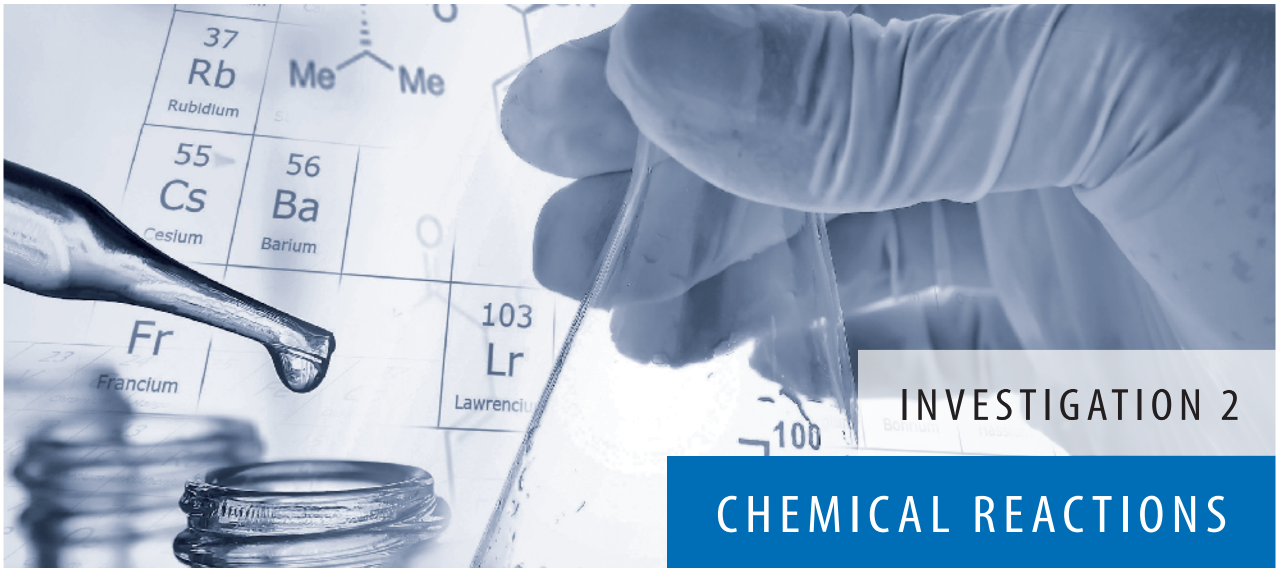
INVESTIGATION 2
CHEMICAL REACTIONS



INVESTIGATION 2

CHEMICAL REACTIONS

Safety

- Chemical splash-resistant goggles, log pants, closed lab coat, and shoes that completely enclose the foot must be worn throughout the experiment.
- Handle glassware with care. DO NOT use cracked or chipped glassware.
- ALWAYS wash your hands before leaving the laboratory
- Have two people work together to stretch balloon over the mouth of the flask, one to manage the balloon and one to hold the flask.

Waste Disposal

PRE-LAB 2

- Dispose of the solutions in the Erlenmeyer flask down the drain.

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- Waste from your decanted copper sulfate solution should be contained in a labeled waste beaker at your lab station.
- Waste from acetone washes should be collected in a different beaker.
- When your experiment is complete, dispose of the contents of your waste beakers in the "Copper solution waste" jug. **If a jug is ¾ full, DO NOT pour your waste in it**. Ask your instructor for an empty waste jug. In all cases, use as little water as possible to complete the transfer of the waste.

Clean-Up

PRE-LAB 2

- Rinse Erlenmeyer flasks with water.
- Leave flasks and balloons on your workstation.
- Wipe off your workstation's countertop with a wet sponge and dry with a paper towel.
- Have your instructor check you out of the workstation. Your instructor will initial the first page of your proposal form to indicate that you are in compliance with the clean-up procedure.

LAB INVESTIGATION 2

- Turn hot-plate off.
- Using a pencil, write the names of the group members on a label.
- Place a label in your beaker containing the copper product and set the beaker in the plastic bin designated by your instructor.
- Wash remaining glassware thoroughly with water, dry with a paper towel and leave it on your workstation's countertop for the next class to use.
- Wipe off your workstation's countertop with a wet sponge and dry with a paper towel.
- Have your instructor check you out of the workstation. Your instructor will initial the first page of your proposal form to indicate that you are in compliance with the clean-up procedure

CONCEPT OVERVIEW

Chemical reactions can be recognized by color change, the formation of a solid, formation of bubbles, or a change in temperature. Chemists describe these reactions using chemical formulas. You have learned how to write and balance chemical reactions. But if we mix two or more reagents together, how can we determine what products are formed? In this investigation, you will determine the identity of the products that are formed as a result of a chemical reaction.

When aqueous solutions are mixed, sometimes a solid forms and sometimes a solution results. The reaction in which a solid is produced is called a **precipitation reaction** and the solid formed is referred to as a **precipitate**. These reactions are driven by solubility of the products and can be predicted from known solubility rules.

When solid metal is added to a solution, sometimes a reaction occurs. These are called **oxidation-reduction** reactions and depend on a transfer of electrons. The element or ion that loses electrons is **oxidized** and the element or ion that gains electrons is **reduced**.

For chemical reactions with multiple reactants, it is likely that one of the reactants will be completely used before the other. When this reactant is used up, the reaction stops and no more product is made. The reactant that is used up first is called the **limiting reactant**.

Balancing Chemical Reactions

1. The substances undergoing reaction are called reactants, and their formulas are placed on the left side of the arrow.
2. The substances generated by the reaction are called products, and their formulas are placed on the right side of the arrow.
3. Plus signs (+) separate individual reactant and product formulas, and an arrow (→) separates the reactant and product sides of the equation.
4. The relative numbers of reactant and product species are represented by coefficients (numbers placed immediately to the left of each formula). A coefficient of 1 is typically omitted.
5. It is common practice to use the smallest possible whole-number coefficients in a chemical equation, as is done in this example.

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

Reactants Products

6. The balanced equation is read left to right: 1 mole CH_4 and 2 moles O_2 react to produce 1 mole of CO_2 and 2 moles of H_2O

Stoichiometry Problem Solving

Coefficients in balanced equations provide the relative moles of chemical species, allowing a quantitative assessment of the relationships between the amounts of substances consumed or produced by the reaction. These quantitative relationships are known as the reaction's **stoichiometry**. The stoichiometry or mole ratio allows us to convert from moles of substance A to moles of substance B. A typical calculation map would be:

$$\text{grams A} \rightarrow \text{moles A} \rightarrow \text{moles B} \rightarrow \text{grams B}$$

Example: A typical reaction between lithium and water is given below. How many grams of H_2 are produced from 9.89 g of Li?

$$2\,Li + 2\,H_2O \rightarrow 2\,LiOH + H_2$$

$$9.89\ g\ Li \times \frac{1\ mole\ Li}{6.94\ g\ Li} \times \frac{1\ mole\ H_2}{2\ mole\ Li} \times \frac{2.016\ g\ H_2}{1\ mole\ H_2} = 1.44\ g\ H_2$$

Limiting and Excess Reactants

- **The limiting reactant** (or **limiting reagent**) is the reactant that is completely consumed in a chemical reaction and limits the amount of product.
- **The reactant in excess** is any reactant that occurs in a quantity greater than is required to completely react with the limiting reactant.
- The amount of product that can be made from the limiting reactant is called the **theoretical yield.**
- **The actual yield** is the amount of product actually produced by a chemical reaction. This value is determined experimentally.
- **The percent yield** is calculated as follows:

$$\%\ \text{yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 \qquad \textbf{Equation 2.1}$$

If you are given two reactant amounts, then you have to determine which one is limiting using stoichiometry. This problem ultimately is just a series of if/then questions answered with stoichiometry.

If reactant A is limiting, then I could make X amount of product.

If reactant B is limiting, then I could make Y amount of product.

Whichever is the **smaller** value, X or Y, tells you the limiting reactant and the theoretical yield.

DATE: ____________________ SECTION/GROUP: ____________________

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INVESTIGATION 2: PRE-LAB

BALLOON RACE – WHAT IS LIMITING AND WHAT IS IN EXCESS?

Each of the flasks will contain the same amount of acetic acid ($HC_2H_3O_2$), but each balloon will contain a different amount of sodium hydrogen carbonate ($NaHCO_3$). The molar mass for $NaHCO_3$ is 84.0 g/mol. There is an acid/base indicator which will change from red (acid is present) to green (if no acid is present). The chemical reaction that occurs is given below.

$$\underset{\text{acetic acid}}{HC_2H_3O_2(aq)} + \underset{\text{sodium hydrogen carbonate}}{NaHCO_3(s)} \rightarrow \underset{\text{carbon dioxide}}{CO_2(g)} + \underset{\text{water}}{H_2O(l)} + \underset{\text{sodium acetate}}{NaC_2H_3O_2(aq)}$$ **Equation 2.2**

BALLOON RACE SET-UP

7. Add 25.0 mL of acetic acid to each flask.
8. Add a 3-4 drops of indicator to each flask.
9. Measure the amount of sodium hydrogen carbonate indicated for each flask and transfer to a balloon with the funnel.
10. Carefully stretch the balloon over the mouth of the flask. Have someone firmly hold the flask.
11. Shake the contents of the balloon into the flask and swirl the contents.

Complete the Following Table:

Table 2.1

Flask	Volume of 1.00 M $HC_2H_3O_2$	Mole $HC_2H_3O_2$	Mass of $NaHCO_3$	Mole $NaHCO_3$ (84.0 g/mol)
1	25.0 mL	0.0250 mole	0.700 g	
2	25.0 mL	0.0250 mole	1.00 g	
3	25.0 mL	0.0250 mole	2.10 g	
4	25.0 mL	0.0250 mole	4.20 g	
5	25.0 mL	0.0250 mole	6.30 g	

Make some Predictions:

12. Which balloon(s) will be the biggest? Why?

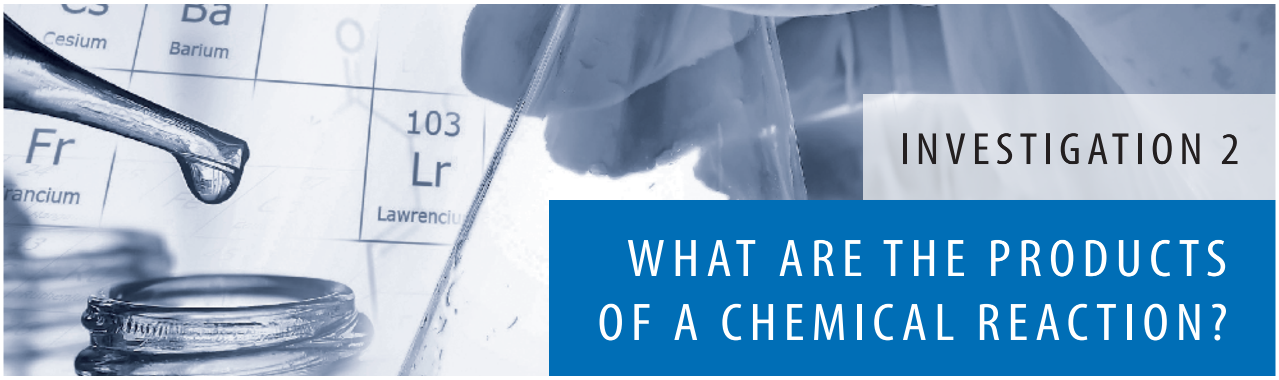
13. In which flask(s) will the solution remain red? Why?

Make some observations:

Table 2.2

Flask	Color of Solution After Reaction	Balloon Size S, M or L	Solid Residue Y/N	What reactant was limiting, i.e. used up?	What reactant was in excess, i.e. some left over?
1					
2					
3					
4					
5					

Reconcile your prediction with your observations. Write a definition for limiting and excess reactants based on your observations.



INVESTIGATION 2

WHAT ARE THE PRODUCTS OF A CHEMICAL REACTION?

When solid iron filings are added to a solution of copper(II) sulfate an oxidation reduction reaction occurs to form copper metal and one of two possible iron sulfate compounds. In your reaction, the iron should be the limiting reactant since you will be recovering copper metal and do not want a mixture of solids. You will identify the reaction that occurs based on the amount of copper you recover.

Your Task

The unbalanced equations for the two possible reactions are given below, you are to determine which reaction takes place using your knowledge of limiting reagents and theoretical yields.

$$CuSO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + Cu(s) \qquad \textbf{Equation 2.3}$$

$$CuSO_4(aq) + Fe(s) \rightarrow Fe_2(SO_4)_3(aq) + Cu(s) \qquad \textbf{Equation 2.4}$$

Guiding Question

What are the products of a chemical reaction (or what iron compound is formed)? How much copper (Cu) is produced?

Materials

You may use the following materials during your investigation.

- $CuSO_4 \bullet 5\ H_2O$ (MW – 249.69 g/mol)
- Iron filings
- Glassware (beakers, glass rod)
- Electronic Balance
- Hot plate
- Spatula
- Acetone
- 50-mL beakers
- Alcohol thermometer

Getting Started

As a group you will need to determine the specifics on how to proceed with regard to tests you will perform. However, below is a general explanation of how to rather quickly get copper (II) sulfate and iron to react.

- You should use at least 8.00 g of copper (II) sulfate and no more than 1.10 g of iron.
- Given the possible reactions and your amounts of starting materials, how much solid copper product should be formed from each reaction?
- Prepare a solution of $CuSO_4 \cdot 5\ H_2O$. The solubility is 31.6 g per 100 mL of water. So, how much water is needed for 8.00 g?
- This reaction happens the best when iron is added to a warm (50 °C to 75 °C) aqueous solution of copper (II) sulfate. The solution should not be brought to a boil and the iron should not be added while the beaker is heating.
- Stir the reaction mixture for 3 - 5 minutes.
- Solid copper will be produced as the result of this reaction. Decant the liquid.
- It should be rinsed several times with water to remove contaminates before it is dried and weighed.
- Acetone evaporates faster than water, so you may want to speed your drying time with a final acetone wash.

LAB REPORT

What are the Products of a Chemical Reaction?

Once you have completed your work, you will prepare an *investigation report* that consists of three sections. Your report should answer these questions in 2 pages of text. This report must be typed (12 pt font and 1-inch margins) and any diagrams, figures, or tables should be embedded into the document (these are not counted in the 2-pages of text).

Generally, you need one page for the first two sections and the second page for third section.

SECTION 1

What concept were you investigating and how does it relate to the guiding question?

- See the information on limiting reagents and theoretical yields in the concept overview.
- Identify the two possible reactions.
- Describe how you will use product yield to answer the guiding question.

SECTION 2

How did you go about your work and why? This is NOT the details of your procedure, but a discussion and justification of the process.

- Describe the chemical reaction
- Describe how you recovered the copper.
- Provide the theoretical yield calculations for each reaction.
- Sample calculation of %yield

SECTION 3

What is your argument? This third section is where you not only present your data, but also use the values you obtain as evidence in your reasoning. Statements like, “see data table for values” are NOT acceptable.

- State your claim
- Support your claim with evidence
- Justify the evidence.
- Data Table
- Discuss the validity and reliability of your data.
- Compare with the other groups. Discuss reasons for differences.

DATE: ______________________ SECTION/GROUP: ______________________

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Lab Investigation 2 Proposal

The Guiding Question…

Hypothesis 1

IF...

Hypothesis 2

IF...

The Test

AND...

Procedure

What data will you collect?

How will you analyze the data?

What safety precautions will you follow?

Predicted Result if hypothesis 1 is valid

THEN...

Predicted Result if hypothesis 2 is valid

THEN...

I approve of this investigation. ______________________ ______________________

Instructor's Signature Date

Data Tables and Observations

Data Analysis and Results Tables

Claim