CHEMISTRY AND SOCIETY (LAB MANUAL)



Saadia Khan
Triton College

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CHEMISTRY AND SOCIETY



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Licensing

*A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.*

CHAPTER OVERVIEW

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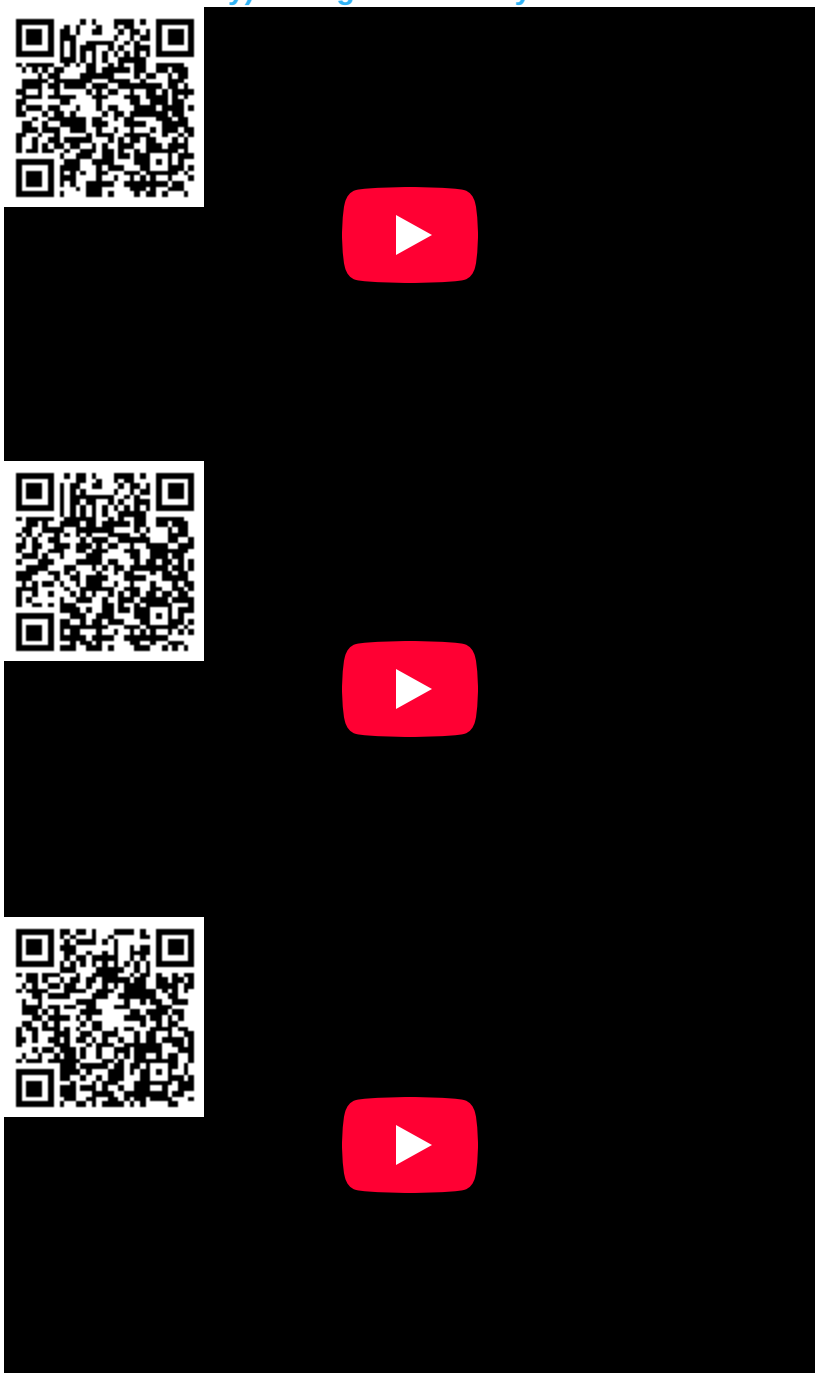
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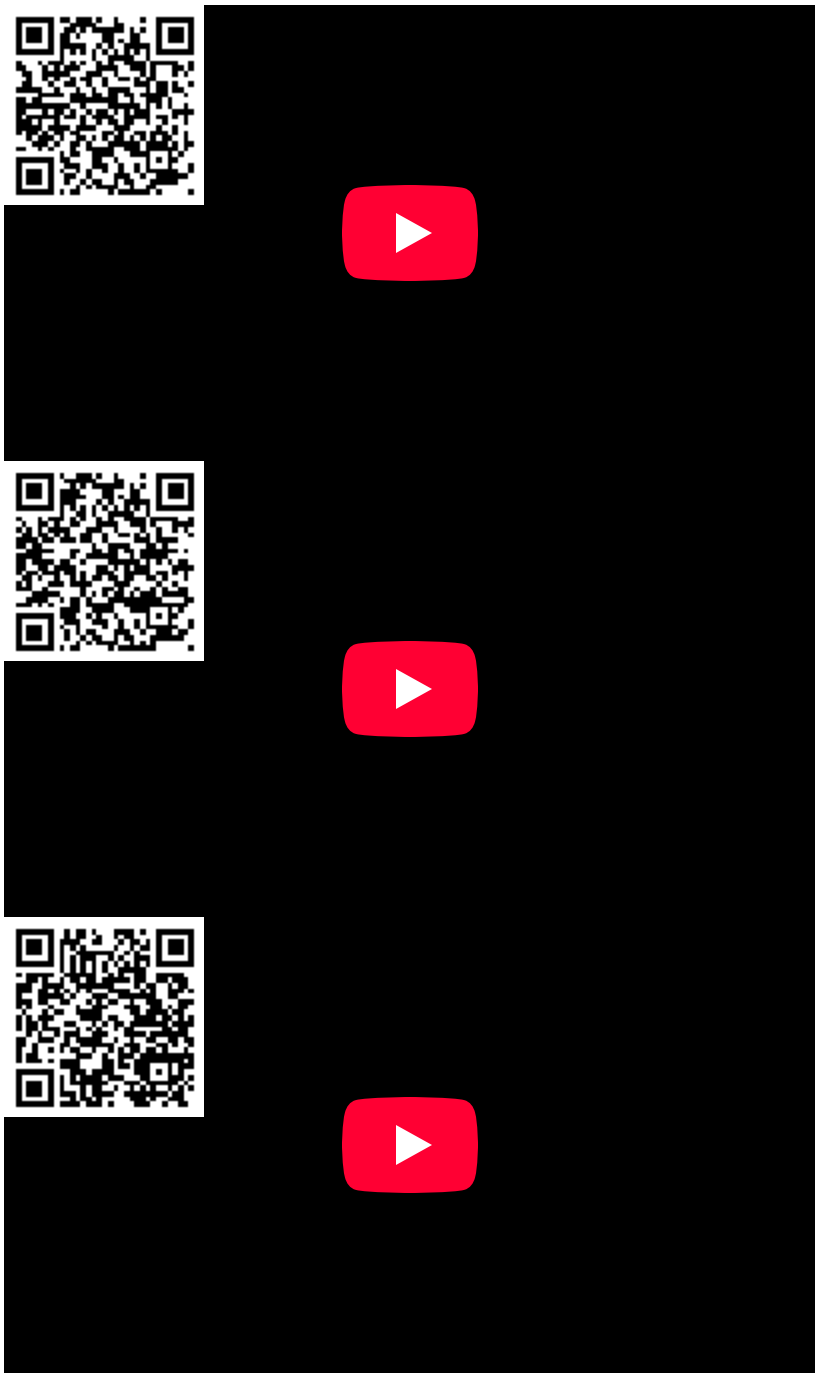
0.1: LAB SAFETY VIDEOS

Safety Orientation Videos

Students will find below the eight Lab safety orientation videos. The first six are part of the College Lab Safety Series by the American Chemical Society. Students should watch the first seven videos before signing the safety contract and attempting the safety quiz. The eighth video is an older version of the College Lab Safety video by the American Chemical Society, which should be watched, time permitting, as it provides detailed dos and don'ts in a college lab setting.

1) ACS (American Chemical Society) College Lab Safety Series





2) Lab Safety and Techniques- Crash course safety



3) Safety Video by American Chemical Society (1991)



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0.2: LAB SAFETY CONTRACT

Triton College Chemistry Division

Student Safety Contract

Purpose

At Triton College, safety is our number one priority. A list of rules has been developed and provided to you in this student safety contract to ensure a safe science laboratory experience. These rules must always be followed. Please be advised that you will be asked to leave the laboratory if you violate these rules.

No exceptions!!

This contract is available in both PDF and .doc formats. Download, sign, and date both contract pages before you participate in the laboratory sessions. Your signature indicates that you have read this contract and agree to abide by the rules. You will keep a copy for your records and upload or submit one to your instructor via your Blackboard or Learning Management System (LMS) as directed.

I, _____, dated _____, agree that I will comply with the following safety rules. I will:

1) Always wear safety goggles in the laboratory.

2) Always wear appropriate clothing in the laboratory. This includes long pants, shirts with sleeves, and closed shoes (i.e., no sandals). Also, I understand that long hair must be tied back, and loose or baggy clothing or jewelry must be secured.

*Note: Students violating rules one and/or two will be asked to leave the lab immediately. No second chances!! NO EXCEPTIONS!!

3) Read laboratory instructions beforehand and ask the instructor about any part of the lab I am unsure about.

4) Use proper equipment for laboratory procedures.

5) Never perform unauthorized experiments or work alone in the laboratory.

6) Never remove chemicals or other materials/equipment from the laboratory area.

7) Read the labels on reagent bottles carefully, remove only small amounts of reagent with the proper tools, and never return unused chemicals to the bottle.

8) Dispose of broken glass and waste chemicals in the appropriate waste container.

9) Immediately inform the instructor of a chemical spill or accident (even minor ones) in the laboratory.

10) Never taste or smell any chemicals.

11) Know the location of eyewash fountains, fire extinguishers, fire blankets, safety showers, first aid kits, and exits.

12) Do not bring food or drink into the lab; refrain from eating or drinking in the laboratory. This includes chewing gum and eating candy.

13) Keep aisles clear. Books, purses, backpacks, and other personal belongings will be kept outside or under the lab benches.

14) I will responsibly conduct myself at all times in the laboratory. Horseplay, practical jokes, and pranks are dangerous and prohibited.

15) Clean my work area before leaving the lab.

16) Wash my hands before I leave the lab.

Agreement

I, _____, have read and agree to follow all the safety rules outlined in this contract. I realize I must obey these rules to ensure my safety and that of my fellow students. I will fully cooperate with my instructor and fellow students to maintain a safe lab environment. I will also closely follow all oral and written instructions provided by the instructor, the science

department, and the college. I am aware that any violation of this safety contract, resulting in unsafe conditions in the laboratory or misbehavior on my part, may lead to my removal from the laboratory, a failing grade, and/or dismissal from the course.

_____ _____

Student Signature Date

_____

Course section and number

Questions

1) Are you color blind? Yes/No

2) Do you have any allergies? Yes/No

If yes, please list specific allergies.

3) Do you wear contact lenses? Yes/No

4) If you are pregnant, breastfeeding, or trying to conceive, avoid working with heavy metal compounds and organic solvents. Notify your instructor and request a list of chemicals used in this course. Use this list to consult with your physician before proceeding with the course. Under your physician's supervision, you may need to purchase a respirator, which a doctor must fit and adjust to your needs.

5) Please inform your instructor of any other medical conditions or situations you feel we should be aware of to ensure your safety and the safety of others while working in the laboratory. Please be aware that anything written in this contract will remain confidential.

Please click here to download this contract in PDF or Word format. Complete the contract and upload it as directed by your instructor before the first lab experiment.

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0.3: LAB SAFETY QUIZ

Multiple-Choice Questions

1. What should you do if a chemical splashes into your eyes?
   - A) Rub your eyes vigorously
   - B) Rinse your eyes with water for at least 15 minutes
   - C) Close your eyes and wait for the pain to subside
   - D) Apply a cold compress
2. Which of the following is NOT appropriate lab attire?
   - A) Closed-toe shoes
   - B) Long pants
   - C) Loose, flowing clothing
   - D) Safety goggles
3. What is the first thing you should do if you spill a chemical on your skin?
   - A) Wipe it off with a cloth
   - B) Rinse the affected area with water immediately
   - C) Apply a bandage
   - D) Ignore it if it doesn't hurt
4. Where should you dispose of broken glassware?
   - A) Regular trash bin
   - B) Recycling bin
   - C) Designated glass disposal container
   - D) Sink
5. Which of the following statements about lab safety is TRUE?
   - A) Eating and drinking are allowed in the lab
   - B) You should always work alone in the lab
   - C) Always read labels and safety data sheets before using chemicals
   - D) It's okay to leave a Bunsen burner unattended

True/False Questions

6. Always wear safety goggles when handling chemicals.
   - True
   - False
7. It's safe to taste chemicals in the lab to identify them.
   - True
   - False
8. You should be familiar with the location of safety equipment, including fire extinguishers, eyewash stations, and safety showers.
   - True
   - False
9. When working in the lab, it is recommended to tie long hair back.
   - True
   - False
10. Using your phone in the lab is acceptable as long as you're careful.
    - True
    - False

Click here to download this quiz in Word or PDF format. Complete and upload it as directed by your instructor. Your instructor may have additional or different questions for you as part of the safety quiz in your Learning Management System.

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0.4: ADDITIONAL RESOURCES



OSHA® QUICK CARD™

Hazard Communication Standard Pictogram

The Hazard Communication Standard (HCS) requires pictograms on labels to caution users of the chemical hazards that they may be exposed to. A pictogram consists of a symbol on a white background framed within a red border and represents a distinct hazard(s). The pictogram on the label is determined by the chemical hazard classification. Each pictogram may only appear once on a label. If multiple hazards require the use of the same pictogram, it may not appear a second time on the label.

HCS Pictograms and Hazards

Health Hazard • Carcinogen • Mutagenicity • Reproductive Toxicity • Respiratory Sensitizer • Target Organ Toxicity • Aspiration Toxicity	**Flame** • Flammables • Pyrophorics • Self-Heating • Emits Flammable Gas • Self-Reactives • Organic Peroxides • Desensitized Explosives	**Exclamation Mark** • Irritant (skin and eye) • Skin Sensitizer • Acute Toxicity (harmful) • Narcotic Effects • Respiratory Tract Irritant • Hazard Not Otherwise Classified (non-mandatory) • Hazardous to Ozone Layer (non-mandatory)
Gas Cylinder • Gases Under Pressure • Chemicals Under Pressure	**Corrosion** • Skin Corrosion/Burns • Eye Damage • Corrosive to Metals	**Exploding Bomb** • Explosives • Self-Reactives • Organic Peroxides
Flame Over Circle • Oxidizers	**Environment** (non-mandatory) • Aquatic Toxicity	**Skull and Crossbones** • Acute Toxicity (fatal or toxic)

For more information:
OSHA® Occupational Safety and Health Administration
www.osha.gov (800) 321-OSHA (6742)

U.S. Department of Labor

OSHA 3491-08R 2024

Note to instructors:

* The Safety Contract is the one used by Triton College. The Word file is available for adapting for other institutions.

*The included images show equipment commonly used in Triton College labs. If your college or institution uses different equipment, please use your own images.

*Images and Word files of all documents are available upon request to instructors. Email: saadiakhan@triton.edu

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1: LAB 1 - TAKING MEASUREMENTS IN THE CHEMISTRY LAB

PURPOSE

The purpose of this experiment is to

• Become proficient in taking length, mass, volume, and temperature measurements.

• Experimentally determine the density of water.

• Calculate the density of various rectangular blocks and possibly identify the block based on its density.

INTRODUCTION

Welcome to the chemistry lab! This lab may be your first experience working in a lab setting for many of you. As you will learn in this class and other chemistry courses (should you need to take them in the future), many of the experiments you conduct will require you to record data of a measurement. Measurements are important not only in science courses but also in everyday life activities. For example, when cooking in the kitchen, you may be asked to measure certain ingredients. In this experiment, you will learn to take measurements associated with length, mass, volume, and temperature, four of the most common properties dealt with in the chemistry lab.

Length

Length measurements are often taken using a centimeter ruler. When we use a centimeter ruler that is subdivided into tenths of centimeters (like the ones we will be using in the lab), we always write our measurements to the hundredth place (two digits past the decimal point). For example, consider the object shown below in Figure 1:

Example 1.1

Consider the red block shown below in Figure 1 and record its length.

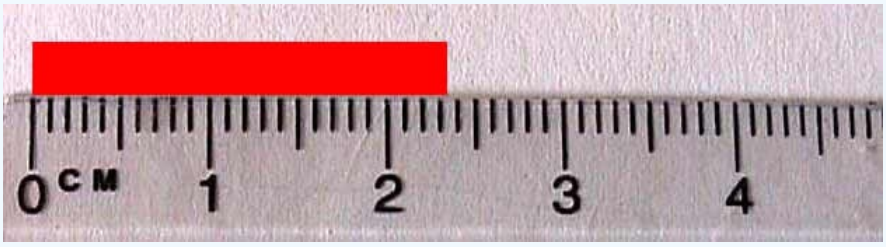


Figure 1.1: Image of a Ruler in cm, measuring a Red Rectangular Object. (Copyright; Adapted)

Solution

Because it fits halfway between 2.3 and 2.4, we can record its length as 2.35 cm.

Note: If the measurement were exactly 2.3, we would record the length as 2.30 cm; if it landed on 2 cm, we would write that as 2.00 cm.

In all your experiments, a milligram balance (which measures to three decimal places) will be used for all mass measurements. When recording mass from a milligram balance, we write the exact number displayed on the balance. For example, if the mass of an object is given as 157.223 g, we write 157.223 g in the data table. Your instructor will demonstrate how to operate and zero the balance in more detail.

Volume

To determine a liquid's volume, we will use a graduated cylinder. The volume is read at the bottom of the curved line, called the meniscus, and recorded to one digit past the decimal point.

Example 1.2

Consider the image below and measure the volume of liquid in the graduated cylinders.

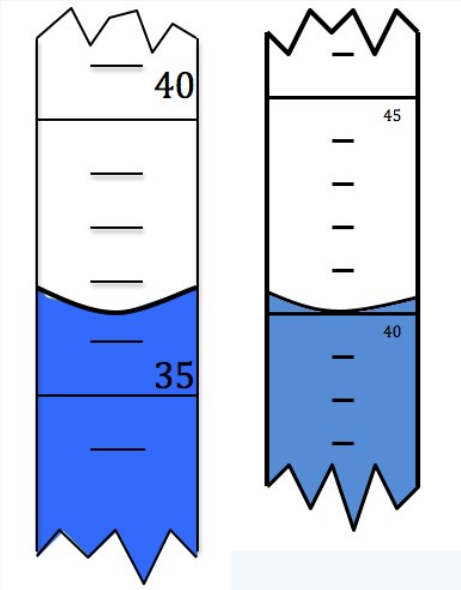


Figure 1.2: Volume Measurement Using a Graduated Cylinder. (Adapted)

Solution

The volume of liquid in the graduated cylinder on the left in Figure 2 below would read 36.5 mL. The volume of liquid in the rightmost graduated cylinder would be 40.0 mL.

In this experiment, we will also measure the volume of a rectangular solid using a centimeter ruler. Once we have measured the object's length, width, and height, we can calculate its volume using the following formula:

$$\text{Volume} = (\text{length}) \times (\text{width}) \times (\text{height})$$

Example 1.3

Consider a rectangular object with dimensions of 6.50 cm in length, 3.00 cm in width, and 2.25 cm in height. Calculate the volume of the rectangular object.

Answer

The volume would be recorded as

Volume = (6.50 cm) x (3.00 cm) x (2.25 cm) = **43.9 cm**

(Note: In this class, we will always round the volume measurements of a rectangular block to three digits. These measurements will be further explained in future chemistry classes.)

Temperature

A thermometer is read to one digit past the decimal point, like a graduated cylinder. We will be using Celsius thermometers to measure temperature during our experiments. For example, if an object's temperature is 11 °C, we would record the value as 11.0 °C.

Density

Another property that we will explore in this lab is density. Density is defined as the amount of material in a given volume of substance and can be expressed as follows:

$$Density = \frac{mass}{volume} \tag{1.1}$$

Each substance has a unique density at a certain temperature. For example, the density of water at room temperature is 1.0 g/mL, regardless of the amount of water present. This density characteristic can be used to infer the identity of an unknown substance. However, other tests would also need to be performed to confirm the presence of a substance.

In this experiment, you will be asked to determine the density of water and various rectangular blocks experimentally. Based on the calculated densities of the rectangular blocks, you will then identify the blocks (if possible) based on a table of known densities. Consider the following examples:

Example 1.4

9.0 mL of water was shown to have a mass of 9.010 g. Using this information, determine the density of water.

Solution

$$Density = \frac{Mass}{Volume} = \frac{9.010\ g}{9.0\ mL} = 1.0\ g/mL \tag{1.2}$$

(Note: We use g/mL as the units for the density of a liquid. In this lab, we will be rounding all density of liquid values to two digits, which will be explained in future chemistry courses.)

Example 1.5

A small rectangular block with dimensions of 3.00 cm in length, 2.00 cm in width, and 1.00 cm in height was found to have a mass of 67.805 g. Using the information provided and the table of densities on the next page, calculate the density of the block and identify it (if possible, using Table 1).

Solution

First, we can calculate the volume of the block as follows:

Volume = (3.00 cm) x (2.00 cm) x (1.00 cm) = 6.00 cm^3

Next, the density can be calculated:

$$Density = \frac{Mass}{Volume} = \frac{67.805\ g}{6.00\ cm^3} = 1.0\ g/cm^3 \tag{1.3}$$

Referring to Table 1, we can identify the solid as lead because it has the same density value as lead.

(Note: We use g/ cm^3 as the units for the density of a solid. In this lab, we will be rounding all density of solid values to 3 digits, which will be explained in future chemistry classes.)

Table 1: Densities of Known Solids

Table 1.1: Densities of Known Solids

Substance	Density
Aluminum	2.7 g/cm^3
Bronze	8.7 g/cm^3
Gold	19.3 g/cm^3
Iron	7.9 g/cm^3
Lead	11.3 g/cm^3
Silver	10.5 g/cm^3
Steel	8.0 g/cm^3
Tin	7.3 g/cm^3

SAFETY PRECAUTIONS:

1) Always wear chemical splash goggles when working on this experiment.

2) Take caution while measuring the temperature of boiling water, as the beaker and equipment will be hot.

3) Clean up your work area when you are finished with the experiment and return all equipment and glassware to their designated places.

Table 1.2:Equipment and Chemicals Needed for the Experiment

Equipment	Equipment	Equipment	Chemicals
Centimeter ruler	Glass stirring rod.	Celsius thermometer	Tap water
Watch glass	125.0 mL Erlenmeyer flask	Various rectangular blocks	A pail of ice (provided by the instructor)
Evaporating dish	100.0 mL graduated cylinder	Test tube rack	Beaker of boiling water (provided by the instructor)
Large or medium test tube	10.0 mL graduated cylinder	Milligram balance	

* Images of equipment needed in this lab can be found in the appendix (the equipment may be subject to changes, so follow your instructor's directions).

EXPERIMENTAL PROCEDURE

Part A: Taking Measurements of Length, Mass, Volume, and Temperature.

1) Using a centimeter ruler, determine the following:

- The diameter of a watch glass
- The length of a large or medium test tube
- The length of a glass stirring rod

Record your measurements of the two digits past the decimal point.

2) Using a milligram balance, determine the mass of the following objects: watch glass, 125.0 mL Erlenmeyer flask, evaporating dish, and 10.0 mL graduated cylinder. Record your values in the data table. Record all the numbers shown on the milligram balance.

3) Fill a 100.0 mL graduated cylinder to the 100.0 mL mark. Record this as the initial volume in the data table. Pour water from the graduated cylinder to fill a large or medium test tube. Record the new volume in the graduated cylinder. Pour the water from the test tube into the sink and repeat the procedure twice. Record all measurements to one decimal place.

4) Using a Celsius thermometer, measure the following:

- Room temperature (hold the thermometer in the air and wait for the temperature to stabilize)
- Temperature of ice (place the thermometer in the pail of ice provided by the instructor)
- Temperature of boiling water (place the thermometer in the beaker of boiling water supplied by the instructor)

Record all measurements to one decimal place.

Part B: Density of Water

1) Determine the mass of an empty 10.0 mL graduated cylinder.

2) Add 1.0 mL to 9.0 mL of water to the graduated cylinder and record the correct volume.

3) Record the combined mass of the water and graduated cylinder.

4) Subtract the mass of the empty graduated cylinder from the combined mass of the water and cylinder to obtain the mass of water.

5) Using the mass of water and the volume of water (from step 2), calculate the density of water and record your answer in two digits.

6) Repeat steps 1-4 two more times, using a different amount of water each time.

7) Calculate the average density of water by adding up the three density values and dividing the sum by three.

Part C: Density of Various Rectangular Blocks

1) Obtain three different rectangular blocks and record either the color and the Unknown letter or the Unknown number for the unknown rectangular metal block whose density you will find.

2) Using a milligram balance, determine the mass of each rectangular block.

3) Using a centimeter ruler, determine each rectangular block's length, width, height, and volume.

4) Calculate the density of each rectangular block.

5) Using Table 1, provide a possible identity for each rectangular block. If an identity cannot be determined, enter 'N/A' in the data table.

PRE-LAB QUESTIONS Name _____

1) 15.5 mL of an unknown liquid had a mass of 12.050 g. Calculate the density of the unknown liquid.

2) A small rectangular block was shown to have the following dimensions: 2.85 cm by 1.75 cm by 3.50 cm. If the mass of the block was 127.432 g, calculate the density. Use the densities of known solids table above to infer the identity of the unknown block (if possible).

3) Click on the link below (or copy and paste it into your browser) to access a virtual simulation regarding density. https://phet.colorado.edu/sims/html/density/latest/density_all.html [phet.colorado.edu]

From here, click on *mystery*, and go through the following procedure using only set 1:

1: Drag box 1A to the balance and record the weight in kg.

2: Add box 1A to the 100.00 L pail and record the volume difference as the volume of box 1A. (For example, if the volume of water becomes 105.50 L once box 1A is added, the volume of box 1A would be 105.50 L – 100.00 L = 5.50 L.)

3: Calculate the density of box 1A in kg/L by dividing the mass by the volume.

4: Repeat steps 1-3 for the remaining boxes and record the density values in the table below.

5: Click on the density table, and using the densities you calculated, provide an identity (if possible) for each box.

Table 1.3: Identifying the Identity of Boxes

Box	Density (kg/L)	Identity
1A		
1B		
1C		
1D		
1E		

(Note: Simulation by Phet Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0(opens in new window) (https://phet.colorado.edu).

DATA AND OBSERVATIONS

Table 1.4: Measurements Data

Type of Measurements	Data
Diameter of the watch glass	
Length of test tube	

Length of stirring rod	
Mass of a watch glass	
Mass of 125 mL Erlenmeyer flask	
Mass of the evaporating dish	
Mass of 10.0 mL graduated cylinder	
The initial volume of water in a 100 mL cylinder	
The volume of water in the cylinder after the first pour	
The volume of water in the cylinder after the second pour	
The volume of water in the cylinder after the third pour	
Room temperature	
Temperature of ice	
The temperature of boiling water	

Table 1.5: Data Table for Calculation of Density of Water

	Trial 1	Trial 2	Trial 3
Mass of the empty graduated cylinder			
Mass of the graduated cylinder and water			
Mass of water			
Volume of water			
Density of water			

Average density of Water:

Part C: Density of Various Rectangular Blocks

Table 1.6: Data Table for Calculation of Density of Various Rectangular Blocks

Block Color or Number.			
Mass of the Block			
Length of Block			
Width of Block			
Height of Block			
The volume of the Block			
Density of the Block			
Identity of the Block			

POST-LAB QUESTIONS

1) What was the biggest takeaway from this experiment?

2) Describe three possible sources of error in this experiment.

3) In pre-lab question 3, you determined the volume of each box by subtracting the initial volume of water in the pail from the total volume of water. Explain why this procedure can be used to determine the volume of the block.

4) How did your average experimental density in part B compare with the actual density of water?

5) **Part A**: When 8.0 mL of an unknown liquid was added to a 25.000 g graduated cylinder, the combined mass of the liquid and cylinder was 31.355 g. Using this information, determine the density of the unknown liquid.

Part B: Someone claims that the unknown liquid described in Part A is methanol. Can you prove this using only your calculation result? (Hint: Google search for the density of methanol, ethanol, and isopropyl alcohol.)

Please click here to access the Pre-Lab, Data Tables, and Post-Lab in Word or PDF format. Complete and upload as directed by your instructor.

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2: LAB 2 - INTRODUCTION to GRAPHICAL ANALYSIS

Learning Objectives

The purpose of this experiment is to

- Gain experience in interpreting data from graphs.
- Given a data set, construct a graph and identify the type of relationship observed.
- Determine the relationship between pressure and volume, and temperature and volume, of a gas using graphical analysis.
- Experimentally determine the relationship between volume/boiling point and percent composition/density using graphical analysis.

Many of the experiments you will be conducting may require you to determine the mathematical relationship between two variables. One way to accomplish this is by constructing a graph. For example, consider the following pairs of data, which will be generically labeled as X and Y. A graph of this data is shown below.

Example 2.1

Consider the following pairs of data, which will be generically labeled as X and Y. A graph of this data is shown below. Summarize the relationship.

Generic Table 1

X	Y
1	2
2	4
4	8
8	16
16	32
32	64

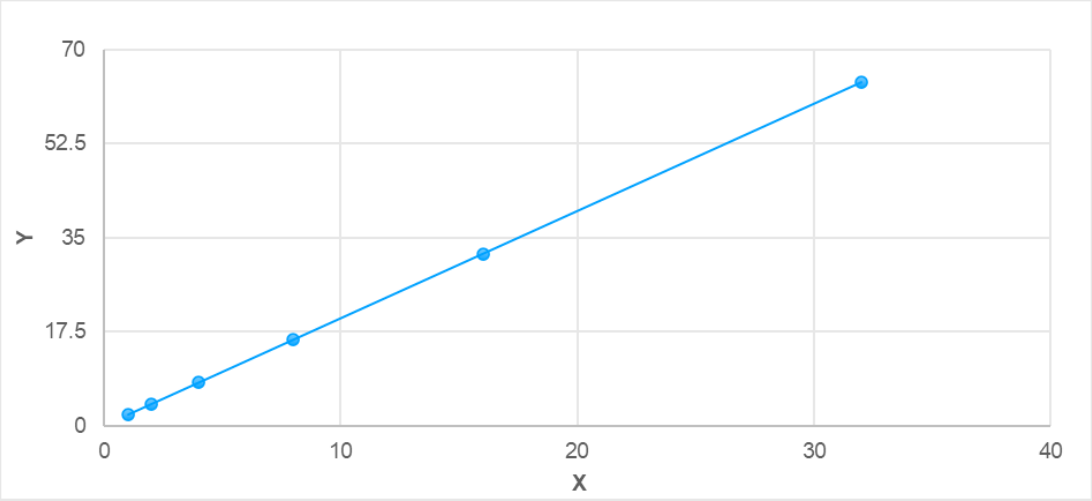


Figure 1: A Graph Indicating a Direct Relationship Between Two Variables. Y varies directly with X and can be summarized as: Y = 2x

Solution

As the graph below, plotted using the data from the above table of example 1, shows, Y varies directly with X and can be summarized as Y = 2X.

This is known as a direct relationship between the two variables.

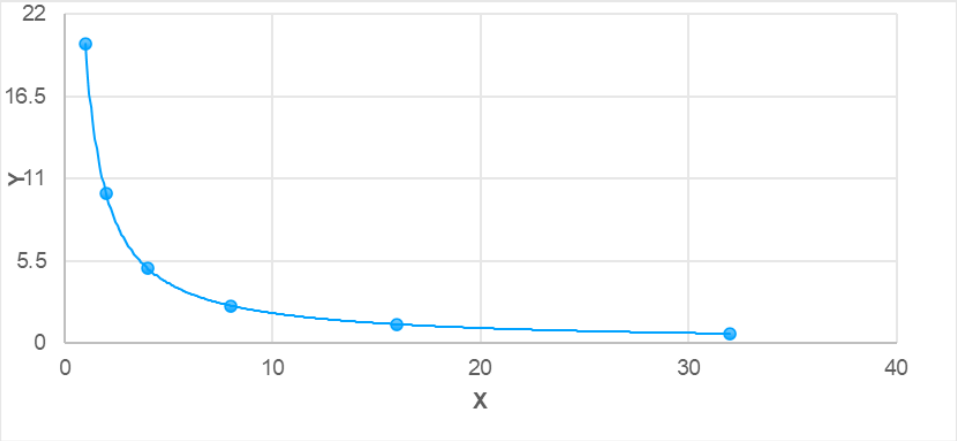
As another example, consider the following generic data.

Example 2.1

Consider the following generic data table and graph generated using the following data. Summarize the relationship indicated.

Generic Data

X	Y
32	20
2	10
4	5
8	2.5
16	1.25
32	0.625



Solution

The graph above, using data from Example 2, shows that as X increases, Y decreases, indicating an inverse relationship. The equation summarizing the data is Y = 20/x. Indicating an Inverse Relationship Between Two Variables. Y varies inversely with X and can be summarized as: Y = 20/x

In this experiment, you will construct graphs from data sets and be asked to identify the relationship between two variables. First, you will learn how to create graphs using certain programs.

Click on the link below (or copy and paste it into your browser) for information on using Excel to construct graphs:

https://www.ablebits.com/office-addins-blog/make-scatter-plot-excel/(opens in new window)

The link below walks you through creating graphs in Google Sheets:

https://www.jotform.com/blog/how-to-make-an-x-y-graph-in-google-sheets/(opens in new window)

If you are proficient with creating graphs using another program, feel free to use that to construct graphs in this experiment.

SAFETY PRECAUTIONS

1) Always wear chemical splash goggles while working with chemicals in this experiment.

2) Be careful when handling hot plates, and use beaker tongs or hot mittens to remove beakers from hot plates.

3) Dispose of all waste in the appropriate waste containers as your instructor indicates.

4) When you finish the lab, clean your work area and return all chemicals and equipment to their appropriate places.

EQUIPMENT* AND CHEMICALS NEEDED

• 100 mL beaker

• 600 mL beaker

• Hot plate

• Celsius Thermometer

• 100 mL graduated cylinder

• 10 mL graduated cylinder

• Milligram balance

• Stirring rod

• Ethanol

• Tap water

• Graphing program of choice

• Non-halogenated waste container

* Images of equipment needed in this lab can be found in the appendix (the equipment may be subject to changes; follow your instructors' directions).

EXPERIMENTAL PROCEDURE

Part I: Exploring Volume and Pressure Relationships in Gases

An experiment was run to determine what happens to the pressure of a gas in a syringe when the volume is increased. Experimental data were given as follows:

Volume and Pressure Relationship

Volume (X-axis)	Pressure (Y-axis)
2 L	25.0 atm
4 L	12.5 atm
6 L	8.3 atm
8 L	6.3 atm
10 L	5.0 atm
12 L	4.2 atm

The volume of the gas was measured in liters (L), and the pressure was measured in atmospheres (atm). Using your graphing program of choice, construct a graph of volume vs. pressure, include a line to connect the points, and generate an equation to summarize the data.

Part II: Exploring Temperature and Volume Relationships in Gases

An experiment was run to determine what happens to the volume of a gas when the temperature is increased. Data was given as follows:

Temperature and Volume Relationship

Temperature (X-axis)	Volume (Y-axis)
298 K	25.0L
350 K	29.4 L
375 K	31.5 L
425 K	35.7 L

Temperature (X-axis)	Volume (Y-axis)
500 K	42.0 L
650 K	54.5 L

The gas temperature was expressed in kelvins (K), and the volume was measured in liters (L). Using your graphing program of choice, construct a graph of temperature vs. volume, include a line to connect the points, and generate an equation to summarize the data.

Part III. Exploring the Volume and Boiling Point of Water

1) The instructor will assign each group a certain volume of water to use. The volumes of water used will be as follows: 50.0 mL, 100.0 mL, 200.0 mL, 300.0 mL, 400.0 mL, and 500.0 mL. If your group is assigned 50.0 mL of water, use a 100 mL beaker. If your group is assigned one of the other volumes, use a 600 mL beaker.

2) Using a 100 mL graduated cylinder, add the assigned amount of water to the appropriate beaker. Heat the water on a hot plate and set it on high. Once the water boils, record its temperature. Remember to round temperature readings to one digit past the decimal point.

3) Turn off the hotplate and remove the beaker from it using beaker tongs or hot mittens. Once the hotplate is cool, please return it to the appropriate lab drawer.

4) Gather data from the other lab groups and construct a graph of volume (mL) on the x-axis and temperature (^{o}C) on the y-axis.

Part IV. Exploring the Percent Composition and Density of an Ethanol Solution

1) Using a milligram balance, determine the mass of an empty 10 mL graduated cylinder.

2) Add 10.0 mL of water to the graduated cylinder and determine the total mass of the graduated cylinder and the water. (Note: This will be the 0% ethanol reading.)

3) Subtract the mass of the empty graduated cylinder from the total mass to obtain the mass of water.

4) Using the density equation learned in the previous lab, calculate the density of water.

5) Pour the water and add 2.0 mL of ethanol and 8.0 mL of water to the graduated cylinder. Using a glass stirring rod, gently stir the mixture in the graduated cylinder for 1 minute. Then, determine the mass of the mixture and the graduated cylinder. (Note: This mixture consists of 20% ethanol by volume. We determine this by dividing the volume of ethanol, which is 2.0 mL, by the total volume of the mixture, which is 10.0 mL, and multiplying the quotient by 100 to obtain the percent.

6) Subtract the mass of the empty graduated cylinder from the total mass to obtain the mass of the 20% mixture.

7) Calculate the density of the 20% ethanol mixture using the density equation. (We divide the mass of the mixture by 10.0 mL, the total volume.)

8) Pour the contents of the mixture into the non-halogenated waste container as directed by your instructor.

9) Repeat steps 5-8 using 4.0 mL of ethanol and 6.0 mL of water (40% ethanol mixture).

10) Repeat steps 5-8 using 6.0 mL of ethanol and 4.0 mL of water (60% ethanol mixture).

11) Repeat steps 5-8 using 8.0 mL of ethanol and 2.0 mL of water (80% ethanol mixture).

12) Repeat steps 5-8 using 10.0 mL of ethanol (100% ethanol mixture).

13) Construct a graph of percent ethanol (x-axis) vs. density (y-axis). Include a line connecting the points and an equation summarizing the data.

Caution

Include all the graphs generated as attachments

PRE-LAB QUESTIONS Name _____

1) Which program will you use to create graphs in this experiment? Briefly explain your decision.

2) Briefly describe the difference between a direct and inverse relationship between data pairs.

3) Consider the following generic data:

Generic Data

X	Y
1	1
2	4
4	16
8	64
16	256
32	1024

Using your program of choice, construct a graph of X vs. Y, include a line to connect the points, and generate an equation to summarize the data. (Include your graph as an attachment.)

For parts I and II, include your graphs as attachments.

Part III: Exploring the Volume and Boiling Point of Water

Exploring the Volume and Boiling Point of Water

Volume of Water (mL)	Boiling Point (^oC)
50.0	
100.0	
200.0	
300.0	
400.0	
500.0	

Include your graph of volume vs. boiling point as an attachment.

Part IV: Exploring Percent Composition and Density of an Ethanol Solution

Mass of empty 10.0 mL graduated cylinder =

Exploring Percent Composition and Density of an Ethanol Solution

Percent Ethanol	Mass of Graduated Cylinder and Solution	Mass of Solution	Volume of Solution	Density of Solution (g/mL)
0%			10.0 mL	
20%			10.0 mL	
40%			10.0 mL	
60%			10.0 mL	
80%			10.0 mL	
100%			10.0 mL	

Caution

Include your graph of percent ethanol vs. density as an attachment.

1) What new skills did you learn from performing this experiment, and what relevance can this have in your everyday life?

2) Refer to the graph generated in part I. How would you describe the relationship between the volume and pressure of a gas?

3) Use the graph and equation generated in part I to predict the pressure that 3 L of the gas would exert.

4) Refer to the graph generated in part II. How would you describe the relationship between the temperature and volume of a gas?

5) Use the graph and equation generated in part II to predict the volume of the gas at a temperature of 100 K.

6) Refer to the graph generated in part III. How would you describe the relationship between water's volume and boiling point?

7) Refer to the graph generated in part IV. How would you describe the relationship between the percentage of ethanol in the mixture and the density of the mixture?

8) What is the difference between a linear and an exponential relationship? Out of the five graphs generated in this experiment (one from the pre-lab and four from the lab component), which of the graphs, if any, are linear? Which are exponential?

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LAB 3: SEPARATION OF SAND AND SALT

Learning Objectives

The purpose of this experiment is to

- Separation of a mixture containing an unknown composition of sand and salt.
- Calculate the percentage of sand and salt in the unknown mixture.

INTRODUCTION

Matter can be classified as a pure substance or a mixture. Pure substances include elements and compounds. Elements are the simplest forms of matter that cannot be decomposed into other types of matter. They are found in the periodic table. A compound is a chemical combination of elements. Mixtures can either be homogeneous, if they are uniform throughout, or heterogeneous, if they are non-uniform.

Mixtures can be separated by physical methods such as filtration, decantation, distillation, and evaporation. In this experiment, you will use filtration and evaporation to separate a mixture of sand and salt. Once the mixture is separated, you will be asked to determine the respective percentages of sand and salt. The following example illustrates how to perform these calculations.

Sample Problem:

Example $LAB3.1$

A mixture of sand and salt had a mass of 3.750 g. Once separated, the mass of sand was determined to be 1.873 g. The mass of recovered salt was 1.877 g. This information determines the respective percentages of sand and salt in the mixture.

Solution

To find the percentage of a component in a mixture, we use the following formula:

$$\text{Percentage of a component} = \left(\frac{\text{mass of component}}{\text{mass of mixture}}\right) \times 100 \qquad \text{(LAB 3.1)}$$

The percentage of sand would be

$$\text{Percentage of sand} = \left(\frac{1.873\ \text{g}}{3.750\ \text{g}}\right) \times 100 = 49.95\% \qquad \text{(LAB 3.2)}$$

And the percentage of sand would be

$$\text{Percentage of salt} = \left(\frac{1.877\ \text{g}}{3.750\ \text{g}}\right) \times 100 = 50.05\% \qquad \text{(LAB 3.3)}$$

SAFETY PRECAUTIONS

1) Wear chemical splash goggles throughout the experiment.

2) Gloves are provided if you wish to wear them.

3) Be careful when handling glassware while it is being heated and after it has been heated, as it will be hot. Allow all hot glassware to cool to room temperature before touching it.

4) At the end of the experiment, dispose of the sand in the "recovered sand jar" on the lab cart.

5) At the end of the experiment, wash the watch glass and evaporating dish containing the recovered salt in the sink with plenty of soap and water.

6) Be sure all glassware is clean and all equipment is returned to its proper place.

EQUIPMENT* AND CHEMICALS NEEDED

• Milligram balance

• 50.0 mL beaker

• Stirring rod

• Hot plate

• Evaporating dish

• Watch glass

• Beaker tongs

• Spatula

• Ring stand

• Ring clamp

• Wire gauze pad

• Bunsen burner

• Deionized water in the wash bottle

* Images of equipment needed in this lab can be found in the appendix (the equipment may differ or be subject to changes; follow your instructor's directions).

EXPERIMENTAL PROCEDURE

1) Using a milligram balance, weigh the following:

• an empty 50.0 mL beaker

• An empty evaporating dish with a watch glass.

2) Using a spatula, add approximately 1.00 - 2.000 g of an unknown mixture (record the mixture number or letter) to the 50 mL beaker.

3) Obtain the mass of the mixture and the beaker, and record the total mass. (Subtracting the mass of the empty beaker from the total mass will give you the mass of the mixture.)

4) Using a wash bottle, add enough deionized water to the 50 mL beaker to completely cover the mixture. Continuously stir the mixture with a stirring rod for approximately 5 minutes to dissolve the salt.

5) Decant (pour) the saltwater into the evaporating dish, keeping the sand in the 50 mL beaker.

To recover the sand, follow steps 6 through 8. To retrieve the salt, follow steps 9 through 11. Depending on the number of members in your lab group, these steps may be performed simultaneously.

6) To dry the wet sand, place the 50.0 mL beaker on a hot plate on a low setting.

Note: Once the beaker gets warm, the sand may pop. Hold the beaker with tongs and use a stirring rod to move the sand particles around it to prevent this.

7) Once the sand is completely dry and does not clump together (it will appear like sand on a beach on a hot summer day), turn off the hot plate and allow the beaker to cool. You can remove the beaker from the hot plate using beaker tongs.

8) Once the beaker is cool, obtain the mass of the 50.0 mL beaker and sand. (Subtracting the mass of the empty beaker from the combined mass of the beaker and sand will give you the mass of sand.)

9) Under the hood, set up a ring stand containing a ring clamp and wire gauze pad. Place a Bunsen burner a few inches below the wire gauze pad. (Note: Your instructor will demonstrate how to set up this apparatus. Once you set up your apparatus, be sure your instructor approves it before moving on to the next step.)

10) Place the evaporating dish on the wire gauze pad and cover it with the watch glass. Light the Bunsen burner under the wire gauze pad and heat the mixture until all the water evaporates and there is no condensation on the watch glass. Then, turn off the burner and allow the evaporating dish to cool.

11) Once the evaporating dish is cool, obtain the mass of the evaporating dish, the watch glass, and the salt. (Subtracting the mass of the empty evaporating dish and watching glass from the mass of the evaporating dish, watching glass, and salt will give you the mass of

salt.)

12) Clean up all equipment, as specified in the safety precautions section.

PRE-LAB QUESTIONS Name _____

1) Briefly describe a procedure that can separate a mixture of sand and salt in three steps.

2) Define the following terms and provide an example of each.

Homogeneous mixture:

Heterogeneous mixture:

Element:

Compound:

3) A mixture weighing 5.000 g was shown to contain 2.445 g of sand and 2.555 g of salt. What is the percentage of sand and salt in the mixture?

4) Explain how the Law of Conservation of Matter can be applied to the previous question (Pre-lab #3).

DATA AND OBSERVATIONS

Unknown number/letter =

DATA TABLE

Mass empty a 50.0 mL Beaker	
Mass of the Beaker and the Mixture	
Mass of Mixture	
Mass of the Beaker and Sand	
Mass of Sand	
Mass of Empty Evaporating Dish and Watch Glass	
Mass of Evaporating Dish, Watch Glass, and Salt.	
Mass of Salt	

Percentage of Sand in the Mixture (Show Work):

Percentage of Salt in the Mixture (Show Work):

The combined Percentage of Sand and salt in the mixture (show work):

POST-LAB QUESTIONS

1) What are some potential sources of error in the experiment, and how can they be used to explain any discrepancies in the mixture's combined percentage of sand and salt?

2) Classify the following samples of matter encountered in the experiment as a homogeneous mixture, a heterogeneous mixture, an element, or a compound.

A mixture of Sand and Salt:

Sand:

Saltwater:

Salt:

Deionized water:

3) In this experiment, decantation separated the sand from the saltwater. What other method could have been used to achieve this separation?

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LAB 4: ATOMIC STRUCTURE AND FLAME TESTS

PURPOSE

The purpose of this experiment is to

· Perform flame tests on solutions containing various elements, and examine the colors produced.

· Explore the emission spectrum of hydrogen.

INTRODUCTION

During the lecture, you learned about two models of atomic structure: the Rutherford and Bohr models. The Rutherford model states that the majority of the atom's mass comes from the nucleus, which is positively charged and resides at the center of the atom. In this model, electrons randomly orbit the nucleus in circular paths. The Bohr model, proposed after hydrogen's structure was examined in more detail, explains that protons and neutrons are located inside the atom's nucleus, whereas electrons exist in specific energy levels outside the nucleus.

When solutions containing various elements are heated, electrons transition from a lower to a higher energy level. Electrons eventually will return to their original energy levels, and when they do so, they often emit energy in the form of visible light. Evidence of the Bohr model can be seen by the light produced as materials containing certain elements are heated. Because electrons exist in specific energy levels and are not randomly placed outside the nucleus, each element has its characteristic pattern of energy levels and, as a result, emits its characteristic pattern of light.

As you will see in this experiment, flame tests produce a continuous, characteristic color for given elements. When viewed through a diffraction grating (a component that divides light into its constituent colors), the spectrum is discontinuous, and the colors appear as thin, vertical lines. Each vertical line corresponds to specific energy transitions for electrons in an atom of a heated element. This produces a characteristic fingerprint for the element and can be used as an identifying feature. In this lab, you will examine the emission line spectrum for hydrogen using a spectroscope containing a diffraction grating.

SAFETY PRECAUTIONS

1) Wear chemical splash goggles at all times when working in this lab.

2) Make sure that no materials (book bags, purses, notebooks, etc.) are placed near open flames.

3) Exercise caution when working with Bunsen burners and have your instructor check your setup before you light the burner.

4) Turn off the gas immediately after working with the Bunsen burner.

5) Carefully handle all solutions used in this experiment. Gloves are provided if you wish to use them.

6) Do not touch the hydrogen gas tube while you are observing the line spectrum, as it will be hot.

7) Place all materials in the appropriate waste container and clean your work area when finished.

EQUIPMENT* AND CHEMICALS NEEDED

- Well plate
- Nichrome wire
- Bunsen burner with hose
- Matches or lighter or striker
- 50.0 mL beaker
- Hydrogen emission spectrum tube
- Handheld spectroscope
- Dilute solutions (approximately 0.5 M) of either the chlorides or nitrates of Li, Na, K, Ca, Sr, Ba, and Cu^{+2}
- 1.0 M HCl

* Images of equipment needed in this lab can be found in the appendix (the equipment may differ a little or be subject to changes, follow your instructors' directions).

EXPERIMENTAL PROCEDURE

Part I: Flame Tests

1) Add 10 drops of solutions containing Li, Na, K, Ca, Sr, Ba, and Cu^{+2} to individual wells in a well plate.

2) Using a 50.0 mL beaker, obtain 10.0 mL of 1 M HCl.

3) Obtain a Bunsen burner with a hose and nichrome wire.

4) Bring all equipment (listed in 1-3) to your lab bench. Once you are ready to begin, carefully turn on/light the burner, as guided by your instructor.

5) Dip the nichrome wire into the HCl solution and hold the tip of the wire into the flame until it produces no color. This amounts to cleaning the wire.

6) Dip the tip of the wire into the lithium solution and hold it in the flame until a specific color is produced. You may have to repeat this procedure a few times to saturate the wire with the lithium solution.

7) Once you observe the color lithium produces in the flame, repeat steps 5-6 for the remaining elements.

8) When you are finished with this part of the experiment, be sure to thoroughly clean the nichrome wire and turn off the gas.

Part II. Hydrogen Emission Spectrum

Using a spectroscope, observe the hydrogen emission spectrum (which will be set up by your instructor) and record the thin, vertical lines you see in the data/observations section of this lab.

PRE-LAB QUESTIONS Name _____

1) Identify the location, mass, charge, and role of the proton, neutron, and electron.

2) Differentiate between the Rutherford and Bohr models of atomic structure.

3) How can the Bohr model be applied to the colors observed from fireworks?

DATA AND OBSERVATIONS

Part I: Flame tests

Element	Color
Lithium	
Sodium	
Potassium	
Calcium	
Strontium	
Barium	
Copper	

Part II: Hydrogen emission spectrum

Replicate the observed lines in the hydrogen emission spectrum below (draw a vertical line by the indicated colors)

Red Orange Yellow Green Blue Violet

POST-LAB QUESTIONS

1) What was the biggest takeaway from performing this experiment?

2) Many streetlights are orange/yellow. Based on the results from part I, what element may be present in streetlights?

3) Based on the results from part I, which element(s) may be present in colors produced by the following fireworks?

Part A: Violet

Part B: Crimson red

4) How many vertical lines did you observe in the hydrogen emission spectrum? What do these vertical lines indicate?

5) How might the hydrogen emission spectrum differ from that of another element, such as neon?

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LAB 5: ELECTRON DOT STUCTURES AND MOLECULAR MODELS

There are two labs associated with Lab 5. Your instructor will let you know which one will be performed or a combination of two.

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LAB 5A : INTRODUCTION TO CHEMICAL BONDING

The purpose of this experiment is to:

- Draw Lewis structures for molecules with one central atom.
- Predict the three-dimensional shape of a molecule.
- Determine whether a molecule is polar or nonpolar.

- Draw Lewis structures for molecules with one central atom.
- Predict the three-dimensional shape of a molecule.
- Determine whether a molecule is polar or nonpolar.

During the lecture, you learned about ionic and covalent compounds. Ionic compounds are formed between a metal and a nonmetal (or cation and anion). In ionic compounds, electrons are transferred from the metal to the nonmetal, and the ions are held together by electrostatic attraction. Covalent compounds involve only nonmetals, and electrons are shared between atoms. In this lab, we will explore bonding in covalent compounds.

Bonding in covalent compounds is represented by Lewis structures, which show electrons as bonds or lone pairs. The following procedure summarizes how to draw a Lewis structure for a molecule with one central atom.

Step 1: Determine the number of bonds each element wants to form. We get this information from the element's position to the noble gases (column 8A). For example, since the halogens (F, Cl, Br, and I) and hydrogen are one position away from the noble gases, they will want to form 1 bond in any stable covalent compound. The elements under 6A (O, S, Se, and Te) will want to form two bonds because they are two positions away from the noble gases. Al and P, three positions away, will want to form three bonds, and C and Si will want to form four bonds.

Step 2: Place the element that wants to form the most bonds in the center and start by drawing single bonds to the other elements. Check to make sure all elements form the correct number of bonds. If not, use double or triple bonds.

Step 3: Once all elements form the correct number of bonds, place lone pairs on elements to fulfill the octet rule, which states that all elements want to be surrounded by eight electrons (the same number of valence electrons as the noble gases). Lone pairs can be placed on atoms as follows:

If an element forms one bond, give it three lone pairs.

If an element forms two bonds, give it two lone pairs.

If an element forms three bonds, give it one lone pair.

If an element forms four bonds, give it zero lone pairs.

The exception to this rule is hydrogen, which will only want to form one bond and have zero lone pairs because its nearest noble gas, helium, only has two valence electrons. This is known as the duet rule.

Consider the Lewis structure for water, H_2O, as an example. As explained in step 1, oxygen will want two bonds, and hydrogen will want one bond. We put oxygen in the center and draw single bonds to each hydrogen, as follows:

H–O–H

Checking the structure, we see that oxygen forms the two bonds it wants, and each hydrogen forms one bond. Now, we complete the structure by adding lone pairs. Referring to step 3, since oxygen forms two bonds, we give it two lone pairs. Hydrogen has only one bond and zero lone pairs. The complete Lewis structure can be shown as follows:



In this structure, oxygen is now surrounded by 8 electrons, following the octet rule, and each hydrogen is surrounded by two electrons, following the duet rule.

Note: We can represent electrons as dashes or dots. One dot means one electron and a dash means an electron pair (or two electrons).

Once the Lewis structure for a molecule is drawn, we can predict its three-dimensional shape. We get the shape by examining the electron arrangement around the central atom. This will be explored further in the pre-lab assignment, but in the meantime, refer to the course lecture notes for more information about the relationship between the Lewis structure and the three-dimensional shape.

After determining a molecule's shape, we can predict whether it will be polar or nonpolar. Recall from the lecture that polar molecules have a net charge distribution, and electrons are unequally shared between atoms. In a nonpolar molecule, electrons are equally shared between atoms, and there is no net charge distribution. We can assign polarity to molecules as follows:

Linear, trigonal planar, and tetrahedral molecules with all outer atoms the same will be nonpolar.

A molecule will be polar if

1) It is bent or trigonal pyramidal.

2) If it is linear, trigonal planar, or tetrahedral all outer atoms are not the same.

SAFETY PRECAUTIONS

1) No chemicals will be involved in this lab. However, be sure to handle models and other equipment with care.

2) After completing this assignment, put all equipment back in its original place and clean your work area.

EQUIPMENT NEEDED

- Molecular model kit or 3D printer
- Cell phone or camera to record structures of molecules (if using a 3D printer)

1) Using molecular models or a 3D printer, construct each of the molecules listed in the data table. (Note: Since each model kit may be slightly different, your instructor will provide specific instructions on how to use it. If using a 3D printer, refer to the procedure provided in this lab.)

2) Based on the molecule you constructed, draw the Lewis structure, showing all bonds and lone pairs.

3) Predict the three-dimensional shape of each molecule and then predict whether it is polar or nonpolar.

PRE-LAB QUESTIONS Name _____

1) What is the difference between a bonding pair and a lone pair of electrons?

2) As explained in the introduction, once a Lewis structure is drawn, the molecule's three-dimensional shape can be predicted. Click on the link below (or copy and paste it into your browser).

https://phet.colorado.edu/sims/html/molecule-shapes/latest/molecule-shapes_en.html

Click on the model and keep molecule geometry (which will be the shape) always selected. In the first structure, you can see that the central atom is bonded to two atoms and has no lone pairs. In the table below, write the shape that corresponds to this structure. Then, create molecules corresponding to the remaining descriptions in the table and record the shape. Under bonding, you can click the single, double, or triple bond to add bonds and the X to remove bonds. To add or remove lone pairs, use the lone pair box.

Description of the central atom	Shape
The central atom is bonded to two atoms and has no lone pairs.	
The central atom is bonded to three atoms and has no lone pairs.	
The central atom is bonded to four atoms and has no lone pairs.	
The central atom is bonded to three atoms and has one lone pair.	
The central atom is bonded to two atoms and has two lone pairs.	

Note: All simulations available at https://phet.colorado.edu *are open educational resources available under the Creative Commons Attribution license (CC-BY).*

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3) Referring to the simulation used in pre-lab question 2, what shape would molecules with the following descriptions assume?

Part A: The central atom forms two double bonds and has no lone pairs.

Part B: The central atom forms two single bonds and one double bond and has no lone pairs.

Part C: The central atom forms one triple bond and one single bond and has no lone pairs.

DATA AND OBSERVATIONS

Molecule	Lewis Structure	Shape	Polar or nonpolar
HOCl			
HCN			
CO_2			
PH_3			
OF_2			
CH_2Cl_2			
COH_2			
CH_4			
NBr_3			
$CSCl_2$			

1) Which of the molecules provided in the data table are linear? Explain why some of these linear molecules are polar whereas others are nonpolar.

2) In this experiment, we explored molecules with only one central atom. However, larger molecules exist, and they can be drawn using the same procedure you followed. Draw Lewis structures for the following molecules:

$$H_2O_2,\ H_2CO_2$$

(Hint: Make sure all elements form the correct number of bonds.)

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LAB 5B: Molecular Geometries – 3D Printing

PURPOSE

The purpose of this experiment is to

• Visualize the 3D geometry of molecules with a central atom surrounded by 2, 3, or 4 terminal atoms.

• Create and print 3D models of representative molecules.

INTRODUCTION

The 3-dimensional structure of a molecule is a very important predictor of the molecule's physical and chemical properties. One important property of a molecule is its polarity. Most covalent bonds are polar; however, the overall polarity of a molecule will depend on its 3D geometry. Given a drawing of a molecule, its 3D structure can sometimes be difficult to imagine, making predictions about its polarity problematic. The 3D structure can be evaluated more easily with a small 3D model, such as that created by a 3D printer.

SAFETY PRECAUTIONS

Be sure to follow all your instructor's instructions regarding properly using your 3D printer. Parts of the printer can be hot, and the mechanical moving parts can cause injury unless proper care is taken.

EQUIPMENT NEEDED

· 3D printer

· Computer with the 3D chemical structure drawing and 3D printing software installed (described below)

EXPERIMENTAL PROCEDURE

The following programs will be used for the instructions for this lab. These are all available free of charge.

· JmoL[1] to create a 3D computer model of a molecule and export it as an STL file.

· Ultimaker CURA [2] to slice the STL file and create the g-code needed by the 3D printer.

For each of the compounds in the data table, you will

1. create a 3D computer model of a molecule of the compound.

2. export an STL file that can be "sliced" by CURA.

3. import the STL file into CURA, slice it, and generate the g-code.

4. move the g-code to the printer and create a 3D print of the molecule.

5. use the model to help predict the molecule's polarity.

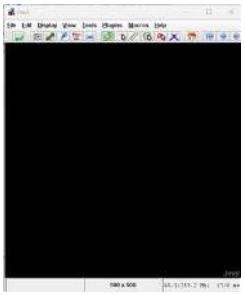
Complete the following Preliminary Exercise to practice the steps involved.

Preliminary Exercise – Printing a 3D model of carbon tetrafluoride, CF_4.

Complete the following steps to build and print your first model.

1. Create a 3D computer model.

a. Open Jmol by clicking on the Jmol.jar file. This will open the application's 3D window.



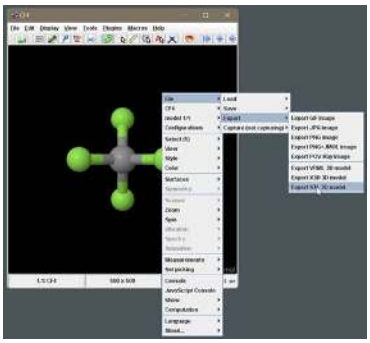
b. Select Get MOL from the File menu. You can enter each molecule in the Data Table as a formula (e.g., CF4) or by name (e.g., tetrafluoromethane). Sometimes, the formula will not work. If you have difficulties, ask your instructor for assistance.



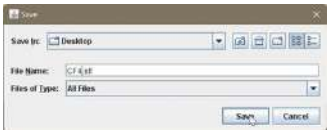
c. When you press enter or click OK, a 3D molecule model will display in the window.

2. Export an STL file.

a. Right-click on the Jmol display window and open successive menus to select File►Export►Export STL 3D model.



b. Choose a folder and give your file a name with the .stl extension.



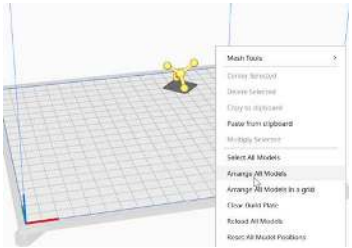
3. Slice the STL file in CURA.

a. Open CURA then click on the open file icon.



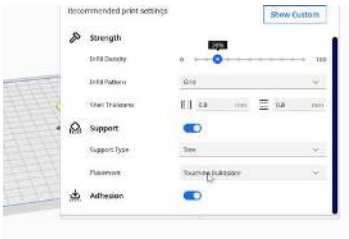
b. Browse to where you saved the STL file and open it.

c. The model will be displayed on the printing surface. Right-click on the printing surface and select “Arrange all models” to move your model to the center of the surface.

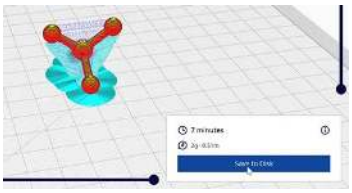


d. You can do various manipulations to the 3D model, such as scaling and tilting it, but the default will usually work well. Ask your instructor for help if you are unsure.

e. Make sure that you include supports for your print. The Tree type supports work well with these models; usually, selecting "Touching Buildplate" will be sufficient. If you have trouble with the print, try "Everywhere" for your support placement and ask your instructor for assistance.



f. Click on the SLICE button. When the slicing is done, the program will display the time needed to print the model. Click the "Preview" button to see what the print and supports will look like. Get your instructor's approval before continuing.



g. Export the G-code by clicking on the Save to Disk button.

h. Copy the saved .gcode file to an appropriate removable card as per your instructor.

4. Print the model.

a. Insert the memory card in your printer and use the printer's control knobs to select your model. The printer will start warming up the nozzle and should begin printing within a few minutes.

b. Once the printing is complete, carefully remove the model and its supports from the printing surface.

c. The supports should be carefully removed using needle-nose pliers or other tools provided by your instructor.

5. Predict the polarity of the molecule.

a. Look at the model carefully and rotate the model to answer these questions:

Does the molecule contain polar bonds?

In what direction(s) are the polar bonds?

Are the bonds symmetrically oriented so that their individual polarities cancel each other out? Or are they asymmetrically oriented so there will be a net dipole in the molecule?

b. Enter the observations and conclusions in the Data Table.

PRE-LAB QUESTIONS Name _____

1) Describe the similarities and differences between ionic bonds, polar covalent bonds, and pure covalent bonds.

2) Describe, in your own words, how the number of electron domains determines the geometry around a central atom of a small molecule.

3) Describe, in your own words, how the shape of a small molecule can make the molecule polar or nonpolar.

DATA AND OBSERVATIONS

Molecule	CO_2	Lewis Structure
# valence electrons		

# of electron domains		
Electron domain geometry		
# of lone pairs		
Molecular geometry		3D Sketch/Image
Polar or nonpolar?		

Molecule	CF_4	
# valence electrons		Lewis Structure
# of electron domains		
Electron domain geometry		
# of lone pairs		
Molecular geometry		3D Sketch/Image
Polar or nonpolar?		

Molecule	NH_3	
# valence electrons		Lewis Structure
# of electron domains		
Electron domain geometry		
# of lone pairs		
Molecular geometry		3D Sketch/Image
Polar or nonpolar?		

Molecule	H_2O	
# valence electrons		Lewis Structure
# of electron domains		
Electron domain geometry		
# of lone pairs		
Molecular geometry		3D Sketch/Image
Polar or nonpolar?		

3D Printing

You will be assigned to build a model and print a small molecule. Follow the steps from the Preliminary Exercise and substitute your molecule for carbon tetrafluoride, CF_4. After you have completed the model, complete the following table.

Molecule		
# valence electrons		Lewis Structure
# of electron domains		
Electron domain geometry		

# of lone pairs		
Molecular geometry		3D Sketch/Image
Polar or nonpolar?		

POST-LAB QUESTIONS

1. How does the 3D model help you to determine if a molecule is polar or nonpolar?

2. Is the 3D model different than you expected in any way? If so, how?

3. What are the advantages and disadvantages of 3D printing the model vs. looking at the model on a computer screen?

ADDITIONAL INFORMATION REGARDING SOFTWARE

Here are some suggested software packages that can be used to complete this lab. These are all free of charge.

- A program to create and save a stereolithography file, known as an STL file. This is a 3D solid model that can be "sliced" and printed.

o Jmol (requires java): https://sourceforge.net/projects/jmol/files/Jmol/. The download consists of a zip file containing all the files needed to run the program. Simply extract the files to a folder of your choice. The program is started by clicking the Jmol.jar file.

o Note: If Java is not available on your computer, an online version can be accessed on the Hack-a-mol website (https://chemapps.stolaf.edu/jmol/jsmol/hackamol.htm)

- A slicer program to prepare the STL file for printing and generate the g-code that the printer needs to make the print.

o If your printer comes with a slicer program, use it.

o One of the best slicer programs is Ultimaker CURA (https://ultimaker.com/software/ultimaker-cura/). The program must be installed on your computer, so some administrative rights are required.

o There are also several free sites that can generate g-code from an STL file online. An example is Creality Cloud https://www.crealitycloud.com/blog/tutorials/how-to-convert-stl-to-gcode. Many others can be found by searching the web.

[1] Jmol: an open-source Java viewer for chemical structures in 3D. http://www.jmol.org/

[2] https://ultimaker.com/software/ultimaker-cura/

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LAB 6: INTRODUCTION TO SOLUTIONS- SOLUBILITY AND CONDUCTIVITY

PURPOSE

The purpose of this experiment is to:

• Explore the conductivity of various solutions.

• Predict whether a substance acts as a strong electrolyte, weak electrolyte, or nonelectrolyte.

INTRODUCTION

When substances dissolve in water, they can act as strong electrolytes, weak electrolytes, or nonelectrolytes. Strong electrolytes completely ionize in water. Examples include soluble ionic compounds and strong acids (HCl, HBr, HI, HNO_3, H_2SO_4, $HClO_4$, $HClO_3$). Consider the dissolution of sodium chloride, as shown below:

$$NaCl\ (aq) \rightarrow Na^+\ (aq) + Cl^-\ (aq)$$

When NaCl dissolves in water, it completely breaks apart into its constituent cation (Na^+) and anion (Cl^-). Similarly, when HCl forms a solution with water, we assume that 100% of the molecule will ionize as follows:

$$HCl\ (aq) \rightarrow H^+\ (aq) + Cl^-\ (aq)$$

Weak electrolytes include weak acids (any acid other than the seven listed above) and weak bases. These substances only partially ionize in water. For example, when acetic acid, $HC_2H_3O_2$, dissolves in water, some of the molecules will ionize into H^+ and $C_2H_3O_2^-$, but most of what is present in aqueous solution will remain as $HC_2H_3O_2$.

Nonelectrolytes will not ionize in water and will remain entirely as the molecule. Examples include soluble covalent compounds. When sugar, $C_{12}H_{22}O_{11}$, is added to water, it will exist as $C_{12}H_{22}O_{11}$ and will not break apart.

The ions present in the solution allow an electrolyte to conduct electricity. The greater the number of ions present in the solution, the greater the conductivity. Strong electrolytes are better conductors than weak electrolytes since they have more ions present in the solution. Nonelectrolytes will not act as conductors because they do not ionize.

One way to determine how a substance dissolves in water is by measuring the conductivity of the solution that forms. Some conductivity meters show numerical values. The larger the value, the greater the conductivity. Others use a light to indicate conductivity. The brighter the light, the greater the conductivity. In this experiment, you will use battery-operated conductivity meters to measure the conductivity of 12 different solutions/substances. A bright green light means strong conductivity and a red light indicates no conductivity. Based on the light produced, you will then infer whether the solution acts as a strong electrolyte, weak electrolyte, or nonelectrolyte.

SAFETY PRECAUTIONS

1) Always wear chemical splash goggles while working with chemicals in this experiment.

2) Use the conductivity meters carefully and rinse the electrodes after each use in each solution and when you are finished with the experiment.

3) Dispose of all waste, as directed by your instructor, and thoroughly clean your work area and all equipment used.

EQUIPMENT* AND CHEMICALS NEEDED

• Well plate

• Disposable plastic droppers

• Deionized water

• Ethanol

• Gatorade

• Tap water

• 0.5 M - 1 M solutions of NaCl, $CaCl_2$, HCl, $HC_2H_3O_2$, NaOH, NH_3, $NaHCO_3$, $C_{12}H_{22}O_{11}$ (Be sure the concentration of each solution is the same.)

• Battery-operated conductivity meter with light bulb

* Images of equipment needed in this lab can be found in the appendix (the equipment may differ slightly or be subject to changes or updates; follow your instructors' directions).

EXPERIMENTAL PROCEDURE

1) Obtain a well plate and half-fill the wells with the following solutions: NaCl, $CaCl_2$, HCl, $HC_2H_3O_2$, NaOH, NH_3, $NaHCO_3$, $C_{12}H_{22}O_{11}$, ethanol, Gatorade, tap water, and deionized water. To do this, you could use the droppers from the bottles in which the solutions are placed or disposable plastic droppers.

2) Test the conductivity of each solution using the conductivity meter. Record the color of light produced in the data table. Be sure to rinse the electrodes on the conductivity meter with deionized water between each solution used.

3) Pour the contents of the well plate into the sink and wash with plenty of soap and water.

4) Thoroughly clean your work area and all equipment used. Return equipment to the appropriate place before leaving the lab.

PRE-LAB QUESTIONS Name _____

1) In your own words, define the following terms:

Strong Acid:

Weak Acid:

Strong Base:

Weak Base:

Ionic Compound:

Covalent Compound:

Solvent:

Solute:

Solution:

2) Classify the following compounds as ionic or covalent.

$Ca(NO_3)_2$ **:**

$AlCl_3$ **:**

$C_6H_{12}O_6$ **:**

NH_3 **:**

3) Classify the following compounds as Strong Acid, Weak Acid, Strong Base, or Weak Base.

HBr :

H_2SO_4 :

NH_3 :

KOH :

HF :

4) When a solution is tested with a battery-operated conductivity meter, a bright green light is shown. Based on this observation, would you predict the solution to act as a strong electrolyte, a weak electrolyte, or a nonelectrolyte?

DATA AND CALCULATIONS

Under the heading "Results of Conductivity Test," describe the color of the light bulb. For classification of solution, write strong electrolyte, weak electrolyte, or nonelectrolyte.

Solution	Results of the Conductivity Test	Classification of Solution
NaCl		
$CaCl_2$		
HCl		
$HC_2H_3O_2$		
NaOH		
NH_3		
$NaHCO_3$		
$C_{12}H_{22}O_{11}$		
Ethanol		
Gatorade		
Tap water		
Deionized water		

POST-LAB QUESTIONS

1) Summarize the results of the experiment concerning the color of the lightbulb turned in the presence of different types of solutions.

2) Account for differences in the results of the conductivity test on tap water and deionized water.

3) Vinegar is made up of 5% acetic acid ($HC_2H_3O_2$) in water. Based on the results of this experiment, what would you expect to see if vinegar is tested with the conductivity meter?

4) Explain the results of the conductivity test on Gatorade.

5) Which solution would you expect to have a higher conductivity: NaCl or $CaCl_2$? Explain.

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LAB 7: INTRODUCTION TO CHEMICAL REACTIONS AND EQUATIONS

PURPOSE

The purpose of this experiment is to:

• Perform several chemical reactions and record observations.

• Balance chemical equations.

INTRODUCTION

Chemistry is defined as the study of matter and its changes. Changes in matter can be classified as physical or chemical. A physical change occurs when different forms of the same material are produced. Phase changes (such as melting or boiling) and solution formation (like the dissolution of sodium chloride in water to form saltwater) are examples of physical changes. Physical changes can be reversed without having to run a chemical reaction.

Chemical changes produce new materials. In a chemical change, atoms are rearranged as reactants (the starting materials) and are converted into products (the new materials). Chemical changes can be represented by chemical equations. Consider the conversion of hydrogen and oxygen into water:

$H_2 + O_2 \rightarrow H_2O$

When a chemical reaction occurs, matter cannot be created or destroyed, meaning that the same number and type of atoms must be shown on each side of the equation. To illustrate this, we must balance the equation by adding a whole number of coefficients before each element or compound. We can balance the above equation as follows:

$$2\ H_2 + O_2 \rightarrow 2\ H_2O$$

The total number of atoms on each side of the equation can be found by multiplying the added coefficient by the given subscript. On the left side of the equation, we see four hydrogens (2 x 2) and two oxygens (1 x 2). The right side of the equation also has four hydrogens (2 x 2) and two oxygens (2 x 1). Since this equation now has the same number of atoms on each side, it is considered balanced. For more information on balancing equations, refer to the course lectures and notes.

In this experiment, you will be recording observations from ten chemical reactions. Observations will include evidence of a reaction, such as the formation of a gas, precipitate, or odor, as well as changes in color or temperature. Then, you will be asked to balance each equation associated with the given reactions.

SAFETY PRECAUTIONS

1) Always wear chemical splash goggles while working on this experiment.

2) Gloves will be provided, should you choose to wear them. Be sure to thoroughly wash your hands after completing this experiment.

3) Exercise caution when working with Bunsen burners. Keep notebooks, purses, books, and other belongings away from open flames. When heating test tubes, follow all directions provided by your instructor.

4) Thoroughly read and reread labels on bottles to make sure you are mixing appropriate solutions.

5) Discard chemical waste into appropriate waste containers as indicated by your instructor.

6) When you finish the experiment, thoroughly clean your work area and return the chemicals and equipment to their original locations.

EQUIPMENT* AND CHEMICALS NEEDED

• Bunsen burner with hose

• Well plate

• 600 mL beaker

• Matches or lighter or Striker

- Spatula
- Wire cutters or scissors
- Test tube rack
- Test tube holder
- 3 medium-sized test tubes
- 25 cm strip of copper wire
- Solid $NaHCO_3$
- Solid $CuSO_4.5H_2O$
- Solid Na_2CO_3
- 1 M HCl
- 0.5-1 M solutions of NaCl, $AgNO_3$, $CaCl_2$, Na_3PO_4, $BaCl_2$, Na_2SO_4, $FeCl_3$, KSCN, $CuSO_4$ and NaOH
- Solid waste container
- Inorganic waste container

* Images of equipment needed in this lab can be found in the appendix (the equipment may differ a little or be subject to changes; follow your instructors' directions).

EXPERIMENTAL PROCEDURE

1) Gather the following equipment:

- Bunsen burner with hose
- Matches or lighter
- Test tube holder
- Test tube rack
- 25 cm strip of copper wire
- Medium size test tube containing a small scoop of solid $NaHCO_3$ (baking soda)
- Medium size test tube containing a small scoop of solid $CuSO_4 . 5H_2O$

Note: Rinse and dry your spatula between obtaining the two solids to avoid cross-contamination.

2) Carefully light the Bunsen burner, following all instructions provided by your instructor. Hold the tip of the copper wire into the flame for 10-15 seconds. Remove the wire, note any changes in the part of the copper wire placed in the flame, and record your observations.

3) Using a test tube holder, place the tip of the test tube containing $NaHCO_3$ into the flame for approximately 10-15 seconds, as directed by your instructor. Hold the test tube at an angle, ensuring the open end is not pointed toward you or your lab partners. Record any observations.

4) Using a test tube holder, place the tip of the test tube containing $CuSO_4 .5H_2O$ into the flame for approximately 10-15 seconds, as directed by your instructor. Hold the test tube at an angle, ensuring the open end is not pointed towards you or your lab partners. Record any observations.

5) Turn off the burner. Dispose of the copper wire in the solid waste container. Pour the remaining solids in the test tubes into the inorganic waste container. Clean your work area before proceeding to the next step of the experiment.

6) Add a small scoop of solid Na_2CO_3 to a medium-sized test tube. Place the test tube in a test tube rack and add 10 drops of 1 M HCl. Record your observations. Pour the contents of the test tube into the inorganic waste container.

7) Obtain a well plate and add 5-10 drops of each solution to the following wells:

Well 1: NaCl and $AgNO_3$

Well 2: $CaCl_2$ and Na_3PO_4

Well 3: $BaCl_2$ and Na_2SO_4

Well 4: $FeCl_3$ and KSCN

Well 5: $CuSO_4$ and NaOH

Well 6: $FeCl_3$ and NaOH

Record your observations. Pour the contents of the well plate into a 600 mL beaker. Then, pour the contents of the 600 mL beaker into the inorganic waste container.

8) Thoroughly clean all glassware with soap and water. Return all equipment and chemicals to their appropriate places. Clean your work area before leaving the lab.

PRE-LAB QUESTIONS Name _____

1) Briefly define the following terms:

Melting:

Freezing:

Evaporation:

Condensation:

Sublimation:

Deposition:

2) Would the changes defined above be considered physical or chemical? Explain.

3) In a chemical reaction, the physical states of reactants and products are often given in parentheses (as you will see in this experiment). What do the following terms represent?

(s) :

(l) :

(g) :

(aq) :

4) What is a precipitate? Which of the notations in pre-lab question 3 can be used to represent the formation of a precipitate?

DATA AND OBSERVATIONS

For each reaction, **balance** the provided equation and record **observations and evidence** of the reaction.

Reaction 1: Copper wire and heat

$Cu\ (s) + O_2\ (g) \rightarrow CuO\ (s)$

Observations:

Reaction 2: $NaHCO_3$ and heat

$NaHCO_3\ (s) \rightarrow Na_2CO_3\ (s) + H_2O\ (g) + CO_2\ (g)$

Observations:

Reaction 3: $CuSO_4 \cdot 5H_2O$ and heat

$CuSO_4 \cdot 5H_2O \rightarrow CuSO_4\ (s) + H_2O\ (g)$

Observations:

Reaction 4: Na_2CO_3 and HCl

Na_2CO_3 (s) + HCl (aq) → NaCl (aq) + H_2O (l) + CO_2 (g)

Observations:

Reaction 5: NaCl and $AgNO_3$

NaCl (aq) + $AgNO_3$ (aq) → $NaNO_3$ (aq) + AgCl (s)

Observations:

Reaction 6: $CaCl_2$ and Na_3PO_4

$CaCl_2$ (aq) + Na_3PO_4 (aq) → $Ca_3(PO_4)_2$ (aq) + NaCl (aq)

Observations:

Reaction 7: $BaCl_2$ and Na_2SO_4

$BaCl_2$ (aq) + Na_2SO_4 (aq) → $BaSO_4$ (s) + NaCl (aq)

Observations:

Reaction 8: $FeCl_3$ and KSCN

$FeCl_3$ (aq) + KSCN (aq) → $Fe(SCN)_3$ (aq) + KCl (aq)

Observations:

Reaction 9: $CuSO_4$ and NaOH

$CuSO_4$ (aq) + NaOH (aq) → $Cu(OH)_2$ (s) + Na_2SO_4 (aq)

Observations:

Reaction 10: $FeCl_3$ and NaOH

$FeCl_3$ (aq) + NaOH (aq) → $Fe(OH)_3$ (s) + NaCl (aq)

Observations:

POST-LAB QUESTIONS

1) Refer to reaction 1. Explain why oxygen is a reactant when copper wire is heated.

2) Refer to reaction 4. Imagine the reaction was performed in the presence of a lit match. What would you predict to happen?

3) Refer to reaction 8. Account for the color change observed during this reaction.

4) Classify the following changes as **physical or chemical**.

Part A: A match is lit.

Part B: Isopropyl alcohol is dissolved in water to form a solution of rubbing alcohol.

Part C: A piece of bread begins to mold.

Part D: When sodium metal is added to water, hydrogen gas is produced.

Part E: Stream condenses on a mirror during a hot shower.

5.) Provide three examples of physical changes and three examples of chemical changes that you encounter in daily life. Write a balanced equation to describe one of the chemical changes you describe.

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LAB 8: INTRODUCTION TO ACIDS AND BASES

PURPOSE

The purpose of this experiment is to

• Determine the pH of various solutions.

• Examine how pH affects litmus paper and red cabbage indicator.

• Identify solutions as acidic, basic, or neutral.

INTRODUCTION

pH is a measure of the hydrogen ion concentration in a solution. We can use pH values to identify whether a solution is acidic, basic, or neutral. The pH scale ranges from 0-14. Acidic solutions have a pH of less than 7, neutral solutions have a pH of 7, and basic solutions have a pH greater than 7.

In this experiment, we will first use litmus paper to determine whether a solution is acidic or basic. We will then use pH paper and a pH meter to measure the pH of the solution. Finally, we will explore the effect of pH on the red cabbage indicator, which changes colors at various pH levels.

SAFETY PRECAUTIONS

1) Always wear chemical splash goggles when working on this experiment.

2) Gloves are provided, should you wish to use them.

3) Dispose of all waste, as indicated by your instructor.

4) Thoroughly clean your work area when finished and return all equipment and chemicals to their appropriate place.

EQUIPMENT AND CHEMICALS NEEDED

• Well plate

• pH meter

• Deionized water in a water bottle

• Red litmus paper

• Blue litmus paper

• pH paper

• Kimwipes

• Stirring rod

• Red cabbage indicator

• Tap water

• 0.5 M - 1 M solutions of vinegar, baking soda, bleach, detergent, ammonia

• Soft drink

• Glass cleaner

• Rubbing alcohol

* Images of equipment needed in this lab can be found in the appendix (the equipment may differ a little or be subject to changes, follow your instructors' directions).

EXPERIMENTAL PROCEDURE

1) Obtain a well plate and add 10 drops of each solution listed in the equipment needed section (or refer to the data table) to individual wells.

2) Determine what color each solution turns the red litmus paper. To do this, dip the end of a strip of paper into the solution in the first well. To avoid wasting the litmus paper, tear off the part that was previously used and dip the remaining end into the next solution.

Repeat this process for each solution. (You can likely test 3-4 solutions with a single strip of litmus paper.). In the data table, record what color the solutions turn the red litmus paper.

3) Repeat step **2 using blue litmus paper**.

4) Repeat step **2 using pH paper**. In this case, you could match the color of each solution turning the pH paper to the pH chart provided with the pH paper.

5) Determine the pH of each solution using a pH meter. Depending on the pH meter you use, specific instructions may be available. Consult your instructor for more information. Rinse the pH probe between solutions with deionized water, then gently pat dry it with a Kim wipe before immersing it in the next solution.

6) Add 2-3 drops of red cabbage indicator to each solution. Stir each solution with a stirring rod (rinsing and wiping the stirring rod between solutions), and record in the data table the color each solution turns.

7) Pour the contents of the well plate into the sink and rinse with plenty of water.

8) Thoroughly wash all glassware with soap and water and return all equipment and chemicals to the appropriate place. Clean your work area before leaving the lab.

PRE-LAB QUESTIONS Name _____

1) What color does red litmus paper turn in acidic and basic solutions?

2) What color does blue litmus paper turn in acidic and basic solutions?

3) List three properties of acids.

4) List three properties of bases.

5) What is an indicator? How can it be used to detect changes in the pH levels of solutions?

DATA AND OBSERVATIONS

Complete the following table. In the column headed “Color red litmus paper turns,” “Color blue litmus paper turns,” and “Color solution turns with red cabbage indicator,” record the color observed. Under pH paper and pH meter, record the pH value.

	Color Change of Red Litmus Paper	Color Change of Blue Litmus Paper	pH value from pH paper	pH value from pH meter	Color Change with Red Cabbage Indicator	Is the solution acidic, basic, or neutral?
Tap water.						
Deionized water						
Vinegar						
Baking soda						
Bleach						
Detergent						
Ammonia						
Soft drink						
Glass cleaner						
Rubbing alcohol						

POST-LAB QUESTIONS

1) Rank the following (litmus paper, pH paper, pH meter, red cabbage indicator) from least to most accurate in determining the pH value of a solution.

2) What color does the red cabbage indicator turn in acidic solutions?

3) What color does the red cabbage indicator turn in basic solutions?

4) Which tests (litmus paper, pH paper, pH meter, red cabbage indicator) were used to determine whether the solution was acidic, basic, or neutral?

5) Did any of the test results surprise you? If yes, which ones, and why?

6) Provide three examples of acids and three examples of bases used in everyday life that were not explored in this experiment.

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LAB 9: INTRODUCTION TO REDOX REACTIONS

PURPOSE

The purpose of this experiment is to

• Run a series of redox reactions and record observations.

• Create an activity series for various metals.

INTRODUCTION

Redox reactions (oxidation-reduction reactions) occur when electrons are transferred between reactants. In these reactions, one species is oxidized (or loses electrons), and another is reduced (or gains electrons). (Note: In future chemistry courses, you will be exploring additional definitions of oxidation and reduction.) One way to identify oxidation is to observe when the charge on an atom increases or becomes more positive. In the following reaction

$Na \rightarrow Na^{+} + e^{-}$,

sodium would be oxidized because the charge increases from 0 on the left to +1 on the right. In a reduction, the charge on an atom decreases, or becomes more negative, as shown in the example below:

$Zn^{+2} + 2e^{-} \rightarrow Zn$

In this experiment, we will explore redox reactions in which a metal is placed in an aqueous solution containing other metal ions. These reactions will take the following form:

$$2\ Li\ (s) + MgCl_2\ (aq) \rightarrow 2\ LiCl\ (aq) + Mg\ (s)$$

In these types of reactions, the solid metal is oxidized, and the metal in aqueous solution is reduced. Referring to the above example, Li is oxidized, and Mg is reduced. These reactions are also known as single replacement reactions because the metals are switching places.

As you will see from this experiment, not all these reactions will occur because some metals are more reactive than others. The reactivity of metals can be summarized in an activity series, which lists metals in order of increasing reactivity. More reactive metals are listed at the top of the series, and fewer reactive metals are listed at the bottom. For example, consider an activity series of generic metals A, B, C, X, Y, and Z.

B

C

Z

X

A

Y

According to this activity series, B would be the most reactive metal, and Y would be the least reactive metal. If we placed metal B in a solution containing C ions, a reaction would occur. Also, if we placed metal Z in a solution containing Y ions, a reaction would occur. However, no reaction would occur if metal A were placed in a solution containing B ions because B is more reactive than A. So, in summary, a reaction will occur if a metal is placed in a solution containing ions of a metal listed below it in the activity series.

Now, consider the following data concerning the reactions of Li, Ca, Na, and Mg:

According to experimental results, Li is the most reactive metal, and Mg is the least reactive metal. Based on this data, the following activity series may be created:

Li

Ca

Na

Mg

During this experiment, you will place metals in solutions containing various metal ions. You will be asked to record observations of reactions that occur. If a reaction does not occur, you will write NR (no reaction) in the data table. Then, based on the results of this experiment, you will create an activity series listing the metals explored from most to least reactive.

SAFETY PRECAUTIONS

1) Always wear safety goggles when working with chemicals in this experiment.

2) It is advisable to wear gloves when working with chemicals in this experiment.

3) Be sure to thoroughly read labels on reagent bottles to ensure the correct chemicals are always used.

4) Dispose of all waste, as directed by your instructor.

5) Thoroughly clean all glassware, equipment, and your work area when finished working on this experiment.

EQUIPMENT* AND CHEMICALS NEEDED

• Four medium-sized test tubes

• Test tube rack

• Mg (s), Zn (s), Pb (s), Cu (s)

• 1 M HCl

• Dilute nitrate or chloride solutions (less than 1 M) of Mg, Zn, Pb, and Cu

• Inorganic waste container

* Images of equipment needed in this lab can be found in the appendix (the equipment may differ a little or be subject to changes, follow your instructors' directions).

EXPERIMENTAL PROCEDURE

1) Cut four small strips of Mg (s) and place them into four separate medium size test tubes. Place the test tubes in a test tube rack. Cautiously and slowly add 5-10 mL of the following solutions to each test tube:

Test tube 1: zinc solution

Test tube 2: lead solution

Test tube 3: copper solution

Test tube 4: 1 M HCl

Let the reactions proceed for approximately 10 minutes. Then, record your observations in the data table. If a reaction did not occur, record this as NR in the data table. Discard the waste into the inorganic waste container, clean and dry your test tubes, and save them for the next step.

2) Repeat step 1 using Zn (s) instead of Mg (s) and replacing the zinc solution in test tube 1 with the magnesium solution.

3) Repeat step 1 using Pb (s) instead of Mg (s) and replacing the lead solution in test tube 2 with the magnesium solution.

4) Repeat step 1 using Cu (s) instead of Mg (s) and replacing the copper solution in test tube 3 with the magnesium solution.

5) Thoroughly clean all glassware and equipment and return them to the appropriate place.

6) Clean your work area before leaving the lab.

PRE-LAB QUESTIONS Name _____

1) In your own words, define oxidation and reduction.

2) True or false: Oxidation always occurs with reduction. The two cannot happen independently.

3) Based on the activity series in the introduction, would you expect the following reactions to occur? Why or why not?

Reaction 1: $Ca\ (s) + 2\ LiCl\ (aq) \rightarrow CaCl_2\ (aq) + 2\ Li\ (s)$

Reaction 2: 2 Na (s) + $MgCl_2$ (aq) → 2 NaCl (aq) + Mg (s)

Reaction 3: Mg (s) + 2 LiCl (aq) → $MgCl_2$ (aq) + 2 Li (s)

DATA AND OBSERVATIONS

Complete the following data table by recording your observations. For reactions that did not occur, write NR.

	Mg Solution	Zn Solution	Pb Solution	Cu Solution	HCl
Mg (s)	XXXXXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXXXXX X				
Zn (s)		XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX			
Pb (s)			XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX		
Cu (s)				XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXX	

POST-LAB QUESTIONS

1) Based on the information provided in the data table, write an activity series for Cu, H, Mg, Pb, and Zn. (For more details, see the activity series presented in the introduction.)

2) Circle the best response.

For the reactions that occurred during this experiment, the solid metal was (oxidized/reduced) and the metal in aqueous solution was (oxidized/reduced).

3) Refer to the activity series you created in post-lab question 1 and predict whether the following reactions would occur as written.

Cu (s) + $MgBr_2$ (aq) → $CuBr_2$ (aq) + Mg (s)

Pb (s) + 2 HNO_3 (aq) → $Pb(NO_3)_2$ (aq) + H_2 (g)

Zn (s) + $CuSO_4$ (aq) → $ZnSO_4$ (aq) + Cu (s)

4) Provide five examples of redox reactions that occur in everyday life.

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LAB 10: SYNTHESIS AND ANALYSIS OF SOAP

PURPOSE

The purpose of this experiment is to

• Synthesize soap using the saponification reaction.

• Test the synthesized soap against a commercial liquid soap.

INTRODUCTION

We use soap daily when we shower, wash our hands, or clean various materials. It consists of a polar (hydrophilic) head and a nonpolar (hydrophobic) tail. When soap is used, oils and greasy dirt bond to the hydrophobic end, and rinsing with water washes everything away. Soap can be prepared through a process known as saponification. In this reaction, a triglyceride (or fat) reacts with a base, such as sodium or potassium hydroxide, to produce glycerol and the sodium or potassium salts of the acids.

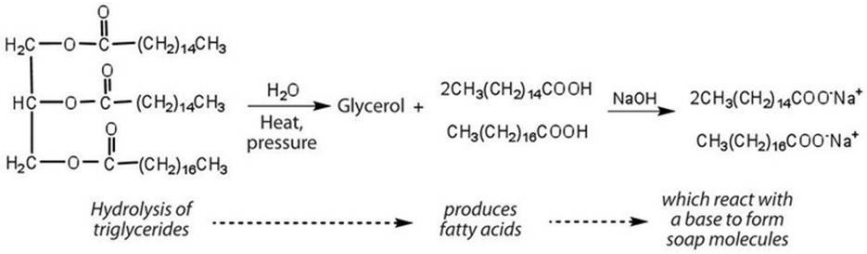


Figure 1: Glycerol and sodium or potassium salts of the fat, known as crude soap. Image taken from General, Organic, and Biological Chemistry (Ball et. al) CC BY-NC-SA

In this experiment, you will first synthesize crude soap by reacting to an oil with sodium hydroxide. Then, the synthesized soap will undergo various tests, and the results will be compared with a commercial liquid soap.

SAFETY PRECAUTIONS

1) During this experiment, wear chemical splash goggles while working with chemicals.

2) Take care when handling hot equipment. Use hot mitts to remove equipment from the hot plate or ask your instructor to do so.

3) Do not test any soap products synthesized during this experiment on your body.

4) When you are finished with the experiment, clean your work area and dispose of waste as indicated by your instructor.

EQUIPMENT* AND CHEMICALS NEEDED

• 100 mL graduated cylinder

• Stirring rod

• Spatula

• Deionized water

• 50 mL beaker

• 250 mL beaker

• 400 mL beaker

• Hot plate

• pH paper

• Two medium-sized test tubes with rubber stoppers

• Hot mitts

• Cheesecloth

• Saturated sodium chloride solution

• Ethanol

• 3.0 M NaOH

• Vegetable oil, olive oil, and/or coconut oil (Note: Perhaps separate groups could be assigned different oils)

• Solid fat (such as vegetable shortening)

• Watch glass

• Commercial liquid soap

• Halogenated organic waste container

* Images of equipment needed in this lab can be found in the appendix (the equipment may differ a little or be subject to changes, follow your instructors' directions).

EXPERIMENTAL PROCEDURE

1) Using a graduated cylinder, measure out 10.0 mL of vegetable oil, olive oil, or coconut oil. Pour the oil into a 250.0 mL beaker.

2) Add 10.0 mL of ethanol and 15.0 mL of 3.0 M NaOH to the 250. mL beaker. Stir the resulting mixture with a stirring rod for 2 minutes.

3) Gently heat the mixture on a hot plate, stirring occasionally for 20 minutes. If, after 20 minutes, more than one layer is still present in the beaker, continue to heat and stir until only one layer remains.

4) Using hot mitts, remove the beaker from the hot plate and allow it to cool on the bench top.

5) Once the mixture is cool, add 50. mL of saturated sodium chloride to 250. mL beaker. Continuously stir the mixture for 5 minutes. This will cause the soap to precipitate from the mixture.

6) Cover the beaker with cheesecloth and pour the mixture into a 400. mL beaker. The crude soap will remain in the original 250. mL beaker. Pour the contents of the 400. mL beaker into the halogenated organic waste container.

7) Using a spatula, add some of your soap to a 50 mL beaker and dissolve it in deionized water.

8) Pour your soap solution into a medium-sized test tube. Using pH paper, determine the pH of the soap.

9) Cover the test tube with a rubber stopper and vigorously shake it. Record the foaming test results in the data table.

10) Spread a solid fat (such as vegetable shortening) onto a watch glass. Then, wash this off with your soap solution and record the results. Clean and dry the watch glass and save it for step 14.

11) Dispose of your soap and solution into the halogenated organic waste container or as directed by your instructor.

12) Add 5 mL of commercial liquid soap and 5 mL of deionized water to a medium size test tube. Stir the mixture for 2 minutes. Using pH paper, determine the pH.

13) Cover the test tube with a rubber stopper and vigorously shake it. Record the foaming test results in the data table.

14) Spread a solid fat (such as vegetable shortening) onto a watch glass. Then, wash this off with the commercial soap solution and record the results.

15) Thoroughly clean your work area and return all glassware/equipment to the appropriate place when finished.

PRE-LAB QUESTIONS Name _____

1) In your own words, what is soap? How is soap used as a cleansing agent?

2) What organic functional group is present in a triglyceride?

3) Draw the structure of glycerol. What organic functional group is present in glycerol?

4) In your own words, describe what happens during the saponification reaction.

DATA AND OBSERVATIONS

Oil used in Soap Synthesis:

Write observations for each of the following steps in the synthesis of soap:

Step 2: Add 10 mL of ethanol and 15 mL of 3 M NaOH to the 250 mL beaker. Stir the resulting mixture with a stirring rod for 2 minutes.

Step 3: Gently heat the mixture on a hot plate, stirring occasionally for 20 minutes. If, after 20 minutes, more than one layer is still present in the beaker, continue to heat and stir until only one layer remains.

Step 5: Once the mixture is cool, add 50 mL of saturated sodium chloride to the 250 mL beaker. Continuously stir the mixture for 5 minutes. This will cause the soap to precipitate from the mixture.

Step 6: Cover the beaker with cheesecloth and pour the mixture into a 400 mL beaker. The crude soap will remain in the original 250 mL beaker.

Testing Synthesized Soap and Commercial Liquid Soap

Test	Synthesized soap	Commercial soap
pH test (record pH)		
Foam test (record observations)		
Cleaning of oil off watch glass (record observations)		

POST-LAB QUESTIONS

1) In the safety precautions section, it was advised not to use synthesized soap on your body. Explain why.

2) Briefly describe how your synthesized soap solution compares with the commercial soap solution regarding the pH, foaming, and cleaning ability.

3) If a different oil is used to synthesize the soap, would you expect the results of the pH test, foaming test, and cleansing test to be different?

4) In this experiment, you synthesized crude soap. What additional steps would need to be taken to commercialize the soap?

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Lab 11: ANTACID ANALYSIS- INTRODUCTION TO NEUTRALIZATION REACTIONS

PURPOSE

The purpose of this experiment is to:

• Perform a microscale acid-base neutralization reaction.

• Observe the behavior of an indicator in acidic and basic solutions.

• Determine the effectiveness of a name brand and generic brand antacid in relation to each other.

INTRODUCTION

Neutralization occurs when an equal amount of acid reacts with an equal amount of base to produce water and a salt, as shown below:

$HCl\ (aq) + NaOH\ (aq) \rightarrow H_2O\ (l) + NaCl\ (aq)$

Recall from previous lectures that we defined an acid as a substance that produces hydrogen ions when dissolved in water. Bases produce hydroxide ions when dissolved in water. In future chemistry classes, you will go into more detail about these reactions and the concept of neutralization. In this experiment, we will be applying the concept of acid-base neutralization to antacids, substances that counteract excess acid (HCl) in the stomach to relieve indigestion and heartburn. The active ingredient in many antacids is calcium carbonate, which reacts with excess HCl, as follows:

$CaCO_3\ (s) + 2\ HCl\ (aq) \rightarrow CaCl_2\ (aq) + CO_2\ (g) + H_2O\ (l)$

First, the antacid will be dissolved in HCl solution and react according to the above equation. This process will amount to consuming an antacid tablet to relieve an upset stomach. However, after the reaction is complete, excess HCl will remain in solution. The amount of HCl remaining will be determined by reacting it with NaOH in the presence of phenolphthalein, an indicator that is colorless in acidic solution and pink in basic solutions. The less HCl remaining in solution (or the fewer drops of NaOH required to complete neutralization) indicates the greater effectiveness of the antacid. Consider the following example:

An antacid was dissolved in HCl solution, and 20 drops of this solution were then transferred to a well plate. Two drops of phenolphthalein indicator were added to the well, resulting in a colorless solution. NaOH was then added drop wise to the well. After the addition of five drops of NaOH, the solution remained a faint pink color. Based on this information:

1) It took 5 drops of NaOH to react with the excess acid.

2) This means the antacid neutralized 15 drops of the acid (20-5).

When comparing two antacids, the one that requires fewer drops of NaOH to complete neutralization will be identified as the more effective antacid. During this experiment, you will be comparing the effectiveness of a name-brand antacid with a generic antacid.

SAFETY PRECAUTIONS

1) Always wear chemical splash goggles while working with chemicals in this experiment.

2) Handle all chemicals with care.

3) Follow all the clean-up instructions as provided by your instructor.

EQUIPMENT* AND CHEMICALS NEEDED

• Mortar and pestle

• Three disposable plastic droppers

• Well plate

• 50 mL beaker

• 600 mL beaker

• Stirring rod

• Two 250 mL Erlenmeyer flasks

• Name brand antacid

• Generic brand antacid

• 0.5 M HCl

• Phenolphthalein indicator

• 0.5 M NaOH

• Non-halogenated organic waste container

• Inorganic waste container

* Images of equipment needed in this lab can be found in the appendix (the equipment may differ or be subject to changes; follow your instructors' directions).

EXPERIMENTAL PROCEDURE

1) Before beginning the experiment, prepare the relieved upset stomach solutions. It would be best if the instructor or lab assistant did this. Using a mortar and pestle, crush a name-brand antacid tablet (or tablets) amounting to 500 mg of active ingredient. Transfer the crushed tablet to a 250 mL Erlenmeyer flask and add 30 mL of 0.5 M HCl. Make sure the antacid tablet is dissolved as best as possible. This solution can then be transferred to a reagent bottle labeled "name-brand antacid solution."

2) Repeat step 1 using a generic brand antacid tablet. The solution can then be transferred to a reagent bottle labeled "generic antacid solution."

3) Obtain a well plate. Using a disposable plastic dropper, transfer 20 drops of the name-brand antacid solution to three wells. (Note: Be sure that the number of drops transferred to each well is as accurate as possible. It is best to transfer the drops slowly, one at a time, while holding the dropper straight up and not angled. You may also want to count aloud as you add the drops.)

4) Add 2 drops of phenolphthalein indicator to each well.

5) Quarter-fill a 50 mL beaker with 0.5 M NaOH solution. Using a disposable plastic dropper (the same size as the one used in Step 3), add the NaOH solution drop wise to the first well. Use a stirring rod to stir the solution between each drop added. Continue this process until a faint pink color remains without disappearing. Record, in the data table, the number of drops of NaOH required to complete neutralization.

6) Repeat Step 5 with the remaining two wells.

7) Repeat Steps 3-6 with the generic brand of the antacid solution.

8) Pour the contents of the well plate into a 600 mL beaker and pour the solution in the beaker into the non-halogenated organic waste container.

9) Pour the excess NaOH into the inorganic waste container.

10) Dispose of the used droppers into the appropriate container or as directed by your instructor.

11) Clean your work area and all glassware before leaving the lab and return all equipment to the appropriate place.

PRE-LAB QUESTIONS Name _____

1) Briefly explain how antacid is used to relieve an upset stomach.

2) What is the purpose of using phenolphthalein indicator in this experiment?

3) 20 drops of a relieved upset stomach solution were transferred into a well plate. Two drops of phenolphthalein indicator were added. It was shown that 8 drops of NaOH were required to turn the solution to a permanent faint pink color. How many drops of acid were neutralized by the antacid?

4) Imagine the experiment described in pre-lab question 3 was repeated using another antacid. This antacid required 6 drops of NaOH to complete neutralization. Based on the results of this experiment, would this antacid be more effective or less effective than the antacid used in question 3? Explain.

DATA AND OBSERVATIONS

Name-brand antacid used:

Active ingredient:

Name brand Antacid	**Trial 1**	**Trail 2**	**Trial 3**
Drops of relieved upset stomach solution added to well	20	20	20
Drops of NaOH required to complete neutralization			
Drops of acid neutralized by antacid			

Average drops of acid neutralized by name-brand Antacid:

_____

Generic brand Antacid:

Active ingredient:

Generic brand Antacid	**Trial 1**	**Trial 2**	**Trial 3**
Drops of relieved upset stomach solution added to well	20	20	20
Drops of NaOH required to complete neutralization			
Drops of acid neutralized by antacid			

Average drops of acid neutralized by generic antacid:

POST LAB QUESTIONS

1) Based on the results of this experiment, which antacid was more effective? Explain.

2) How do your results compare with those of your classmates?

3) What are some sources of error in this experiment?

4) How accurate do you feel this experiment was in determining the effectiveness of the two antacid brands? Explain.

5) Look up the cost of each antacid. Based on the cost and results of this experiment, which antacid do you feel is a better buy?

6) Were the active ingredients in each antacid the same? If yes, why would one antacid show different results than the other?

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LAB 12: INTRODUCTION TO ENDOTHERMIC AND EXOTHERMIC REACTIONS

PURPOSE

The purpose of this experiment is to

• Observe various physical and chemical processes and record observations.

• Determine the temperature change of a process.

• Predict whether a process is endothermic or exothermic.

INTRODUCTION

As you have seen throughout the semester, a process can be physical if it produces different forms of the same material or chemical if a new substance is formed. Physical and chemical changes often occur with the transfer of heat energy between the system and surroundings. The system is defined as the chemicals (reactants and products) involved in the process. Everything else, including the glassware containing the chemicals, the lab bench, and those observing the process, constitutes the surroundings. We always discuss heat transfer with respect to the system. A process in which the system absorbs heat energy is called endothermic. In an exothermic process, the system releases heat energy.

Consider the following reaction:

$$CH_4\,(g) + 2\,O_2\,(g) \rightarrow CO_2\,(g) + 2\,H_2O\,(g)$$

This is the combustion of methane (CH_4), which is used as the gas in some home stoves. This process is exothermic, as it releases heat energy, increasing the temperature of the immediate surroundings.

Next, consider an instant cold pack. When the chemicals inside mix, the system absorbs heat energy, causing a decrease in the temperature of the immediate surroundings, such as the part of the body on which the pack is placed. This is an example of an endothermic reaction.

Physical and chemical changes can be either endothermic or exothermic. In this experiment, you observe and record temperature changes in six processes. You will predict whether the process is endothermic or exothermic based on the temperature change.

SAFETY PRECAUTIONS

1) Always wear chemical splash goggles while working with chemicals in this experiment.

2) Gloves are provided if you wish to wear them.

3) Handle all chemicals carefully and read all labels on reagent bottles to ensure you mix the correct chemicals.

4) Dispose of all waste as directed by your instructor.

5) Clean your work area and return all the chemicals and equipment to the appropriate place when finished.

CHEMICALS and EQUIPMENT NEEDED

• Medium size test tube

• 10 mL graduated cylinder

• 100 mL graduated cylinder

• Spatula

• 50 mL beaker

• 600 mL beaker

• Celsius thermometer

• Coffee cup

• Solid ammonium nitrate

• Solid calcium chloride

• 1 M HCl

- 1 M NaOH
- Water
- Isopropyl alcohol
- Critic acid
- Solid baking soda
- Mg metal
- Non-halogenated organic waste container
- Inorganic waste container.

EXPERIMENTAL PROCEDURE

1) Add 5 mL of isopropyl alcohol to a medium-sized test tube. Place a thermometer in the test tube containing the isopropyl alcohol and record the initial temperature. (When recording temperature, wait for the thermometer reading to stabilize.) Remove the thermometer from the test tube and hold it in the air. You will notice the temperature reading either increases or decreases. Once the temperature reading reaches a maximum or minimum value, record this as the final temperature. Calculate the temperature change by subtracting the initial temperature from the final temperature. Pour the isopropyl alcohol into the non-halogenated organic waste container.

2) Add 20 mL of water to a coffee cup. Record the initial temperature of the water. Using a spatula, add a scoop of solid ammonium nitrate to the water. Gently stir the solution with the thermometer for approximately 30-45 seconds, and then record the final temperature of the solution. Pour the contents of the coffee cup into the inorganic waste container. Clean and dry the coffee cup and other equipment, then set these items aside for steps 3 and 4.

3) Repeat step 2 using solid calcium chloride instead of ammonium chloride.

4) Add 10 mL of 1 M HCl to the coffee cup. Record the initial temperature. In a 50 mL beaker, obtain 10 mL of 1 M NaOH. Pour the NaOH solution into the coffee cup containing the HCl solution and gently stir with the thermometer for approximately 30 seconds. Record the final temperature of the resulting solution. Pour the contents of the coffee cup into the sink, rinsing with plenty of water. Clean and dry the coffee cup and other equipment, then set these items aside for step 5.

5) Add 20 mL of citric acid to the coffee cup. Place the coffee cup in a 600 mL beaker. Record the initial temperature. Add a scoop of baking soda to the citric acid and record the final temperature. Once the final temperature is reached and the reaction is complete, pour the contents of the coffee cup (and 600 mL beaker) into the inorganic waste container. Clean and dry the coffee cup and other equipment, then set these items aside for step 6.

6) Add 20 mL of 1 M HCl to the coffee cup. Place the coffee cup in a 600 mL beaker. Record the initial temperature. Add (approximately) a 10-15 cm strip of Mg metal to the HCl and record the final temperature. Once the final temperature is reached and the reaction is complete, pour the contents of the coffee cup (and 600 mL beaker) into the inorganic waste container. Clean and dry the coffee cup and other equipment. The coffee cup may now be discarded and other equipment returned to the appropriate place.

7) Clean your work area before leaving the lab.

PRE-LAB QUESTIONS Name _____

1) In your own words, define the following terms:

System:

Surroundings:

Temperature:

Endothermic process:

Exothermic process:

2) What is one way to tell if a process is endothermic or exothermic?

3) When a large scoop of magnesium sulfate is dissolved in a beaker of water at 25 °C, the temperature of the solution rises to 30 °C. Based on this observation, would you predict the dissolution of magnesium sulfate in water to be endothermic or exothermic? Explain.

4) When ice sits at room temperature, it will eventually melt. In this instance, would heat be absorbed or released by the ice? Would this process be endothermic or exothermic?

DATA AND CALCULATIONS

Complete the following table.

Process	Observations of Process	Initial Temperature	Final Temperature	Temperature Change	Endothermic or exothermic?
Evaporation of Isopropyl Alcohol					
Dissolution of Ammonium Nitrate in water					
Dissolution of Calcium Chloride in water					
Reaction of Hydrochloric Acid and Sodium Hydroxide					
Reaction of Citric acid and Baking Soda					
Reaction of Magnesium and Hydrochloric acid					

POST LAB QUESTIONS

1) What was the biggest takeaway from this activity?

2) Generally, if a process is endothermic in one direction, it is exothermic in the opposite direction. Based on your results from step 1 (evaporation of isopropyl alcohol), would you expect condensation (a physical change in which a gas is converted into a liquid) to be endothermic or exothermic? Explain.

3) Predict whether the processes described below would be endothermic or exothermic.

Part A: When placed in a freezer, water is converted into ice.

Part B: Sodium metal reacts explosively when placed in water.

Part C: When heated, ammonium chloride sublimes (a physical change in which a substance is converted from a solid into a gas).

Part D: An instant hot pack is placed on an athlete's leg to relieve pain.

4) Give an example of an endothermic and exothermic process (not described in this experiment) that can be seen in everyday life.

5) Initially, when entering a sauna, you may experience a sharp elevation in temperature. Over time, your body will begin to cool before it heats up again. Using what you learned in this experiment, explain why this happens.

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CHAPTER OVERVIEW

13: Appendix

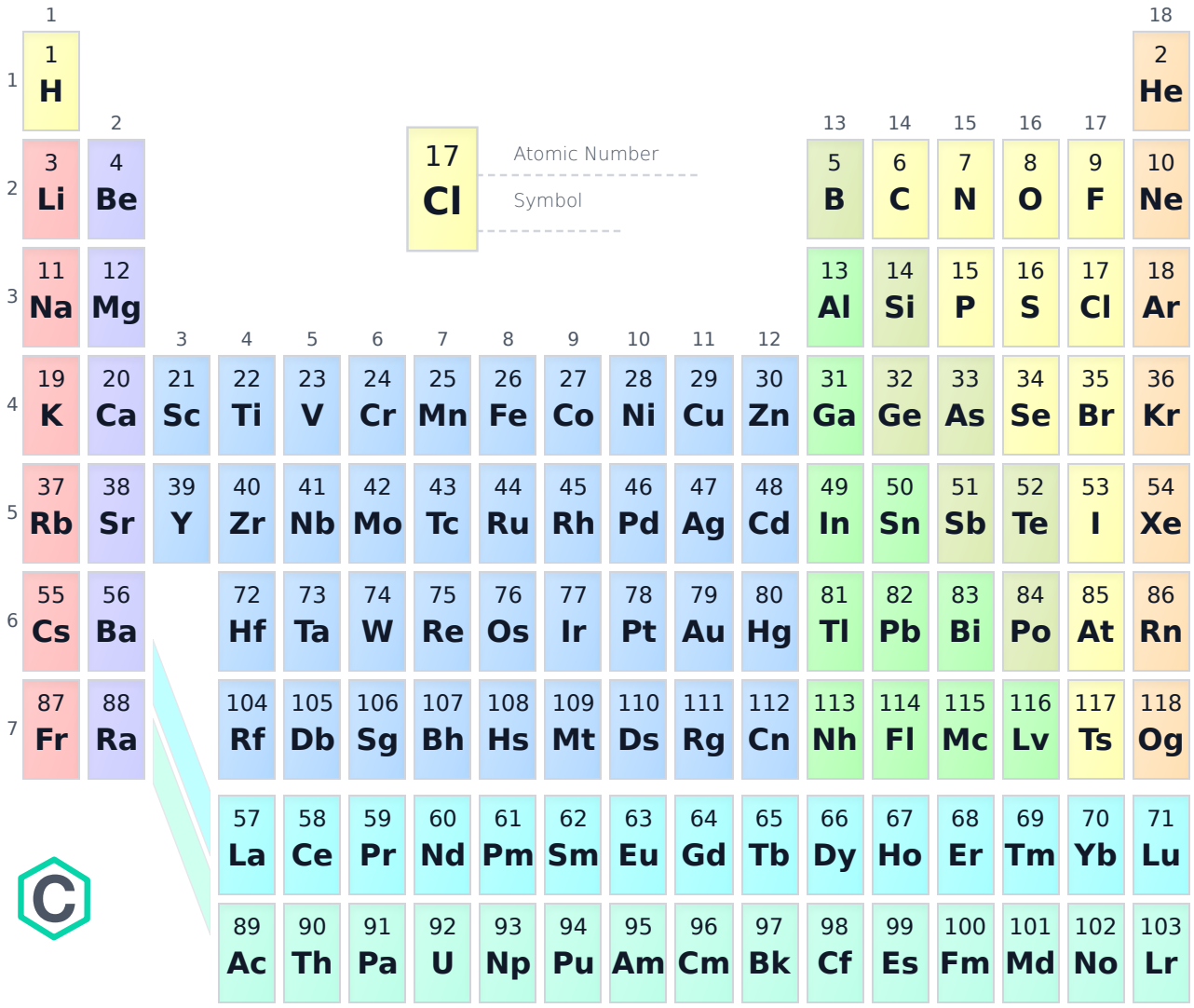
13.1: PERIODIC TABLE
13.2: Images of Equipment Needed for Lab

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13.1: PERIODIC TABLE

PUBCHEM > PERIODIC TABLE

Periodic Table of Elements

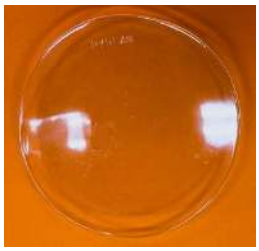


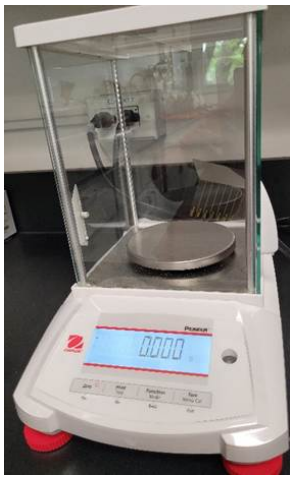
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13.2: Images of Equipment Needed for Lab

Appendix — Equipment Needed

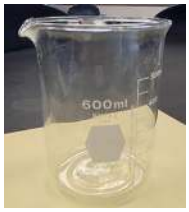
*Images of Equipment Needed for **Lab 1**

Name	Images of Equipment Needed
Centimeter Ruler	 or 
Watch Glass	
Evaporating Dish	
a) Large Test Tube b) Medium Test Tube	a) b)  
Celsius Thermometer	

Milligram Balance	
Glass Stirring Rod	
10.0 ml Graduated Cylinder	
100.0 ml Graduated Cylinder	
Various Rectangular Blocks	

125 ml Erlenmeyer Flask	

*Images of Equipment Needed for **Lab 2**

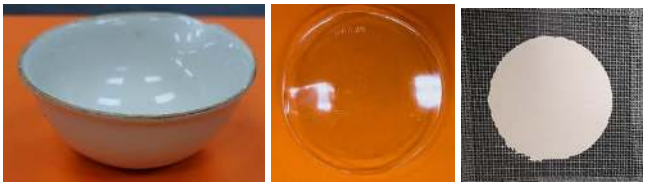
Name	Images of Equipment Needed
100.0 mL Beaker	
600.0 mL Beaker	
Hot Plate	
100.0 mL Graduated Cylinder	

10.0 mL Graduated Cylinder	
Milligram Balance	
Glass Stirring Rod	
Celsius Thermometer	

*Images of Equipment Needed for **Lab 3**



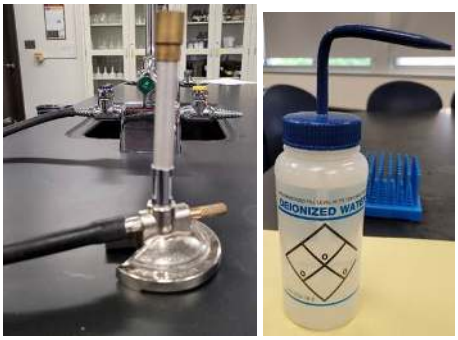
Milligram Balance. Hot Plate 50.0 ml Beaker Glass Stirring Rod



Evaporating Dish Watch Glass Wire Gauze Pad



Beaker Tongs Spatula Ring Stand Ring Clamp



Bunsen Burner Deionized Water in Wash Bottle

*Images of Equipment Needed for **Lab 4**



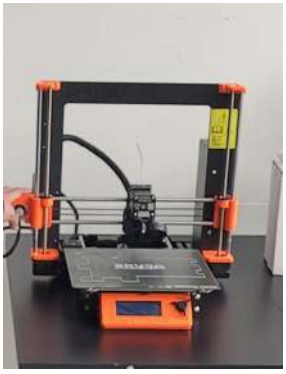
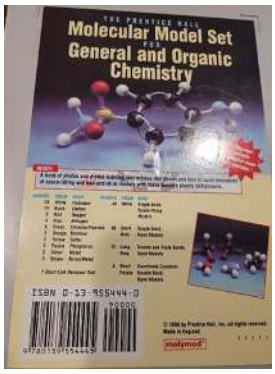
Well Plate Nichrome Wire Bunsen Burner



Matches Lighter Striker 50 ml Beaker

* Images of equipment needed in this lab can be found in the appendix (the equipment may differ slightly or be subject to changes; follow your instructors' directions).

*Images of Equipment Needed for **Lab 5**

3-D Printer Molecular Model Kit

*Images of Equipment Needed for **Lab 6**

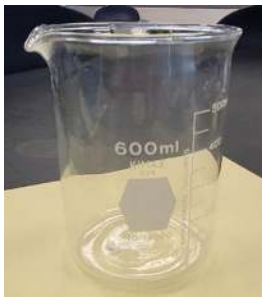




Well Plate Disposable Plastic Droppers Deionized Water

*Images of Equipment Needed for **Lab 7**





Bunsen Burner Well Plate 600.0 ml Beaker







Matches Lighter Striker 50 ml Beaker



Spatula Scissors Test Tube Holder With 3 Test Tubes Test Tube Holder

*Images of Equipment Needed for **Lab 8**



Well Plate Ph Meter Deionized Water



Red And Blue Litmus Paper Ph Paper Kimwipes



Glass Stirring Rod Red Cabbage Indicator

*Images of Equipment Needed for **Lab 9**



Four Medium Size Test Tubes and Test Tube Rack

*Images of Equipment Needed for **Lab 10**





100. mL Graduated Cylinder Deionized Water Stirring Rod



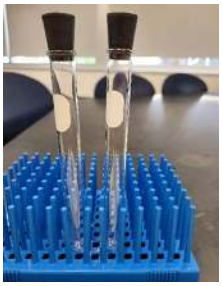


50.0 mL Beaker 250.0 mL Beaker 400.0 mL Beaker





Ph Paper Hot Plate




Two Medium Size Test Tubes with Rubber Stoppers Spatula

*Images Of Equipment Needed for **Lab 11**

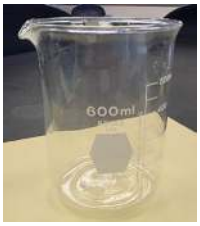



Mortar And Pestle Three Disposable Plastic Droppers





Well Plate Stirring Rod 250.0 ml Erlenmeyer Flask

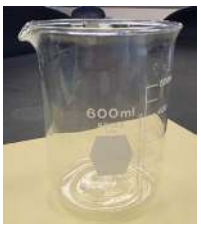
50.0 mL Beaker 600.0 mL Beaker

*Images of Equipment Needed for **Lab 12**





Medium Size Test Tube 100.0 mL Graduated Cylinder 10.0 mL Graduated Cylinder



50.0 mL Beaker 600.0 mL Beaker Spatula



Celsius Thermometer

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