium intake to no more than 2,400 milligrams per day. This is about 1¼ teaspoons of table salt (sodium chloride [NaCl]).

1. Answer the following questions:
   - What is the maximum number of moles of sodium recommended in your diet? How many sodium atoms would this be?
   - If 1 teaspoon salt = 2,000 mg sodium, how many tablespoons of salt would you need to get a mole of sodium? (3 tsp = 1 tbsp)

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Moles Lab Activity 3: Compounds—Water

Materials

- Water
- Graduated cylinder
- Balance

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Mass 50.0 mL of water, using the graduated cylinder. Be sure to subtract out the mass of the cylinder. Record the mass of the water.

2. Find and record the molar mass of water (H_2O).

3. Answer the following questions:
   - Is 50.0 mL of water less than, equal to, or more than one mole of water?

   - How many moles of water are in 50.0 mL of water?

   - How many molecules of water are in 50.0 mL of water?

   - How many individual atoms of hydrogen are in 50.0 mL of water?

   - What is the density of your water sample?

4. Check your answers with the student water experts, and ask them to initial your original data to certify that they are correct.

Extension

1. Solve the problem:
   - Calculate the percent by mass of each element (H and O) in water (H_2O).

   - Calculate the mass of hydrogen in your 50.0 mL of water.

   - Calculate the mass of oxygen in your 50.0 mL of water.

   - Use the density of water to calculate the volume of one mole of water, in mL.

- One swallow of water is about 20 mL of water. How many moles of water are in one swallow? __________ How many molecules of water are in one swallow? ___________

Moles Lab Activity 3: Compounds—Sodium Chloride

Materials

- Sample of sodium chloride
- Sample of calcium chloride
- Test tube
- Weighing dish
- Balance

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Use a weighing dish to determine the mass of the sodium chloride sample in the test tube.

2. Find and record the molar mass of sodium chloride (NaCl).

3. Answer the following questions:
   - Is the amount in the sample less than, equal to, or more than one mole of sodium chloride?

   - How many moles of sodium chloride are in the sample?

   - How many molecules of sodium chloride are in the sample?

   - How many individual ions (both anions and cations) are in the sample?

4. Check your answers with the student sodium chloride experts, and ask them to initial your original data to certify that they are correct.

Extension

1. Calculate the percent by mass of each element (Na and Cl) in the salt sodium chloride (NaCl).

2. Calculate the percent by mass of each element (Ca and Cl_2) in the salt calcium chloride ($CaCl_2$).

3. Pure water freezes at 0°C. When substances are dissolved in water, the solute particles affect the intermolecular attractions of the water, decreasing the freezing point and

elevating the boiling point. This is called a "colligative property." The magnitude of the change is determined by the number (moles) of solute particles dissolved in solution. Which will lower the freezing point of water more—one mole NaCl or one mole of $CaCl_2$? Why?

Moles Lab Activity 3: Compounds—Chalk

Materials

- Sidewalk chalk
- Balance

Procedure

1. Find the mass of a piece of sidewalk chalk.
2. Write your name on the sidewalk or parking lot with the piece of chalk, but do not use it up completely.
3. Find the mass of your piece of chalk following your writing.
4. Answer the following questions, taking the necessary measurements and recording them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.
   - What is the molar mass of chalk (calcium carbonate [$CaCO_3$])?
   - What is the mass of your piece of chalk before writing?
   - What is the mass of your remaining chalk after writing?
   - How many grams of chalk did you leave on the ground?
   - Is the amount left on the ground more than, equal to, or less than one mole of chalk?
   - How many moles of chalk did you leave on the ground?
   - How many molecules of chalk did you leave on the ground?
   - How many individual atoms of oxygen did you leave on the ground?
5. Check your answers with the student calcium carbonate experts, and ask them to initial your original data to certify that they are correct.

Extension

1. Calculate the percent oxygen by mass of chalk (calcium carbonate [$CaCO_3$]).
2. Answer the following questions:
   - How many calcium (Ca) atoms did you leave on the ground?
   - How many atoms (total of all types) did you leave on the ground?
   - Is chalk an ionic or covalent compound? Why?

Moles Lab Activity 3: Compounds—The Fictitious Compound "Candium"

Materials

- Sample of "candium" (mixture of 12 M&M's and 8 Skittles)
- 2 small paper cups
- Balance

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Assume that each kind of candy ("Mm" and "Sk") in the sample of "candium" represents a different type of atom and that the sample is the compound. Write the formula in the format Mm_xSk_y for the compound "candium," using the smallest whole-number ratio of Mm to Sk.

2. Find and record the molar mass of candium. (Assume your sample is one mole.)

3. Find and record the mass of the Mm in your sample.

4. Find and record the mass of the Sk in your sample.

5. Answer the following questions:
   - What is the average mass of an Mm (the molar mass of Mm)?

   - What is the average mass of an Sk (the molar mass of Sk)?

   - What is the percent by mass of Mm in candium? Use this equation:

$$\textbf{\% by mass Mm} = \frac{\textbf{molar mass Mm} \times \textbf{number of Mm atoms in candium formula} \times \textbf{100}}{\textbf{molar mass of candium}}$$

   - What is the percent by mass of Sk in candium? Use a similar equation.

6. Check your answers with your teacher, and ask him/her to initial your original data to certify that they are correct.

Extension

"Candium Isotope" Activity

1. Assume your candium sample is a sample of an *element*, not a compound. In this element, Mm and Sk are the two naturally occurring isotopes of the element. What is the percent abundance (by number) of each isotope in your sample?

2. What is the average atomic mass of the element candium? Use the average mass of each isotope as its mass number and its percent abundance to calculate, using the following formula: [Mass $\#_{(Mm)}$ ($\%_{Mm}$) + Mass $\#_{(Sk)}$ ($\%_{Sk}$)] ÷ 100 = average atomic mass

3. Compare the average atomic mass to the molar mass (total mass of all candies in the sample). What is your percent error?

Moles Lab Activity 4: Solutions—Aqueous Copper (II) Sulfate Pentahydrate

Materials

- Beaker or plastic cup
- Copper(II) sulfate pentahydrate ($CuSO_4 \bullet 5\ H_2O$) crystals
- Graduated cylinder
- Water
- Filter paper
- Funnel
- Ring stand and ring
- Watch glass or Petri dish

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Find and record the molar mass of *hydrated* copper(II) sulfate (copper(II) sulfate pentahydrate [$CuSO_4 \bullet 5\ H_2O$]).

2. Find and record the mass of 0.0125 moles of copper(II) sulfate pentahydrate.

3. Weigh out 0.0125 moles of copper(II) sulfate pentahydrate. Using a graduated cylinder to measure, place 25.0 mL of water into a plastic cup or beaker.

4. Record the color changes you observe as you add the 0.0125 moles of copper(II) sulfate pentahydrate to the water and stir to dissolve completely.

5. Answer the following questions:
   - Is the mixture heterogeneous or homogeneous?
   - What is the solute in this solution?
   - What is the solvent?
   - How many copper atoms are in one mole of copper(II) sulfate?

- How many copper atoms are in your 25.0 mL of copper(II) sulfate solution?
- What is the percent water by mass in copper(II) sulfate?
- What is the percent copper in the 0.0125 moles of copper(II) sulfate?

Extension

1. Predict the appearance of the filtrate (the substances that pass through the filter) if you were to filter the copper(II) sulfate solution.
2. Assemble a filtration apparatus, using a ring stand and ring, a plastic funnel, a beaker, and a piece of filter paper. Sketch and label the apparatus in your data book.
3. Prime the filter with tap water, and filter the copper(II) sulfate solution.
4. Describe the filtrate, and compare it to your prediction. Account for similarities and/or differences. What substances are found in the filtrate?
5. How many oxygen atoms are in one mole of copper(II) sulfate ($CuSO_4$)? Calculate the number of oxygen atoms in your 25.0 mL of saturated copper(II) sulfate solution.
6. Draw a model of an aqueous copper(II) ion by drawing Cu^{2+} surrounded by water molecules. Which end of the water molecules is attracted to the Cu^{2+} ion?
7. Based on the copper(II) ion (Cu^{2+}) and the formula for copper(II) sulfate, what is the charge of the sulfate ion (SO_4)?
8. Place 1 mL of your filtrate on a watch glass, and allow the water to evaporate (this may take a day or two). Draw the shape of the crystals that form.

Moles Lab Activity 4: Solutions—Alum

Materials

- Beaker or plastic cup
- Alum (hydrated aluminum potassium sulfate [$AlK(SO_4)_2 \bullet 12\ H_2O$]) crystals
- Water
- Filter paper
- Funnel
- Ring stand and ring

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Find and record the molar mass of alum (hydrated aluminum potassium sulfate [$AlK(SO_4)_2 \bullet 12\ H_2O$]).

2. Find and record the mass of 0.050 moles of alum.

3. Weigh out 0.050 moles of alum. Using a graduated cylinder to measure, place 25.0 mL of water into a plastic cup or beaker. Add the 0.050 moles of alum to the 25.0 mL of water, and mix thoroughly. Record your observations.

4. Answer the following questions:
   - Is the mixture saturated or unsaturated?
   - What is the solute in this solution?
   - What is the solvent?
   - How many aluminum atoms are in one mole of aluminum potassium sulfate?
   - How many aluminum atoms are in your 25.0 mL of aluminum potassium sulfate solution?
   - What is the percent water by mass in aluminum potassium sulfate?
   - What is the mass of sulfur in the 0.050 moles of aluminum potassium sulfate?

5. Check your answers with your teacher, and ask her/him to initial your original data to certify that they are correct.

Extension

1. Predict the appearance of the filtrate (the substances that pass through the filter) if you were to filter the aluminum potassium sulfate solution.

2. Assemble a filtration apparatus, using a ring stand and ring, a plastic funnel, a beaker, and a piece of filter paper. Sketch and label the apparatus in your data book.

3. Prime the filter with tap water, and filter the $AlK(SO_4)_2 \bullet 12\ H_2O$ solution.

4. Describe the filtrate, and compare it to your prediction. Account for similarities and/or differences. What substances are found in the filtrate?

5. How many sulfur atoms are in one mole of alum? Calculate the number of sulfur atoms in your 25.0 mL of saturated alum solution.

6. How many oxygen atoms are in one mole of alum? Calculate the number of oxygen atoms in your 25.0 mL of saturated alum solution.

7. Place 1 mL of this solution on a watch glass, and allow the water to evaporate (this may take a day or two). Draw the alum crystals remaining after the water evaporates. Show clearly the shape of one crystal.

Moles Lab Activity 5: Synthesis of an Oxide of Copper

Materials
- Hot plate
- Evaporating dish
- Balance
- Granular or powdered copper

Pre-Lab
Copper has two common ions: copper(I) (Cu^{+}) and copper(II) (Cu^{2+}). When heated in air, the copper will react with oxygen gas (O_2) to form an oxide. The Roman numeral is used in the name to differentiate between the two possible oxides of copper. Remember that the Roman numeral indicates the *charge* on the metal, not the *quantity.*

1. Determine the formula for each oxide of copper, and indicate its name. Check with the teacher or the student copper experts for accuracy of these answers before proceeding.
2. Determine the percent oxygen in each oxide.
3. Based on your answers from the previous step, which oxide should form first in this experiment? Why? Write the balanced equation for its formation.
4. The second oxide cannot be formed directly, but is formed from the further oxidation of the first oxide. Write a balanced equation for the formation (synthesis) of the second oxide, using the first oxide and oxygen gas as the reactants.
5. Check that the answers to the pre-lab are correct before performing the experiment below.

Procedure
Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly. You must wear goggles when heating.

1. Find and record the molar mass of copper.
2. Find and record the mass of a clean, dry evaporating dish.
3. Determine the mass of 0.30 moles of copper.

4. Place 0.30 moles of copper into the evaporating dish, and record the total mass before heating.
5. Place the evaporating dish on the hot plate, and turn it on to the highest setting. Heat strongly for at least 15 minutes, and record at least four qualitative observations while heating.

6. Use crucible tongs to carefully remove the evaporating dish from the hot plate, and allow the dish to cool for 5 to 10 minutes.

7. Find the mass of the dish and oxide of copper after heating, and record.

8. Determine the mass of the copper(x) oxide formed.

9. Determine the mass of oxygen reacted (the difference in mass before and after heating).

10. After the product has cooled, observe it carefully for any signs of an incomplete reaction. Record observations.

Analysis

1. Answer the following questions:
   - What is the experimental percent oxygen in your product? Report this in the class data table.

   - Based on your percent oxygen, which oxide most likely was formed?

   - Based on this result, what is your percent error?

   - Look up the color of copper(I) oxide and copper(II) oxide. Does this information support your data? Why, or why not?

   - Is the class data accurate and/or precise? Why, or why not?

   - What experimental errors would account for any differences you observed?

Extension

1. Iron can also form two oxides. Look up the possible oxidation states (charges) for iron, write the formulas for both oxides, and indicate their names.

2. Determine the theoretical percent oxygen of each oxide.

3. In an experiment similar to the one described above, a student reacted 1.20 g of iron and determined that it gained 0.5 grams upon heating. Determine the percent oxygen in the product.

4. Determine the empirical formula for the oxide formed.

5. Identify which oxide was formed in the experiment. What evidence do you have to support this conclusion?

6. Look up the color of each possible oxide of iron. What would be the color of the product in the experiment? Why?

7. In forming the oxides of transition metals with multiple oxidation states by heating them in air, identify the two things that most likely determine which oxide is formed.

Moles Lab Activity 6: Single Replacement and Percent Yield

Materials

- Aluminum foil
- Beaker or plastic cup with 100 mL of 0.5 *M* aqueous copper(II) chloride [$CuCl_2$(*aq*)] (or an acidified copper(II) sulfate solution)
- 100-mL graduated cylinder
- Balance
- Thermometer
- Filter paper
- Funnel
- Funnel stand
- 250-mL or larger beaker

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Take a piece of aluminum foil with a mass of approximately 0.5 grams. Measure and record the exact mass (to 2 decimal places) of the piece of foil.

2. Use the exact mass of your foil and the molar mass of aluminum (to 2 decimal places) to calculate the number of moles in your piece of aluminum. Record.

3. Gently tear the piece of aluminum into small pieces, and put them into a beaker with 100 mL of 0.5 *M* aqueous copper(II) chloride [$CuCl_2$(*aq*)]. Observe carefully, and record at least 10 observations during the reaction, numbering each observation. One aspect of these observations should be temperature: determine whether there is a change in the temperature of the solution by recording the temperature of the solution as the reaction proceeds. The initial temperature and final temperature should count as 2 of your 10 observations.

4. Save your solution for the extension activity, and clean up.

Analysis

1. This is a single replacement reaction.

2. Predict and write the formulas for the two products of the reaction of aluminum metal Al(*s*) with the copper(II) chloride.

3. Write and balance the equation for the reaction, and place the heat term on the appropriate side.

4. Explain why the reaction is a single replacement reaction.

5. What physical evidence indicates that your reaction actually occurred as predicted by the balanced equation?

6. Which reactant is the limiting reactant? What observations support this choice?

7. Draw representative models of the *reactants,* including water molecules, aqueous ions, and aluminum atoms, and label each correctly.

8. Draw representative models of the *products,* including water molecules, aqueous ions, and copper atoms, and label each correctly.

9. Calculate your *theoretical yield,* using the number of moles in your piece of aluminum, and the mole ratio from the balanced equation, calculate the number of grams of copper that would be produced from the reaction.

10. Draw and label an energy diagram for this reaction. Label both axes—the reactants and the products. Use arrows to indicate the heat of reaction (ΔH), and indicate the appropriate sign for ΔH.

Extension

1. Measure and record the mass of a piece of filter paper.

2. Filter the products of the reaction in the experiment above. Wash the filtrate with distilled water, and place the filter paper in the drying oven over night.

3. Remove the filter paper from the drying oven, let cool, and then find the mass of the filter paper and copper product. Record observations.

4. Determine your experimental yield of copper.

5. Compare your experimental yield to the theoretical yield to calculate your percent yield.

6. Indicate two major sources of error in this lab, and predict their effect on the percent yield.

7. Using the volume and molarity of the $CuCl_2$ in the third step of the Procedure above, calculate the number of *moles* of copper ions present in the initial solution.

8. Calculate the number of *grams* of copper ions that were present in the original solution.

9. Compare the grams of Cu ions present in the original solution with the number of grams produced from the reaction (the theoretical yield). Which is greater?

10. Did all of the copper ions in solution become copper atoms? Why, or why not?

11. Prove mathematically which reactant was limiting. Does this support your predictions above?

12. How many total *atoms* of copper were produced (based on your theoretical yield)?

13. Use the balanced equation to prove that this reaction follows the Law of Conservation of Mass.

Moles Lab Activity 7: Alka-Seltzer

Materials

- 250-mL beaker
- 100-mL graduated cylinder
- Water
- Thermometer
- Barometer
- Alka-Seltzer tablet
- Balance

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Measure and record the mass of an Alka-Seltzer tablet.

2. Place 100 mL of water in a 250-mL beaker, and record the combined mass of the water and beaker.

3. Combine and record the masses from steps 1 and 2.

4. Drop the tablet into the beaker, and record three observations during the reaction.

5. Once the reaction has stopped, record the mass again.

6. Clean up, and answer the following questions.

Analysis

1. The antacid in Alka-Seltzer is sodium bicarbonate ($NaHCO_3$). It decomposes to form CO_2 and NaOH. Write a balanced equation for the decomposition of the sodium bicarbonate. (The sodium hydroxide [NaOH] reacts with the citric acid in the Alka-Seltzer to form a neutralized solution.)

2. Answer the following questions, taking the necessary measurements and recording all measurements clearly, with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.
   - What was the mass of the CO_2 gas that was released?

   - How many moles of CO_2 were released?

- How many liters of the CO_2 were released? Assume standard temperature and pressure (STP).

- What amount of sodium bicarbonate is in each tablet? (Use the information on the Alka-Seltzer package to determine this.) Convert this mass to grams.

- What is the number of moles of CO_2 that theoretically should have been produced?

- How many liters would this be at STP?

3. Calculate the percent yield of the amount of gas actually produced by the tablet.

4. Explain two possible sources of error.

5. The room conditions in this experiment are not really STP (it would be awfully cold). Measure the room temperature and barometric pressure. Convert the temperature to degrees Kelvin and the pressure to atmospheres. What is the volume of CO_2 produced, experimentally, at room conditions? (You many use either the Ideal Gas Law or the Combined Gas Law.)

Extensions

Consider the results if you were to do a similar lab by reacting magnesium metal (Mg) with hydrochloric acid (HCl). Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Write a balanced chemical equation to represent this reaction, and indicate which product would be a gas.

2. Answer the following questions:
   - How many moles of hydrogen gas would be needed to produce the same volume as the CO_2 produced in your experiment under the same conditions of temperature and pressure? Why?

   - What mass of hydrogen gas (H_2) would this be?

   - What mass of magnesium would be needed to produce this amount of hydrogen gas?

   - Would you need an excess of acid to produce this amount of hydrogen? Why, or why not?

   - What would be he limiting reactant in this case? Why?

Moles Lab Activity 8: Conservation of Mass—Reaction of Vinegar and Baking Soda

Materials

- Large plastic zip bag
- Baking soda (sodium bicarbonate [$NaHCO_3$])
- Two 50-mL beakers or small cups
- Vinegar (acetic acid [$HC_2H_3O_2$])
- Thermometer or temperature probe

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Make a data table in which to record class data.

2. Place a plastic zip bag on the balance, and record its mass.

3. Add about 4 grams of baking soda (sodium bicarbonate [$NaHCO_3$]) to the bag, and record the mass again. Determine how many moles of $NaHCO_3$ are in the bag.

4. Measure 30.0 mL of vinegar (acetic acid [$HC_2H_3O_2$]) into a graduated cylinder, and then pour the vinegar into a 50-mL beaker or cup.

5. Be certain the outside of the beaker is completely dry. Carefully set the plastic zip bag containing the baking soda on the lab bench. Set the beaker inside the bag, making sure none of the vinegar spills out. Seal the bag.

6. Zero the balance. Carefully set the bag on the balance, making sure none of the vinegar spills out of the beaker. Determine the total mass of the filled bag, and record on the class data table the mass of the bag + baking soda + vinegar *before* the reaction begins.

7. Remove the bag from the balance. Keeping the bag sealed, invert the beaker, and record at least three qualitative observations in your data book. Be sure to note if there is any temperature change.

8. When the reaction is complete, determine the total mass of the filled bag, and record the mass of the bag + baking soda + vinegar *after* the reaction is complete.

9. Determine the change in mass, and record.

10. Empty the bag into the sink (be careful with the beaker), and rinse out the bag with tap water.

Analysis

1. Use the following formula to calculate the percent error:

   $$\textbf{percent error} = \frac{\textbf{mass after} - \textbf{mass before}}{\textbf{mass before}} \times 100$$

(The theoretical value for this lab is the mass with which you began, and the experimental value is the mass that you measured after the reaction was complete.)

2. Answer the following questions:
   - Based on the Law of Conservation of Mass, what should have been the percent error?
   - Do your results support the Law of Conservation of Mass? Why, or why not?
   - Is the class data accurate and/or precise? Why, or why not?
   - What experimental errors would account for any differences you observed?

Extension

1. The products of this reaction are carbon dioxide, water, and sodium acetate ($NaC_2H_3O_2$). Write the balanced equation for the reaction, and identify two ways in which this reaction can be classified. Calculate the theoretical yield (mass) of carbon dioxide, based on the moles of baking soda reacted.

2. Use the materials above to design and describe and/or carry out an experiment to support your calculation. How will the procedure need to change in order to determine the amount of carbon dioxide produced?

3. Calculate your percent error.

4. Carry out the following experiment to determine if the amount of baking soda ($NaHCO_3$) affects the mass of CO_2 produced.
   a. Identify the independent variable and the dependent variable for this experiment.
   b. Identify the constants.
   c. Write an appropriate hypothesis, and support your reasoning.

d. Carry out this experiment with at least four different quantities of baking soda. Make sure some are lower than and some are higher than the quantity used in the original lab.

e. Graph the results. Make sure your graph has the following:
   - Independent variable (IV) and dependent variable (DV) on the correct axis
   - Scaling that is appropriate for the data collected
   - Both axes labeled with the quantity and appropriate units
   - A best fit line or curve drawn

f. Identify the general relationship (trend) between your IV and DV, as shown by the graph. Does this match your hypothesis? Why, or why not?

g. What might account for any discrepancies seen at larger quantities of baking soda?

Moles Lab Activity 9: Percent Water in a Hydrate

Materials

- Copper sulfate pentahydrate ($CuSO_4 \bullet 5\ H_2O$) crystals
- Hot plate
- Evaporating dish
- Crucible tongs
- Eye dropper
- Desiccator (if available)

Pre-Lab

In a *hydrated* compound, water molecules are actually absorbed into the ionic crystal lattice. The formula for a *hydrate* tells the number of water molecules (water of hydration) attached to each formula unit of the ionic compound.

1. Identify the ratio of Cu^{2+} ions to SO_4^{2-} ions in copper(II) sulfate pentahydrate.

2. Identify the number of water molecules per formula unit of copper(II) sulfate.

3. Explain why heating would cause this substance to dehydrate (become *anhydrous*).

4. Calculate the molar mass of copper sulfate pentahydrate ($CuSO_4 \bullet 5\ H_2O$). Show all steps in your calculation.

5. Calculate the percent by mass of water in this hydrate (theoretical value).

Procedure

Take the necessary measurements, and record them with units. Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. Measure and record the mass of a clean, dry evaporating dish.

2. Weigh out approximately 5.0 grams of $CuSO_4 \bullet 5\ H_2O$ into your evaporating dish. Record the exact mass, correct to 2 decimal places, of the evaporating dish + hydrated copper(II) pentahydrate sulfate crystals.

3. Place the evaporating dish on the hot plate. In complete sentences, write at least two qualitative observations of the copper(II) sulfate pentahydrate crystals.

4. Put on goggles, and turn on the hot plate to heat the copper(II) sulfate pentahydrate in the evaporating dish for 7 to10 minutes or until the color change is complete. Observe carefully, and record at least three qualitative observations in your data log.

5. Remove the evaporating dish from the hot plate, using the crucible tongs. Let the dish cool for 10 minutes. Do this in a desiccator, if one is available. Use the tongs to transfer the dish to the balance. Record the mass of evaporating dish and *anhydrous* copper(II) sulfate.

6. Repeat steps 4 and 5 until a *constant* mass is obtained.

7. Using a dropper, add 2 or 3 drops of water to the anhydrous copper(II) sulfate. Record your observations.

Analysis

Show all your calculations, rounding your answers to the teacher-specified number of significant digits and labeling units clearly.

1. What is the mass of water lost in the reaction?

2. Calculate the experimental percent of water in the hydrated copper(II) sulfate pentahydrate, using the mass of water lost and the original mass of the hydrate. Record this in the class data table.

3. Using the above calculation and the theoretical percent of water in hydrated copper(II) sulfate pentahydrate, based on its formula ($CuSO_4 \bullet 5\ H_2O$), calculate the percent error in your experiment.

4. Based on the class data, are the results of this experiment *accurate* and/or *precise*? Explain your reasoning.

5. What would happen if you left the anhydrous copper(II) sulfate sitting out overnight? Why?

6. Is this a chemical change or a physical change? Why?

Extension

1. Calculate the formula for hydrated lithium nitrate ($LiNO_3 \bullet xH_2O$), based on mole ratios determined from the following laboratory data collected in an experiment similar to the one you just completed:
   - mass (g) of hydrated lithium nitrate: 17.00 g
   - mass (g) of anhydrous lithium nitrate: 9.53 g

2. Find the formula, and indicate the name of a second hydrate containing 76.9% CaSO3 and 23.1% H2O by mass.

3. What is the function of a desiccator? What experimental error will you incur if you do not use one in this lab? Why?

4. Would rehydration of the anhydrous salt be endothermic or exothermic? Why?