Chemistry 30
Lab Manual

#_________

Lab Safety

Safety is essential in a science lab, due to the serious risks that can occur from mishandled chemicals, glassware and other material. It is vital that all students are aware of the lab's safety equipment, in particular where it is stored and how to use it. Additionally, students need to act in a conscientious and cautious manner when conducting an experiment or working in the lab.

Safety Equipment

Eyewash Station

An eyewash is used to flush out one or both eyes if they have been contacted with a chemical or abrasive substance. In serious cases, flushing should occur immediately for at least ten minutes (or more, depending on the nature of the substance) using a water faucet.

Safety Shower

The safety shower is used for two purposes: for major chemical spills onto a person's body or if a person's clothing has caught fire. If a chemical has spilled on clothing, it is important that contaminated clothing is removed once in the safety shower, to prevent further injury to the skin.

First Aid Kit

The first aid kit contains a number of items for dealing with minor cuts, burns and scrapes. Inform Ms. Hayduk of any injuries incurred during a lab, regardless of how severe they are.

Fire Extinguisher

Fire extinguishers should be used for putting out small to medium sized fires that are uncontrolled. Before using a fire extinguisher, it is important to ensure it is appropriate for the type of fire. An ABC fire extinguisher, or an all-purpose fire extinguisher, is the most common, because it will put out the most common types of fire – ordinary combustibles, flammable liquids and electrical fires.

Spill Kit

A spill kit contains a number of absorbent substances that can be used to neutralize and safety clean up chemical spills in the lab. A serious chemical spill includes substances that cannot be handled safely (highly corrosive) or an unknown mixture of chemicals. If a serious chemical spill occurs, find Ms. Hayduk immediately; do not attempt to clean up the spill. Ensure that other students remain clear of the area.

Personal Protective Equipment

Personal protective equipment refers to all clothing, helmets and eyewear designed to protect the wearer from injury. Prior to any lab, Ms. Hayduk will inform you which equipment is required to be worn during the activity. Students must wear all of this equipment for the duration of the lab, even if they have completed the activity, provided they are still in the lab area.

Specific Emergency Procedures

Fire

- If the fire is small, use the appropriate fire extinguisher on the fire or extinguish it with a lid or blanket.
- To use a fire extinguisher, follow the acronym PASS: pull out the pin, aim the nozzle at the base of the fire, squeeze the trigger and sweep the spray along the base of the fire until it is extinguished.

- If the fire is large and cannot be controlled, leave the room immediately and pull the fire alarm. All students should file out of the building in a calm manner to the designated meeting spot outside. The last student out of the room should shut the door to impede spread of the fire.
- If a fire alarm goes off during an experiment, students should shut off all gas and heat sources before exiting the lab.

Spill

- If the spill is a harmless substance (e.g. water, vinegar), clean it up immediately with paper towel.
- If the spill is a more hazardous substance, inform Ms. Hayduk immediately. She will clean the spill with the spill kit. If possible, block the spill from spreading and remove any books, bags or personal items from the area.
- If more than one hazardous chemical spills in the same area, especially if they are of unknown composition, tell Ms. Hayduk and evacuate the room immediately. She will assess the danger and take steps to decontaminate the area

Injury

- For minor injuries, use the first aid kit. Make sure to clean any cuts or scrapes before applying a bandage.
- For serious injuries, inform Ms. Hayduk immediately and use a cell phone or the office phone to call 911. Make sure to tell EMS if the injury was caused by contact with a chemical (or broken glass contaminated with chemical).

Laboratory Safety Procedures

This list of safety procedures is general, and does not cover all aspects of safety in the lab. It is important that students use common sense and caution when working in the science lab, and ask for help when instructions or procedures are unclear.

1. Behave in a calm, professional, responsible manner at all times.
2. No food in the lab at any time.
    - Beverages are allowed provided they are in re-sealable containers.
    - Never eat any materials being used for experiments.
3. Use the appropriate personal protective equipment for the activity you (or others) are performing.
    - Do not remove your PPE until you are instructed to do so by the teacher.
4. Keep yourself, your equipment and your workstation clean before, during and after the lab.
    - Handle equipment with care.
    - Wash glassware thoroughly with soap and water.
    - After handling chemicals, wash hands thoroughly with soap and water.
    - Keep aisles and table tops clear of bags and books.
5. Dispose of materials properly.
    - Do not dump any chemicals down the drain unless instructed to by the teacher.
    - Do not put any solid material in the drains.
    - Sharp materials (e.g. dissection pins, broken glass) should be disposed of in the proper waste container – never in the garbage can.
6. Do not touch any chemicals or equipment you have not been instructed to handle.
    - Do not smell or taste chemicals.

- Do not try any unauthorized experiments.
- Do not enter the science storage room.

7. Never leave your lab station unattended.
8. Dress appropriately.
    - Tie back long hair.
    - Avoid wearing loose or dangling clothes or jewelry around chemicals or open flames.
    - Wear closed-toed shoes.
9. Report any accident or incident immediately.

Students who do not follow these safety procedures will not be permitted in the science lab.

WHMIS

WHMIS stands for Workplace Hazardous Material Information System. It is a program designed to protect workers (e.g. students and teachers) who are handling chemicals on a regular basis. There are three key elements to WHMIS:

1. Labels,
2. Safety data sheets; and,
3. Education and training.

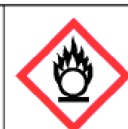
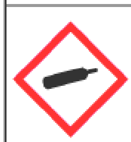
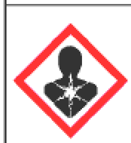
As a student, your primary concern will be with <u>labels</u> and <u>safety data sheets</u> (SDS).

<u>Labels</u>

The purpose of a WHMIS label is to identify the product as controlled and alert the user to the hazards and safe handling procedures of the product. The label provides a summary of the important information about the substance.

As a student, your responsibility is to ensure that <u>any</u> chemicals left in the lab in beakers, flasks or test tubes are labelled with your name, a date and some indication of what is included in the container. You can do this with marker or wax pencil straight on the glassware, or with a paper label firmly attached.

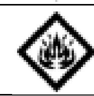
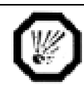
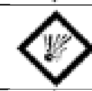
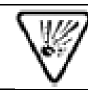
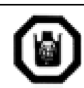
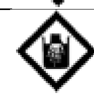
<u>Hazard Symbols</u>

	**Exploding bomb** (for explosion or reactivity hazards)		**Flame** (for fire hazards)		**Flame over circle** (for oxidizing hazards)
	**Gas cylinder** (for gases under pressure)		**Corrosion** (for corrosive damage to metals, as well as skin, eyes)		**Skull and Crossbones** (can cause death or toxicity with short exposure to small amounts)
	**Health hazard** (may cause or suspected of causing serious health effects)		**Exclamation mark** (may cause less serious health effects or damage the ozone layer*)		**Environment*** (may cause damage to the aquatic environment)
	**Biohazardous Infectious Materials** (for organisms or toxins that can cause diseases in people or animals)				

* The GHS system also defines an Environmental hazards group. This group (and its classes) was not adopted in WHMIS 2015. However, you may see the environmental classes listed on labels and Safety Data Sheets (SDSs). Including information about environmental hazards is allowed by WHMIS 2015.

<u>International Hazard Symbols</u>

Not all products and substances are controlled by WHMIS, so they may not have WHMIS labels or symbols. These are other symbols you may see on other household products. The border of the symbol represents the level of danger, and the symbol inside represents the specific hazard. "Danger", shown with an octagon, is the biggest threat. "Caution", given by an upside down triangle, is a smaller threat but should still be considered dangerous!

	Danger	**Warning**	**Caution**
Poison			
Flammable			
Explosive			
Corrosive			

<u>Safety Data Sheets</u>

Safety data sheets (SDS) are used to give more detailed information about the product than the information on the WHMIS label. The information includes:

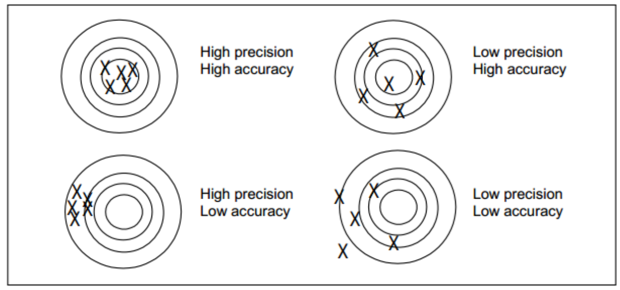
1. Chemical Identification (name, uses, restrictions, supplier information)
2. Hazards (symbol and specific statements)
3. Ingredients and Composition
4. First Aid Measures
5. Fire-Fighting Measures
6. Accidental Release Measures
7. Handling and Storage
8. Exposure Controls and Personal Protection
9. Physical and Chemical Properties
10. Reactivity
11. Toxicological Information
12. Ecological Information (optional)
13. Disposal Considerations (optional)
14. Regulatory Information (optional)
15. Date of Revisions

SDS are available online. It is expected that all students will review the SDS for any chemicals they have not previously handled prior to every lab so they know the safety hazards and the personal protective equipment they should wear.

Experimental Error and Measurements

Accuracy and Precision

Experimental error is the difference between a measurement and the true value, or between two measured values. The amount of error is determined by accuracy and precision.



Accuracy tells how close a measured value is to the theoretical, accepted or "true" value. If this value is unknown, then the accuracy of a measurement cannot be determined.

Precision measures how close two or more measurements are to each other. Precision can also be called "repeatability" or "reproducibility". A measurement that is highly precise, or highly reproducible, will give values that are very close.

Experimental Error

Experimental errors are **unavoidable** influences in performing an experiment or making a measurement that affect the accuracy of the results. "Human errors" are not considered sources of experimental error, since they can be eliminated by careful technique and repeating the procedure if mistakes are made.

Systematic errors, or bias, are a type of experimental error that affect accuracy of a measurement. They are generally caused by flaws in equipment, and are generally difficult to detect. These errors are "one-sided", meaning they will usually give results that are close to each other, but are not close to the true value. Systematic errors can be caused by uncalibrated measuring instruments and flaws in instrument construction.

Random errors affect the precision of a measurement. These errors are "two-sided" because they can fluctuate above or below the true value in repeated trials. Random errors can be reduced by repeating the procedure and taking average values or by using better quality instruments. Common sources of random errors include estimating a measurement that is between graduations on an instrument or recording a value that fluctuates during the reading.

GENERAL Sources of Error

Random error (inconsistencies) in reading measurements	Residue from pouring from one container to another
Contaminants on equipment or in chemicals	Lots of measurements that increase uncertainty in calculations
Calibration of measuring tools (systematic error)	Subjectivity of reading measurements at eye-level (parallax error)
Impurities in chemicals	Reaction does not go to completion
Not enough trials or data	Volume or volume changes are too small to read easily
Heat loss to the environment	Unexpected side reactions

Calculating Experimental Error

Accuracy of Equipment

All measuring equipment has precision depending on the smallest unit of measurement on the instrument.

- Digital Devices:
  - Give the exact reading on the device.
  - The error is half of the last decimal place.

  Example: On a scale with one decimal place, a measurement could be 12.6 g ±0.05 g. This means the mass is somewhere in the range of 12.55 g to 12.65 g.
- Analog Devices:
  - Read to one-half of the smallest graduation.
  - The error is one-half of one graduation.

  Example: For example, a ruler that has graduations of 1 mm must have a measurement that ends in .0 mm or .5 mm, and that length is precise to ±0.5 mm .

Digital equipment and some chemistry glassware generally has a specified accuracy that is written on the instrument. With glassware, some equipment is deliberately very precise (e.g. volumetric flasks), while others are not really intended to be used for measurements (e.g. beakers).

Percent Error

Percent error is the difference in accuracy between a measured, or experimental, value and the true, or accepted, value. It is calculated as follows:

$$\%\,Error = \frac{|Experimental - Accepted|}{Accepted} \times 100$$

The vertical lines on the top of the equation indicates absolute value, which means that negative signs are ignored. If you get a negative answer, record the value without the negative sign.

Percent error can only be used if the true value is known, or can be calculated.

Percent Yield

Percent yield indicates how much product was actually created based on the "ideal", theoretical amount that could be created if the reaction went perfectly. The equation used is:

$$\%yield = \frac{actual}{theoretical} \times 100$$

Percent Difference

Percent difference is used in place of percent error when the true value is unknown. It is used to find the precision of repeated measurements (experimental values, E). The equation used is:

$$\%\,Difference = \frac{|E_1 - E_2|}{\left(\frac{E_1 + E_2}{2}\right)} \times 100$$

Unit Conversions and Scientific Notation

Metric Unit Conversions

To convert between metric units in the same "category", use the staircase method:

Tera	Giga	Mega	Kilo	Hecto	Deca	**BASE**	Deci	Centi	Milli	Micro	Nano	Pico
T	G	M	k	h	da		d	c	m	µ	n	p
10^{12}	10^{9}	10^{6}	1000	100	10	**1**	0.1	0.01	0.001	10^{-6}	10^{-9}	10^{-12}

→

To move to a smaller unit, **multiply** by the number of steps it takes to get to the right prefix.
For example, 5 km = (5×10000) cm = 50000 cm, since it takes five steps to get from kilo to centi.

←

To move to a larger unit, **divide** by the number of steps it takes to get to the right prefix.
For example, 30 mg = (30÷1000) g = 0.03 g, since it takes three steps to get from milli to "base".

Scientific Notation

Scientific notation is used for very large or very small numbers, which are common in science! It is written as a product (multiplication) between a number between 1 and 10 and a power of 10.

3.45×10^{5} is a big number. It has a positive exponent.

2.31×10^{-4} is a small number. It has a negative exponent.

Many scientific calculators have a button that allows the user to enter numbers in scientific notation. It may be "EXP", "$\times 10^{x}$", "EE" or "$y^{1/x}$". It is important that students learn to use this function on their own calculator, to make calculations with scientific notation easier.

To convert to scientific notation:

1. Create a number between 1 and 10 by moving the decimal (for whole numbers, it is after the last digit) to the left. There should be <u>only one non-zero number</u> before the decimal.
2. Count the number of spaces the decimal moves to determine the exponent on the 10.
    a. If the decimal moves <u>left</u>, the exponent is <u>positive</u>.
    b. If the decimal moves <u>right</u>, the exponent is <u>negative</u>.

Example: 3 346 000 000 = 3.346×10^{9}

The decimal moved from the right of the last zero nine places to the left, which gives the exponent of 9. This number has four significant digits, but more could be added by putting zeros or removed by rounding (e.g. 3.346 to 3.35).

To convert to standard form:

1. Multiply the two terms (the decimal between 1 and 10 and the power of 10) together; to ensure you are multiplying or dividing properly. Ask, "<u>Is it reasonable?</u>" after doing a calculation. If you get an answer of 1000 km in 1 m, and you know kilometres are much bigger than metres, you should recognize that the answer does not make sense and there was an error in the calculation.

Comparing Values of Scientific Notation

Numbers with <u>higher</u> exponents on the 10 are greater:

10 > 3 -2 > -5

4 > -1

For numbers with the same exponent, numbers with a larger decimal value are greater:

$$6.43 \times 10^5 > 2.17 \times 10^5$$

$$3 \times 10^{-2} > 1 \times 10^{-2}$$

Factor-Label Method

The factor-label method, also called dimensional analysis, is a problem solving method used for unit conversions and stoichiometric calculations. It is based on the idea of "cancelling" units to get the desired result. To get from one unit to another, conversion factors are used to change the units to the correct ones.

Example: How many inches are in 32 km?

The unit conversions here are:

1.6 km = 1 mile 1 mile = 5280 ft 1 ft = 12 inches

A grid is used to show the work – horizontal lines indicate "divide" (like in a fraction) and vertical lines indicate "multiply" (multiplication signs can also be used).

32 km	1 mile	5280 ft	12 inches
	1.6 km	1 mile	1 ft

Units that are on both the top and the bottom can be crossed out, like this:

32 ~~km~~	1 ~~mile~~	5280 ~~ft~~	12 inches
	1.6 ~~km~~	1 ~~mile~~	1 ~~ft~~

This leaves the answer in inches. To get the value, multiply the numbers on the top together, and divide by the numbers on the bottom:

= (32 × 1 × 5280 × 12) ÷ (1.6 × 1 × 1)

= 2027520 ÷ 1.6

= 1 267 200 inches

Remember to ALWAYS include units in the final answer!

Common Unit Conversions

Length	1 in = 2.54 cm 3.28 ft = 1 m 1 mile = 1.61 km	1 mile = 5280 ft 1 ft = 12 in
Mass	1 oz = 28.3 g 1 kg = 2.20 lb	1 lb = 16 oz
Volume	1 fl oz = 29.6 mL 1 cup = 237 mL	1 tbsp = 3 tsp 1 cup = 16 tbsp = 8 fl oz 1 US pint = 2 cups 1 US quart = 4 cups 1 US gallon = 16 cups
Temperature	$°C = (°F - 32) \times \frac{5}{9}$	$°F = \frac{9}{5} \times °C + 32$

Lab Assessment and Evaluation

Labs can be useful for many reasons.

1. Labs can be used to introduce a new topic. It can be helpful to refer to what you saw during a lab when learning the science behind a new concept or when doing new calculations.
2. Labs can be used to practice a new topic. This may include collecting experimental data and performing calculations with it, or visually confirming something you have learned.
3. Labs can be used to deepen understanding of a topic, by applying concepts to new situations.

Lab Goals

Each lab has *Essential Learning* goals listed. These points should help you to understand the purpose of the lab and to connect it with the appropriate concepts we cover in class.

Assessment

Students are encouraged to work with a partner to collect data during the lab, and with a small group to complete the discussion questions. These responses may be collected and assessed, depending on the lab. <u>Each student should have their own copy of the lab data, calculations and discussion questions</u>.

Students can expect to have questions related to all labs on quizzes and unit tests. These questions will be intended to assess understanding of the lab process and encourage students to make sense of lab data.

Evaluation

Lab questions on summative assessments like quizzes and tests will be given a point score (out of a certain number). Assignments handed in will be graded on a rubric based on the learning goals. Each assignment will be assigned a score from the following table.

Score	Abbreviation	Percentage
Advanced	A+	100%
Proficient	A	85%
Functional	B	70%
Developing	C	55%
Insufficient Evidence	IE	0%
Not Submitted	NHI	0%

An assignment will be given a grade of IE for the following reasons:

Reason	Solution
Missing significant parts of the assignment, or assignment has many major errors	Assignment must be redone and resubmitted, but will receive a late mark.
Assignment was not submitted by the late deadline	Student may choose to do an alternate assignment for that grade, but will receive a late mark.
Assignment was plagiarized (see below)	For the first offense, the assignment must be redone and resubmitted, will receive a late mark and will be given the grade of the original assignment. For subsequent infractions, the assignment will be given a mark of zero (R).

Proficiency Rubric

ADVANCED Fully meeting grade level expectations, with enriched understanding	**PROFICIENT** Fully meeting grade level expectations
Phrases and descriptors often associated with these levels…	
With great insight… *You show a deep and well-developed understanding...* • Consistently applies concepts to new situations • Extends ideas beyond and draws connections to real world situations • Thoroughly explains concepts and consistently demonstrates a deep understanding of the concept or skill • Demonstrates understanding of interconnected details by drawing complex connections to other concepts and models • Can teach the concept to other students • Works independently or works confidently and collaboratively in groups • Consistently uses established skill set for problem solving and selects the most appropriate tools/ strategies for the situation and can explain why (justify) this method was chosen • Solves problems in multiple ways • Describes and analyzes topics with detailed and insightful supporting evidence • Not only clearly understands the outcome but begins to assess the impacts and challenges on self, the class, society and the environment • Consistently reflective and solution-oriented • Engages in a variety of contexts and accurately uses new vocabulary • Problem solving is an integral part of your work and discussions with the teacher include reflective discussion on what worked or didn't and why *The teacher might hear phrases like:* These are the strategies/attempts/examples that I tried and here's what I learned... and why I used it... Here is how I justify my thinking/ reasoning/choices...	*On your own …* • You are becoming confident in applying the concept to new situations • You explain concepts with detail and consistently demonstrate an understanding of the concept or skill • You demonstrate an understanding of interconnected details by drawing connections • Key elements of the essential learning goals are included and demonstrated • Few refinements are needed • You work independently or collaboratively when required • You have an established skill set • You can analyze relevant information and convey your own thoughts and connections to the outcome/concept • You can ask strong questions and support analysis with relevant details and examples • When problem solving with a teacher, you come with questions and possible solutions. You are looking for a conversation which asks you questions to help you think through the assessment. The work submitted after the discussion is original to you (i.e. you have considered the discussion and made a decision that reflects how you can best demonstrate your knowledge.) *The teacher might hear phrases like* I'm wondering about this aspect. Here are a few ideas that I have... I think this is a possible solution because... I wonder if...
In general: Excellent job. Perfect. You totally got it, and you were able to explain it really well.	In general: You get it, but you made a few minor errors. You might have missed part of the explanation, or had a mistake in your explanation, reasoning or calculations.

<table>
<tr>
<th>FUNCTIONAL
Mostly meeting grade level expectations</th>
<th>DEVELOPING
Marginally meeting grade level expectations</th>
<th>INSUFFICIENT EVIDENCE
Not meeting grade level expectations</th>
</tr>
<tr>
<td>With assistance/help you can…
Demonstrate a basic understanding of the concept but need more practice to apply
Key elements of the concept are left out of the explanation.
Begin to examine, describe, or explain concepts or skill but more attention to detail is required to fully demonstrate understanding of the topic.
Show a developing skill set
When problem solving with a teacher, you are looking for answers to general questions. The work submitted after the discussion is improved based only on the teacher's ideas.

The teacher might hear phrases like:
I don't understand....
Do you think this is what I should say?
Is this right? Am I on the right track?
How do I do this?

You may need to improve on…
Making connections to texts, self and others need to be explored
Asking questions and supporting your analysis with details and examples
Seeking assistance only as needed and working toward increasing independence</td>
<td>Even with assistance you are struggling to...
Identify key elements of the concept
Demonstrate an understanding of the topic
Go beyond an emerging skill set
Interpret the context or meaning of the problem
The teacher might hear phrases like
I don't get it.
Where do I start?
I don't understand what this means.
I can't do this. This is too hard.

You probably need to…
Revisit this topic to develop your understanding of the concept
Pay more attention to detail
Talk with your teacher about strategies to try
Learn or relearn some things before you begin or redo this assessment</td>
<td>Even though you submitted an assignment, you have…
Misunderstood the intent of the assessment, or failed to respond based on the Essential Learning goals
Missed key elements of the assessment that are needed to demonstrate your understanding of the concept
Made major errors that make it difficult to determine your level of proficiency
Not completed the work independently or plagiarised your responses
You need to…
Talk with your teacher about the next steps you need to take</td>
</tr>
<tr>
<td>In general:
Mostly good, but you made some errors that show you might not completely understand. You might have missed an important part of the explanation.</td>
<td>In general:
Not so good – you made some big mistakes or your explanation does not show that you know what you're talking about. You had some good parts, but other parts weren't great.</td>
<td>See the table on why you may have received an IE!</td>
</tr>
</table>

Student-Directed Study: Materials Science

Essential Learning:

1. Design and carry out an experiment, including creating a testable question, conducting background research and collecting and analyzing data
2. Determine the suitability of a material for a specific application

Background Information:

This project is to be completed in groups of up to three students. The final project should be a full lab report that includes the following sections:

1. Introduction
    a. Purpose *(2-3 sentences)*
    What are you trying to figure out? This should be specific, and should be something you can actually perform an experiment to answer.
    b. Background Information *(2-3 pages, not including images)*
    Give some detailed information on the topic you choose for your project. Think about what a reader needs to know to understand your experiment and results, and include that information. All information in this section should include in-text citations where necessary.
2. Experimental *(1-2 pages)*
    a. Materials
    Make a complete list of materials you will need to do your testing.
    b. Procedure
    Make a numbered list of steps (in third person, like writing a recipe) that explains how to do the testing. Someone else should be able to follow these instructions independently and get the same results as you. For examples, check other labs in this lab manual!
3. Data and Observations *(1-2 pages)*
    Include all observations, calculations and data from the testing. Do not include any discussion or analysis here – just information.
4. Analysis *(2-3 pages, not including images)*
    In general, you are explaining the significance of your observations. Be sure to address your purpose. Include discussion about your findings, any sources of error, what your conclusions are and any next steps in testing, if you had more time or more resources.
5. Conclusion
    Write a concise summary that answers the question you asked in your purpose. Do not include any information that you didn't already discuss.
6. Works Cited
    Include ALL sources, in APA format. Be sure to also cite these sources within the text of your report whenever you use information from someone else, including images.

Materials and Procedure:

You will have access to all the materials and equipment available in the lab at school. If something is not available, please discuss with Ms. Hayduk to find a solution or alternative.

You will not be given any formal class time to complete this project, so it is expected that you will set up lab time to complete your testing. Please start testing early to ensure you leave yourself lots of time to accommodate for any issues that come up.

Choosing a Topic:

Identify a field of interest from the list below:

- Electronics
- Textiles
- Agriculture
- Food and food packaging
- Environment (water, air or soil management)
- Fuels and petrochemicals
- Polymers and plastics
- Consumer products (cosmetics, detergents)
- Pharmaceuticals
- Process chemicals (coatings, adhesives, sealants)

Once you have chosen an area of interest, consider an issue or product prevalent in that field, then develop a testable question from that field. The experiment does <u>not</u> need to be ground-breaking and original, but you must perform an experiment that you have developed or adapted to answer your question.

For example:
From consumer products: "Which type of hand sanitizer is most effective for killing bacteria?" From this, you would research the types of hand sanitizers, paying particular attention to the ingredients used to make them effective. Other useful information would be the societal and environmental risks and advantages to using hand sanitizers (instead of soap). From this you could perform an experiment in which several people's hands were swabbed unwashed and after using a variety of hand sanitizers. Each swab would be tested in Petri dishes with agar to determine bacterial growth.

Assessment:
This project will be marked on the <u>same scale</u> as the other labs in this course.

Lab 1. Science Skills and Error

Essential Learning:

1. Analyze how the choice of measuring tool affects the accuracy of measurements
2. Explain sources of random and systematic error
3. Recommend strategies for minimizing sources of error

Background Information:

All measurements have error. Error can be inherent in the process of taking the measurement and in the measuring device itself. It is important to note that error is used to refer to uncontrollable factors that affect the accuracy of the data in an experiment.

Systematic error is caused by a flaw in the system, either in the equipment or in the design of the experiment. It is generally skewed in one direction, either too low or too high. It cannot be fixed by repeated trials, since all measurements are affected the same way, but can be minimized by good quality measuring tools, proper calibration and thoughtful experimental design.

Random error is caused by minor inconsistences when measurements are taken. It can be introduced from environment, equipment or human limitations. Random error is present in all experiments, but can be minimized by repeated trials and accounting for assumptions that are made in the course of the experiment.

Materials:

- 50-mL beaker
- 50-mL graduated cylinder
- 50-mL volumetric flask
- Electronic balance

Procedure:

1. Find and record the mass of the dry beaker.
2. Use the beaker to measure, as accurately as possible, 50.0 mL of water.
3. Find and record the mass of the water and beaker.
4. Repeat Steps 1-3 with the graduated cylinder.
5. Repeat Steps 1-3 with the volumetric flask.
6. Dry and put away all equipment.

Calculations:

1. Use the measurements for each trial to determine density of water. Density is calculated using the formula $\rho = m/V$, and has units of g/mL.
2. Calculate percent error of each measurement based on the theoretical density of water (1.00 g/mL)

Discussion:

1. Suggest a purpose for each piece of glassware. When should they be used and when should they not be used?
2. Identify at least three sources of error in this experiment. For each, give a reasonable explanation for how it could be minimized to get more accurate results. Remember that sources of error are unavoidable and do not include mistakes you made during the process.

Lab 2. Intramolecular Forces

Essential Learning:

1. Investigate how intramolecular forces within a molecule affect its physical properties.

Background Information:

A chemical compound can be classified by the type of bonds holding the atoms together, also called intramolecular forces. Ionic bonds form when two atoms with large differences in electronegativity transfer electrons, forming positive and negative ions. These ions are then attracted together. Covalent (molecular) compounds contain atoms that have a lower electronegativity difference. These atoms share electrons, forming single, double or triple bonds. Polar covalent bonds have electrons that are unequally shared, resulting in dipoles that are slightly positive or negative. Non-polar covalent bonds have electrons that are fairly equally shared.

The type of intramolecular forces can contribute to the physical properties of the substance, including its melting and boiling point, its conductivity and its solubility in water. Even the physical appearance of a substance depends on the type of compound it is.

Materials:

- Sodium chloride ($NaCl$)
- Sucrose ($C_{12}H_{22}O_{11}$)
- Wax (C_xH_y)
- Distilled water
- Aluminum foil
- Hot plate
- Multimeter
- Scoopula
- Stirring rods (3)
- 100-mL beakers (3)

Procedure:

Physical Appearance

1. Record the physical appearance of each substance as accurately as possible. Try to come up with at least eight descriptors for each substance. All of these substances are safe to touch.

Melting Point

1. Mold a flat-bottomed tray with foil. Place a **small** amount of each substance in three corners.
2. Place the tray on the hot plate, and turn it to high. Observe for three minutes, then record observations of how the substances melted.
3. Allow the foil to cool while you complete the remaining steps of the experiment.

Solubility in Water and Hexane

1. Place a large scoop of each solid into three different 100 mL beakers. Keep track of which is which!
2. Add approximately 50 mL of distilled water and stir well. Record whether each substance is soluble or insoluble. If it is soluble, you will not see any solid left on the bottom of the beaker.
3. Do not dispose of these solutions, as you will use them for the next step.
4. Record the data for the solubility of each substance in hexane from this table:

Substance	Sodium Chloride	Sucrose	Wax
Soluble in Hexane?	No	No	Yes

Conductivity

1. Set the multimeter to measure resistance (Ω). Check the multimeter settings with Ms. Hayduk before turning it on.
2. Test the resistance of each soluble substance by dipping the end of both wires (not touching each other or the glass) into the beaker containing the substance. Record the measurement for each. *(Note that resistance is inversely proportional to conductivity, so a higher resistance means a lower conductivity.)*
3. Rinse off the wires with distilled water and dry between each substance.

Clean Up

1. Dispose of aluminum foil and solids into the garbage.
2. Rinse off all other equipment into the sink using distilled water.
3. Return all equipment.

Discussion:

1. Classify each substance as ionic, polar covalent or non-polar covalent, based on previous knowledge. Classify water and hexane as polar or non-polar solvents.
2. Write a summary of the physical properties of ionic, polar covalent and non-polar covalent compounds, specifically melting point, solubility in polar solvents, solubility in non-polar solvents and conductivity. Assume the substances used in this lab are representative of the general properties – answer this question based on what you observed!
3. Predict the solubility in water and hexane, conductivity and melting point (high, moderate or low) for:
    a. Coconut oil
    b. Potassium iodide
    c. Fructose ($C_6H_{12}O_6$)
4. Look up the melting points of some ionic and covalent compounds. What is considered a high melting point?

Lab 3. Intermolecular Forces

Essential Learning:

1. Differentiate between the different types of intermolecular forces.
2. Recognize that a material's chemical and physical properties are dependent on the type of bonds and the forces between the molecules.

Background Information:

Intermolecular force is a term to describe how molecules interact with each other. These forces are determined by a combination of the molecule's polarity, molar mass and shape. Intermolecular forces within a single substance include hydrogen bonding, dipole-dipole forces and London forces. Intermolecular forces between two substances include the three mentioned, plus ion-dipole, ion-induced dipole, dipole-induced-dipole.

The strength of intermolecular forces of a substance affects various properties of the substance. In this lab, you will compare the strength of intermolecular forces in various substances by examining a variety of these properties.

Procedure:

Spend 5-10 minutes at each station. Follow the directions at each station, then write observations on what you observed. Be sure to record names and formulas for each substance you examine. You do not need to do the stations in order.

Discussion:

For each station:

1. Use your observations to explain the differences between the behaviour of each substance with respect to the property being examined. Determine how you came to each conclusion, including identifying of the type of bonds present in each substance.
2. Identify the type of intermolecular forces present between the solutes and solvents in station 5.

Lab 4. Fractional Distillation

Essential Learning:

1. Observe and explain the process of fractional distillation, including demonstrating an understanding of intermolecular forces.
2. Make connections between fractional distillation of pop with petroleum.

Background Information:

Distillation is a process that is used to separate a solution that has a varying composition. It makes use of different physical properties of each component, mainly boiling/condensation point.

In this lab, you will separate pop into different components using a simple distillation set up. Pop contains four main fractions that can be separated: water, carbonation (carbon dioxide), syrup and flavouring (an ester).

Materials:

- 50 mL of pop
- 600-mL beaker
- 50-mL beaker
- Aluminum foil
- Ice cubes
- Hot plate
- Graduated cylinder
- One large rubber stopper

Procedure:

1. Measure 50.0 mL of pop in the graduated cylinder, then pour into the large beaker. Take a photo of the liquid against a white background to record the original colour.
2. Place the rubber stopper inside the large beaker so it is centered. Put the small beaker, empty, facing upwards on top of the rubber stopper.
3. Fully cover the mouth of the large beaker with aluminum foil that has been formed into a cone with the point in the middle of the foil directed down over the small beaker.
4. Place this apparatus carefully onto the hot plate. Heat the liquid until it boils.
5. Once the liquid is boiling, place three or four ice cubes into the foil cone to cool the foil. Continue to boil the liquid until the ice has melted. Record observations (including smell!) while the liquid boils.
6. Allow the apparatus to cool for five minutes.
7. Use the graduated cylinder to measure the volume of liquid in the small beaker. Take photos of the liquid left in the large beaker and the liquid in the small beaker to record the colours.

Discussion:

1. Explain what you observed in the lab. Identify the <u>composition</u> of each of the four main components, compare approximate boiling points and describe intermolecular forces of each.
2. Explain in your own words why distillation is a physical process and not a chemical process.
3. Use your textbook (pp 725-726) to read about fractional distillation of petroleum.
   a. How are all the fractions of petroleum similar?
   b. Explain the differences in the fractions and how these properties can be used to separate them.

Lab 5. Properties of Organic Compounds

Essential Learning:

1. Compare properties of compounds with the same functional group and determine differences in intermolecular forces.
2. Compare properties of compounds with different functional groups that have similar size, and determine differences in intermolecular forces.

Background Information:

Alcohols are organic compounds that contain a hydroxyl (-OH) group. **Ketones** contain a double bonded oxygen from a central carbon atom. **Carboxylic acids** contain a double-bonded oxygen and a hydroxyl group on the same carbon.

Evaporation rate, or vapour pressure, is a way to determine the strength of intermolecular forces in a compound. Compounds that have strong forces will not evaporate as quickly. Evaporation is an endothermic process, which draws in energy in the form of heat from the surroundings. A substance that evaporates quickly will have a more significant temperature decrease.

Materials:

- Test tubes containing methanol, ethanol (95%), isopropanol, acetic acid and acetone
- Thermometer with triangle
- Stopwatch
- Facial tissue strips (3)
- Twist ties or rubber bands
- Cardboard fan
- Pipettes
- Gloves

Safety:

ALL COMPOUNDS BEING USED IN THIS LAB ARE DANGEROUS. SAFETY GOGGLES (not glasses), APRONS, GLOVES AND EXTREME CAUTION ARE REQUIRED FOR THIS LAB. If any substance comes in contact with skin, wash the affected area using soap and water for 15 minutes.

Procedure:

Part A: Rate of Evaporation for Different Types of Compounds

Use ethanol, acetic acid and acetone for this procedure.

1. Wrap a strip of tissue around the bulb of the thermometer and secure with a twist tie/rubber band.
2. Place the thermometer on the lab bench so that the bulb of the thermometer extends over the edge. Use the triangle on the thermometer so it will not roll.
3. Choose one person to control the stopwatch and one person to read the temperature on the thermometer. The third person will put a small amount of one of the liquids in a pipette.
4. Record the initial temperature.
5. When everyone is ready, squeeze enough liquid on the tissue to completely saturate it. At the same time, start the stopwatch and observe the temperature.
6. Fan the thermometer bulb with the cardboard. After one minute, record the final temperature. Carefully remove the tissue and wipe the bulb dry.
7. Repeat Steps 3-6 with the other two compounds. When done with the tissue, it can be disposed of in the garbage.

Part B: Rate of Evaporation for the Same Type of Compound

Use methanol, ethanol and isopropanol for this procedure.

8. Repeat the procedure from Part A using methanol, ethanol and isopropanol.

Discussion:

1. Draw the structural or line diagram for each compounds being used in this lab: methanol, ethanol, isopropanol, acetone (ethanone), and acetic (ethanoic) acid. Identify any dipoles in each molecule.
2. For each part of the experiment, the compound will the strongest intermolecular forces will evaporate the slowest (smallest temperature change). Put the compounds in order from strongest forces to weakest based on your observations, and explain if this makes sense based on the molecular structure of each.

Lab 6. Polymers and Plastics

Essential Learning:

1. Understand the life cycle of polymers and plastics, including applications of different types of plastics.
2. Create and compare bioplastics, considering advantages, disadvantages and possible uses for each.

Background Information:

Before beginning this lab, please read all the background information. Prior to starting, please discuss with your group members to come up with your purpose, as this will guide the remainder of your work. In this lab, you will first research the physical and chemical properties of plastics. Then, you will create one or more types of bioplastics following the procedures below. Finally, you will perform an experiment or series of tests to determine the properties and potential applications of the bioplastic(s) you created.

This lab is to be complete in assigned groups of 3-4 students. Students will create a full lab report that includes the following sections:

1. Introduction
    a. Purpose *(2-3 sentences)*
       What are you trying to figure out about the bioplastic(s)? Are you comparing them for a specific application or investigating one to determine for which application it would be best suited?
       Example: Can bioplastics be used to hold drinks of varying acidity for extended periods of time?
    b. Background Information *(2-3 pages, not including images)*
       What is plastic? Where does it come from? What does it look like at the molecular level? What different types of plastics are there, and how are they different? What are some benefits of plastic? What are some drawbacks of plastics? What are bioplastics? Why are bioplastics being developed?
2. Experimental *(1-2 pages)*
    a. Materials
       Make a complete list of materials you will need to test the bioplastic.
    b. Procedure
       Make a numbered list of steps (in third person, like writing a recipe) that explains how to do the testing on the bioplastic. Someone else should be able to follow these instructions independently and get the same results as you. For examples, check other labs in this lab manual!
3. Data and Observations *(1-2 pages)*
   Include all observations, calculations and data from the testing done on the bioplastic. Do not include any discussion or analysis here – just information.
4. Analysis *(2-3 pages, not including images)*
   In general, you are explaining the significance of your observations. Be sure to address your purpose. Include discussion about your findings, any sources of error, what your conclusions are and any next steps in testing, if you had more time or more resources.
5. Conclusion
   Write a concise summary that answers the question you asked in your purpose. Do not include any information that you didn't already discuss.
6. Works Cited
   Include ALL sources, in APA format. Be sure to also cite these sources within the text of your report whenever you use information from someone else, including images.

Students will complete a peer assessment following the completion of this project; be aware that marks may be scaled if students do not contribute equally to the final product.

Lab 7. Equilibrium Straw Model

Essential Learning:

1. Use graphs to compare and analyze an irreversible and reversible reaction model
2. Develop an understanding of equilibrium reactions

Background Information:

A reversible reaction is one in which reactants are being converted to products at the same time as products are being converted back to reactants. There is a forward reaction and a reverse reaction. Irreversible reactions only proceed forward, so it continues until reactants are all used up.

$A + B \rightleftharpoons AB$ *general form for reversible reaction*

$A + B \rightarrow AB$ *general form for irreversible reaction*

Materials:

- Two graduated cylinders of the same size
- Two straws (one "fat" and one "skinny")

Procedure:

Part A

1. Label one graduated cylinder with an "R" (reactants) and one with a "P" (products).
2. Add 20 mL of water to the "R" cylinder.
3. Choose one straw. This straw can only take water out of the reactants.
4. Put each straw all the way to the bottom of the "R" cylinder. Cover the top with a thumb and transfer the water in the straw to the other cylinder.
5. Repeat Step 4 two more times, and then record the volume of water in each cylinder.
6. Continue to transfer water as in Steps 4 and 5 until the volume of each cylinder becomes constant (change of less than 1 mL) for three measurements.

Part B

7. Label one graduated cylinder with an "R" (reactants) and one with a "P" (products).
8. Add 20 mL of water to the "R" cylinder.
9. Choose one straw to be the forward reaction. This straw can only take water out of the reactants. The other straw is the reverse reaction and can only take water out of the products.
10. Put each straw all the way to the bottom of the correct graduated cylinder. Cover the top with a thumb and transfer the water in the straw to the other cylinder. (For the first few transfers, there may not be enough water in the products cylinder for any to be moved.)
11. Repeat Step 4 two more times, and then record the volume of water in each cylinder.
12. Continue to do three transfers at a time as in Steps 10 and 11 until the volume of each cylinder becomes constant (change of less than 0.2 mL) for three measurements.

Discussion:

1. Make a scatterplot that shows Trials on the x-axis and Volume (mL) on the y-axis. Graph your data for both Part A and Part B on the same graph. (This can be done electronically.)
2. Compare the graphs for both systems. Identify how the graphs are the same, and how they are different. Use the words "reversible" and "irreversible". Be specific and reference your data.
3. What would happen for Part B if you kept transferring water? What has happened to the system?

Lab 8. Le Chatelier's Principle

Essential Learning:

1. Predict and observe the effects of various stresses on a reversible reaction
2. Quantitatively examine the effect of a stress on an equilibrium system

Background Information:

Le Chatelier's Principle states that when a system equilibrium is disturbed by a change in environment, the stress will be relieved by a "shift" in the system, towards the reactants (left) or products (right).

For the first part of this lab, the system being observed is:

$$\underset{\text{green}}{CuCl_4^{2-}}{}_{(aq)} + 4\ H_2O_{(l)} \rightleftharpoons \underset{\text{blue}}{Cu(H_2O)_4^{2+}}{}_{(aq)} + 4\ Cl^-_{(aq)} + \text{heat}$$

Materials:

- Medium test tubes (5)
- Test tube rack
- Distilled water
- Solid calcium chloride
- 0.10M silver nitrate
- Scoopula
- Test tube clamps
- Hot water bath
- Two graduated cylinders of the same size (25-mL)
- Two straws, one "skinny" and one "fat"

Procedure:

Part A

1. Fill each test tube with about 2 cm of copper(II) chloride solution. (This is a qualitative lab; exact amount is not important!)
2. The first test tube will be a colour control. Do not add anything else to this test tube. For the other five tubes, perform the tests as outlined in the table below. For each, ensure a colour change occurs; add more reactant if necessary.

Tube 2	Add distilled water. Swirl the test tube to mix the liquids.
Tube 3	Add a small scoop of solid calcium chloride. Swirl the test tube to mix.
Tube 4	Add several drops of silver nitrate. Swirl the test tube to mix.
Tube 5	Lower the test tube into the hot-water bath. Wait until a colour change occurs.

Part B

1. Repeat the Straw Lab as you did before.
   a. Fill one graduated cylinder with 15 mL of water.
   b. "Trade" water between the two cylinders three times, then record the volume of water. Continue this until you have a constant volume of water in each graduated cylinder for three consecutive trials. This is the first equilibrium.
2. Once the volumes are constant, add 5.0 mL of water to the graduated cylinder with less water. Record the new volumes. This is adding a stress to the system by increasing "concentration".
3. Continue to "trade" water between the two cylinders as in Step 1b, using the same straws in each as before. Once the volumes are constant for three trials, stop. This is the second equilibrium.

Discussion:

1. Identify what variable you were changing for each test tube in Part A. Indicate which direction (left or right) the equilibrium shifted.
2. Make a scatterplot that shows Trials on the x-axis and Volume (mL) on the y-axis. Graph your data for both reactants and products <u>on the same graph</u>. At the point when more water was added, indicate this with a vertical line (not with a new trial). (This can be done electronically.)
3. Use your graph and your data to determine which way the equilibrium shifted in Part B. (Hint: it may help to compare the volumes in each cylinder at the first equilibrium and the second – did they both increase by the same amount?)

Lab 9. Solubility Product Constant

Essential Learning:

1. Experimentally determine the solubility product constant of a slightly soluble salt

Background Information:

Solubility is the amount of a solute that can be dissolved in a specific volume of solvent. The solubility product constant (K_{sp}) is a numerical quantity that indicates how soluble a specific solute is. In this lab, you will be mixing lead(II) nitrate and potassium iodide solutions together to experimentally determine the solubility product constant for the reaction.

When these solutions are mixed, they create a bright yellow precipitate. At the very beginning of the production of the solid, it will appear as yellow sparkles or a cloudy colour in the mixture. This is the point at which the solution is saturated and the K_{sp} can be calculated.

Materials:

- 100-mL Erlenmeyer flask
- 25-mL graduated cylinder
- Burette
- Ring stand, burette clamp
- Pipette and bulb
- Thermometer
- 0.010 M lead(II) nitrate solution
- 0.010 M potassium iodide solution
- Distilled water
- Glass funnel

Procedure:

Note: You are looking for sparkles – sparkles will only show up if the light is shining off of them! To check, look into your flask with your back to the window, OR use a light on your cell phone shining into your flask.

1. Use the pipette to add 5.00 mL of lead(II) nitrate solution to the Erlenmeyer flask.
2. Use the graduated cylinder to add 20.0 mL of distilled water to the Erlenmeyer flask.
3. Ensure your burette is filled with potassium iodide. Use the funnel to pour the potassium iodide in to the top of the burette if you need more. Record the initial volume of the solution in the burette.
4. Add the potassium iodide slowly to the lead(II) nitrate solution. Stop when a colour change occurs. Record the final volume of the potassium iodide.
5. Discard the solution in the waste beaker.
6. Record the temperature in the lab.

Calculations:

1. For the reaction between lead(II) nitrate and potassium iodide, write and balance:
   a. The double displacement equation, including states, and;
   b. The dissociation equation, including states.
2. Write the K_{sp} expression for this reaction. Include the theoretical value for K_{sp}.
3. Calculate the experimental value of K_{sp} using the data from your best trial in the lab.

Discussion

1. You measured the air temperature in the lab. How does temperature affect solubility and the value of K_{sp} in this experiment?
2. Explain three significant sources of experimental error in this lab. How do these errors affect your results?

Lab 10. Strong and Weak Acids

Essential Learning:

1. Qualitatively distinguish between strong and weak acids

Background Information:

Strong acids ionize 100% in water. Weak acids ionize less than 50%. This difference means that, for a strong and weak acid with the same concentration, the strong one will have a higher concentration of hydrogen ions in the solution.

pH Hydrion paper is an indicator paper used to measure the approximate pH (concentration of hydrogen ions) of an acid or base. The pH can be determined by the colour change of the paper. A high concentration of hydrogen ions means the pH will be lower.

Materials:

- 0.1 M hydrochloric acid
- 0.1 M acetic acid
- 0.1 M citric acid
- Water
- Four small beakers
- pH Hydrion paper
- Well plate
- Four eye droppers
- Wax pencils
- White paper
- Toothpicks

Procedure:

1. Use a wax pencil to label each beaker (HCl, acetic, citric, H_2O)
2. Collect about 20 mL of each acid in three different beakers. Fill the fourth beaker with water.
3. Add the acids and water into wells as shown in the table below.

Well 1 10 drops of acetic acid	Well 2 7 drops of acetic acid 3 drops of water	Well 3 3 drops of acetic acid 7 drops of water	Well 4 1 drop of acetic acid 9 drops of water
Well 5 10 drops of HCl	Well 6 7 drops of HCl 3 drops of water	Well 7 3 drops of HCl 7 drops of water	Well 8 1 drops of HCl 9 drops of water
Well 9 10 drops of citric acid	Well 10 7 drops of citric acid 3 drops of water	Well 11 3 drops of citric acid 7 drops of water	Well 12 1 drops of citric acid 9 drops of water

4. Stir each well using a toothpick. Use one toothpick per acid, and start by stirring the least concentrated wells first.
5. Dip half a piece of pH paper into each well. Place them on a piece of white paper, then compare them to the colour chart for the paper. Use the colour that represents the lowest pH. Record the pH for each well.

Discussion

1. Examine how the pH of the acids change as more water is added (across a row). Explain what variable you are changing, and how it affects the pH.
2. Examine the pH of the different acids that have the same amount of water added (down a column). Explain why they are not all the same, and give details about how the acids are different that supports what you found.

Lab 11. Acid-Base Titration

Essential Learning:

1. Perform an acid-base titration to determine the pH of an acid sample

Background Information:

A titration is a lab technique used for determining the concentration of an unknown solution. A solution with known concentration and volume is mixed with a solution with unknown concentration and known volume. An indicator changes colour to identify when the mixture reaches a neutral pH. At this point, the concentration of the unknown solution can be calculated using stoichiometry.

Materials:

- Acid sample
- 0.10 M sodium hydroxide
- Pipette and bulb
- Burette, clamp and ring stand
- Erlenmeyer flask, 250-mL
- Phenolphthalein
- White paper
- Funnel
- Distilled water

Procedure:

1. Rinse and fill the burette with 0.10 mol/L NaOH solution.
2. Record the starting volume in the burette to the nearest 0.01 mL.
3. Pipette 10.0 mL of acid into the Erlenmeyer flask. Be sure to empty the pipette properly.
4. Add five drops of phenolphthalein indicator to the acid. It should remain clear.
5. Titrate the acid with the sodium hydroxide solution from the burette until a single drop produces a permanent colour change in the solution from colourless to <u>light</u> pink.
6. Record the final volume of the burette to the nearest 0.01 mL.
7. Wash your Erlenmeyer flask and repeat steps 4-7 at least two more times <u>until you get three consistent results</u> (within 0.5 mL). Record all observations and data.

Calculations

1. Average the amount of sodium hydroxide added, then determine the pH of the acid. The mole ratio of acid to base is 1:2, and the acid is a strong acid with two hydrogen ions.

Discussion

1. Identify and explain three significant sources of experimental error in this lab.

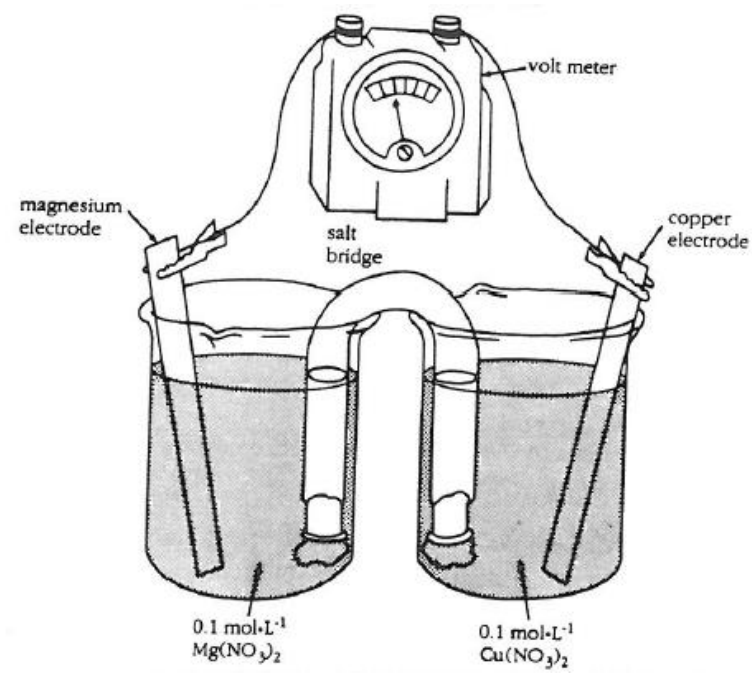
Lab 12. Voltaic Cells

Essential Learning:

1. Construct a voltaic cell to determine experimental voltage

Background Information:

A voltaic cell is a type of electrochemical cell that spontaneously produces electricity using a redox reaction. The two half-reactions are separated in two beakers; the metal electrodes are connected by a wire, and the electrolytes are linked with a salt bridge. The substance in the salt bridge is an ionic solution that is unreactive with both electrolytes.



Materials:

- Metal electrodes
- Electrolyte solutions
- 500-mL beakers
- Multimeter
- Salt bridge

Procedure:

1. Select two metal electrodes and the corresponding electrolyte solutions. Construct the electrochemical cell as shown in the image above. You do not need to use magnesium and copper!
2. Connect the multimeter to the electrodes so the meter gives a positive reading. Record this value.
3. Repeat this process with different electrodes and electrolytes.

Calculations

1. Determine the theoretical value for the cell potential for each of your electrochemical cell set ups. (Hint: you will need to determine which electrode is the anode and which is the cathode.)
2. Calculate the percent error for each cell, based on the voltage you measured and the theoretical value.

Discussion

1. Explain which cell you constructed was the most effective. Explain your definition of "effective". Use all of your data and calculations to make this decision.
2. Give three reasons why the experimental cell potential may be different than the theoretical value.