Experimental Inquiry Manual
General College Chemistry 2
Pikes Peak Community College

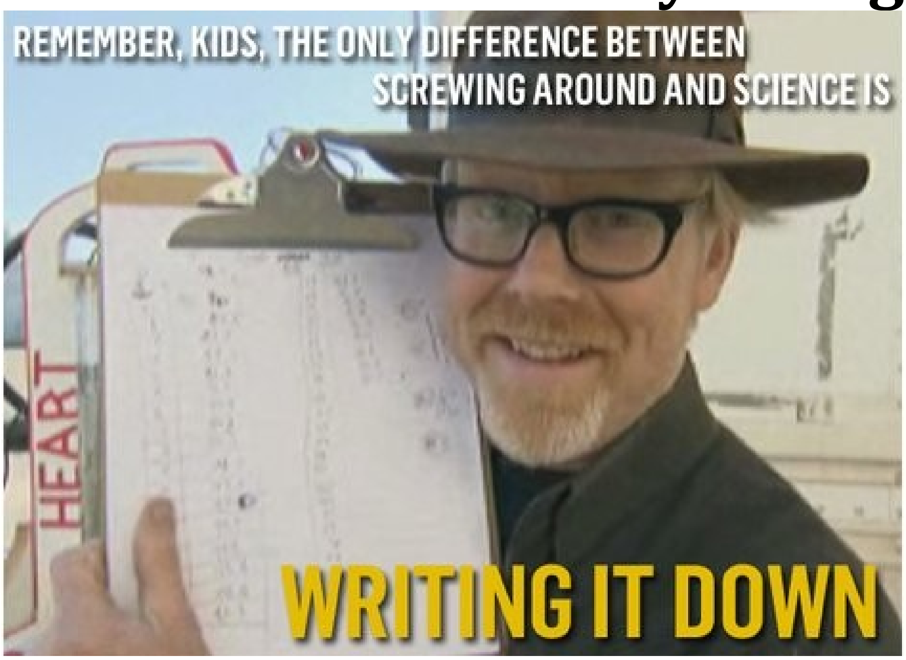


Table of Contents: Investigation Questions

b. Can I kill an electrochemical cell by getting it really cold?

Lab Practical

You will have your lab notebook only to complete certain tasks assigned to you. These will be based on the experiments we have done all semester and will involve identification of unknowns.

The Breaking Bad Scenario

What are the challenges in creating a pure organic substance?

Laboratory Safety Information

You are responsible for **knowing and following** laboratory safety practices and rules, safe chemical handling and disposal procedures, and emergency procedures. Failure to comply with these regulations will result in points being deducted and/or dismissal from the laboratory session. Designated pre-laboratory work is required for you to perform the experiment. You may not be allowed to start the lab if you are tardy. It is imperative that students use safe laboratory techniques at all times. Failure to adhere to safety rules will result in the removal the student from the laboratory to safeguard the entire class.

General Safety, Cleanliness and Behavior Rules:

1. Read all directions for an experiment before entering the laboratory and follow the directions exactly as they are written.
2. Wait for the instructor to provide guidance about the equipment and chemicals being used before starting the experiment. If you are in doubt about anything, ask the instructor.
3. Never perform experiments that are not authorized by your instructor.
4. Never handle any equipment unless you have specific permission.
5. Take care not to spill any materials in the lab. If a spill occurs, ask your instructor immediately about the proper clean-up procedure.
6. Dispose of all material according to the teacher's instructions. Never empty materials into the sink or trash can unless directly instructed to do so.
7. Never eat in the laboratory. Wash your hands before and after each experiment.
8. Never horse play or run in the laboratory. This will result in a zero for the experiment and dismissal from the lab.
9. Know the location and function of all laboratory safety equipment.
10. If chemicals are spilled on the analytical balance, clean it *immediately* using a brush and dust pan. You are responsible for the cleanliness of common equipment and work areas that you use, and lab equipment assigned or otherwise designated for your use. Points will be deducted for failing to clean up after yourself.
11. If broken glass occurs, use a broom and dust pan to collect the glass and dispose in the broken glass container. You are responsible for equipment damage, breakage or loss.
12. Occasionally, glass tubing needs to be inserted into rubber stoppers. The best course of action is to use a ***split*** stopper. If one is not available, make sure to lubricate the tubing with glycerin, use a towel to cover your hand for protection, and twist the tubing and stopper carefully.

Laboratory Dress Code:

1. Wear safety glasses/goggles at all times, specifically at any time heat or glassware is used by anyone in the laboratory. Personal eye glasses are not a substitute for safety glasses/goggles. Only remove safety glasses/goggles when *everyone* is finished with the experiment.
2. Contact lenses are not to be worn in the laboratory. If a chemical gets in the eyes, it will be trapped against the surface of the eye, causing further damage to the eye.
3. Tie back long hair and loose clothing when performing laboratory experiments to avoid getting it in flames or chemical.
4. **Always** wear closed-toed shoes in the laboratory.
5. When in the laboratory, full-length pants or ankle length skirts must be worn. Shoes must cover the whole foot. Shirts with sleeves (no tank tops) are required. Students must be properly attired before entering the lab. Shorts, *short* skirts, **stretch** pants, and any **synthetic** material may not be worn. Make sure that no skin is exposed below the waist or on the abdomen. Natural materials such as cotton and wool are the most resistant to chemicals and heat.

6. If a student comes to the lab dressed inappropriately or without goggles, they will be asked to leave the lab and a zero will be awarded.

First Aid:

1. Report all accidents to the teacher immediately.
2. Apply direct pressure to any severe cuts to stop the bleeding
3. Know the location of the first aid kit.
4. Know the location and use of the fire blanket.
5. If a solution splashes into a student's eyes, the first action should be to use the eye wash.

Heating and Fire Safety:

1. Never reach across an open flame.
2. Know how to light and extinguish a Bunsen burner, never leave a burner unattended.
3. When heating a test tube, point the test tube away from you and other students. Chemicals can rapidly boil and shoot out of the test tube.
4. Never heat a liquid in a closed container.
5. Always use a clamp or tongs when handling hot containers.
6. If a fire occurs in a small container, it can best be extinguished by

a. Turning off the gas
b. Smothering it with sand or the use of a fire extinguisher. Never use water.
c. Call the instructor for help immediately. Most fires we deal with will be class-A fires, which are ***ordinary combustibles***.

7. Never use flammable liquids near a flame; remember the vapors are the flammable, not the liquid.
8. Hot glass looks the same as cold glass, so always be cautious.
9. If a your clothing catches fire, stop, drop, and roll to extinguish the fire.

Chemical Safety:

1. Never use your bare hands to touch any chemicals in the lab.
2. Never taste any substance in the lab.
3. In order to detect the odor of a substance, waft the vapors toward your nose. Do not inhale fumes directly from a container
4. Spillage of certain chemicals, such as acids, bases, or corrosive substances can be damaging to a person’s skin and clothing. Please inform the instructor immediately of any spills.
    a. If a small amount is spilled on the skin, immediately rinse the affected body area at a minimum of 20 minutes.
    b. If a large amount of corrosive material is spilled on a part of a your body, remove the clothing covering that body part and use the safety shower to rinse the affected area for at least 20 minutes.
    c. If a small amount of acid is splashed on the skin, rinse the affected area thoroughly with water.
    d. Baking soda is available in the lab to neutralize large acid spills.
    e. Safety Data Sheets (SDS) are available in the lab prep area.
5. When making a diluted solution of an acid, add acid slowly to water, NEVER the reverse, as excessive heat can result, causing the acid to boil and splash up out of the container.
6. Keep all lids to chemicals on and tightened, so make sure you close the lid after you use it.
7. To remove solid chemicals from a stock bottle, make sure to use a clean spatula and preferably, the designated one.
8. Dispose of all chemicals as instructed by your instructor, do not put the chemical back into the original container.
9. Never eat or drink from any laboratory glassware.

10. The major factors in determining the toxicity of a substance include the dose, route of exposure, as well as personal factors such as age and gender, therefore, assume all chemicals are toxic and dangerous.
11. Never use chipped or broken glassware, as cuts and scratches can occur.

Electrical Safety:

1. Make sure any electrical equipment is OFF when plugging or unplugging from an outlet.
2. Make sure the work area for electrical equipment is clean and dry.
3. Inspect power cords for cuts or abrasions that revel bare wire.
4. Be very aware of the location of power cords to avoid tripping and damage to persons.
5. Clean any equipment after use. Wipe down hot plates after use.

End of Laboratory period rules:

1. Clean all laboratory equipment and return to the proper location.
2. Clean the work station by wiping the benchtop down with water.
3. Unplug and store properly any electrical device.
4. Extinguish all candles and burners at the conclusion of the lab activity.
5. Never remove chemicals or other equipment from the laboratory.
6. Turn off all gas lines to the Bunsen burners.
7. **Finally**, wash your hands before you leave!

Watch the assigned videos in your D2L shell, then take the online safety quiz!
You must get a 90% or above to participate in the first experiment.

Safety Symbols


Electrical Hazard


Combustible Materials


No Open Flames


Corrosive Materials

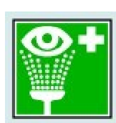

Flammable Symbol

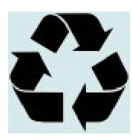

Fire Extinguisher


Toxic Chemical


Non-potable water


Environment Hazard


Eyewash Sign

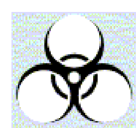

Recycling Sign

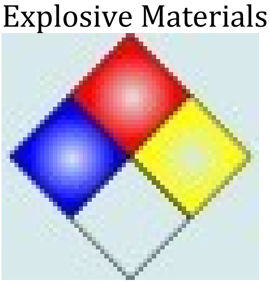

Toxic Materials Sign


Explosive Materials

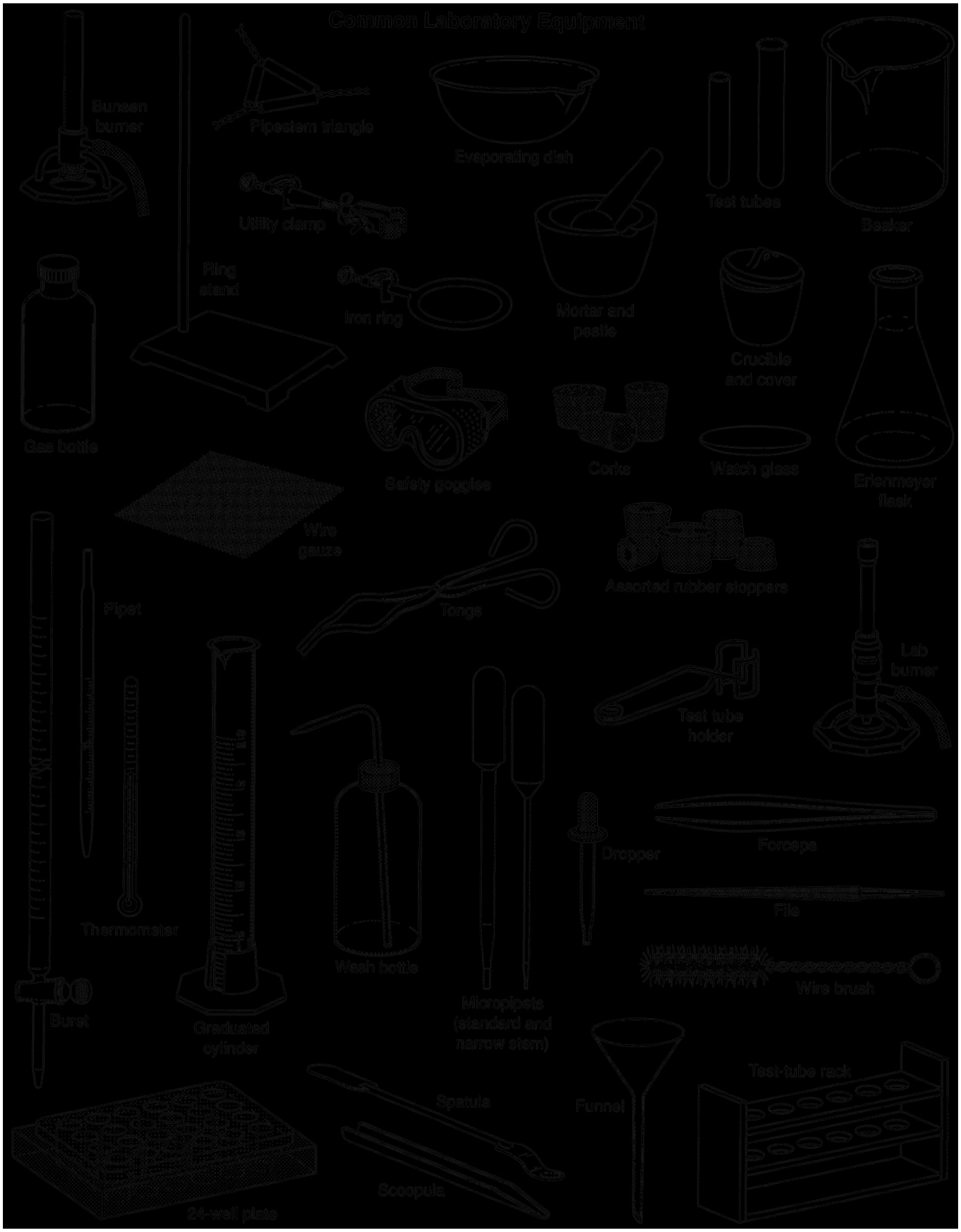

Flammable Sign


Radioactive Sign


Biohazard Sign


Chemistry Hazard Label

General Lab equipment



The Laboratory Notebook and Lab Report

For a scientific experiment to be valid, your method and results must be properly recorded. This enables the validity of your results to be verified and/or inspected later by you, or another scientist. A log of your experiment should be written up in a notebook, making sure to take into account the following points:

- View the notebook as a journal of your experiment, doing the experiment with your notebook in front of you, signing and dating every page on which you record data and observations.
- Every time you do something, write what you are doing in your notebook.
- Every time you measure or observe something, whether ordinary or unusual, write it down.
- If you have an idea which might be useful in explaining your observations or achieving your aims, write it down.
- If you have an idea that may apply to your investigation, write it down before you forget it.
- If something goes wrong and you don't know why, write it down.
- If something goes wrong and you think you know why, write it down.
- If you record something in your notebook that you later think is wrong, do not erase or obliterate it, write down why you think it is wrong.
- If you make deductions or form a hypothesis based on your observations, write it down

Notebook Template

Header:

Make sure to fill out **every** header area of each page of your notebook with your name, the name of the experiment & date.

Pre-lab questions.

These questions/activities are given in the inquiry manual. The points will vary based on assignment. Do these in your lab notebook on a separate to tear out. This is due in the first ***5 minutes*** of the lab period.

Pre-lab -Reagent Table / Hazards data

Prepare a **table** that lists the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Excellent sources for this are the NIST Site, Chemspider, OSHA, NOAA, or PubChem. Choose one chemical to research further and report an interesting fact about it. Cite the source(s) used for all information. Be prepared to know how to dispose of each reagent. Place this table after the prelab assignment in your lab notebook. This is due in the first ***5 minutes*** of the lab period. Start your procedure on the subsequent page so as to not turn in part of your procedure.

Procedure:

Using the information given in this inquiry manual and any other sources you are instructed to look up, prepare a general procedure written out in your lab notebook. This is due before the lab period begins and will be checked by the instructor at the beginning of lab time. Copying another students procedure is forbidden and is considered cheating. You will be dismissed from the lab if you are caught plagiarizing another student's work.

Use a two-column format with the left column used to write the procedures before you come to class, and the right column for recording your experimental observations. You do not have to write any other part of your lab notebook in a two-column format. For the procedure portion, full credit is given for procedures, **coupled with** notes/observations, that ***anyone*** could use to repeat your experiment. **Use numbered steps** and **align** the procedural steps with the corresponding observations. Cite the source of your procedure at the beginning. Leave lots of space between your proposed procedural steps to allow for any additions you may need to add. You should be able to do the experiment from your notebook alone; however, do not just copy the manual into your lab notebook. That is a waste of time and effort. Paraphrase the procedure and write in your own words, as best as you can. This will help you understand what you are doing in the experiment.

Observational Notes:

Full Credit will be given for notes and observations that describe everything you did and saw. Record your observations and any minor changes in the procedure in the right-hand column of your notebook. Be sure to include the actual amount you use of each reagent, reactions times, colors and odors, spills or mistakes. Include observations of **all** chemicals, molarities and anything you did in the lab. Never erase anything in your observations section.

Calculations:

Calculations are can be shown in the procedure or in a separate section labeled "Calculations". If a calculation is done in the procedure, label it as a "**calculation**" **and box the result**. Otherwise you might confuse it for collected/measured data. Also indicate what the calculation was calculating

Signed Each page signed by you the experimenter and your instructor as the witness.

Typed Portion of Lab Report: Results and Discussion

Results and Discussion

The most important part of an experiment is how you interpret the data gathered. This can also be one of the most challenging parts of science. To start the analysis of the experiment and the accompanying data, type a narrative of what you did and observed. Report the main results in a table embedded in the texts **after** you write what you did. Tables provide a good summary of information. Tables are also useful to compare results to each other in a side-by-side format. Do not include in the table primary data(such as time-temperature or pH-titrant volume), as this primary data is used to extract the main result(s) of the experiment. Include the team table(if one was done) embedded here, provide a ***descriptive caption*** on ALL tables or figures.

Conclusion-(Typed 1-2 paragraphs)

Write - ***In conclusion, this experiment was performed in order to***....then explain why you did it and if it answered question posed. Each experiment includes questions given. Address these in your conclusion. If the experiment did not answer the questions posed, then elaborate on what experiment(s) you could perform to answer that question(s) or improve your result(s). Make suggestions on how to improve the method for future experimenters. Discuss any errors you may have made that caused your results to be different than you expected. Discuss your identifications of unknowns, if any. Compare your results to known values, if possible and analyze the team table results.

Post Lab Questions

Each experiment is unique, so post lab questions are tailored to your section. Check D2L announcements for post lab questions and the team table.

Graphing Guidelines:

Any time you are asked to construct a graph, follow the instructions below:

1) Label both axes as to what variable they are representing, including the unit.
2) Give the graph a name at the top of the page.
3) Plot points then circle the points to indicate error for each measurement. The size of the circle does not matter, just right outside the point is sufficient.
4) Draw a best fit line through the points, **DO NOT** connect the dots.

Captions

A caption describes in words what is in a picture, a caption for a table describes what is generally in the table.

- For all figures, give it a Figure number(i.e. Figure 1), and provide a caption that describes what it is communicating, as well as any interpretation(s) of the data.

A Good Figure Caption?

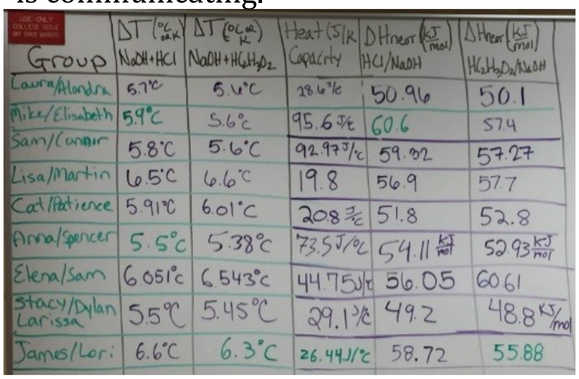
Which head of lettuce would you want to eat by reading the caption only? Neither, not enough information is provided.

Figure 1: This is a picture of a head of romaine lettuce

Figure 2: This is a picture of a head of romaine lettuce.

A good table caption

- For all Tables, give a <u>table number</u>(i.e. Table 1) with a <u>caption</u> describing what is in it and what it is communicating.



Group	ΔT (°C or K) NaOH+HCl	ΔT (°C or K) NaOH+$HC_2H_3O_2$	Heat (J/K) Capacity	ΔHneut (kJ/mol) HCl/NaOH	ΔHneut (kJ/mol) $HC_2H_3O_2$/NaOH
Laura/Alondra	5.7°C	5.6°C	28.6 J/°C	50.96	50.1
Mike/Elisabeth	5.9°C	5.6°C	95.6 J/°C	60.6	57.4
Sam/Connir	5.8°C	5.6°C	92.97 J/°C	59.32	57.27
Lisa/Martin	6.5°C	6.6°C	19.8	56.9	57.7
Cat/Patience	5.91°C	6.01°C	208 J/°C	51.8	52.8
Anna/Spencer	5.5°C	5.38°C	73.5 J/°C	54.11 kJ/mol	52.93 kJ/mol
Elena/Sam	6.051°C	6.543°C	44.75 J/°C	56.05	60.61
Stacy/Dylan Larissa	5.5°C	5.45°C	29.1 J/°C	49.2	48.8 kJ/mol
James/Lori	6.6°C	6.3°C	26.44 J/°C	58.72	55.88

***Figure 3**: This is a table recording the changes in temperature of the reaction between hydrochloric acid and sodium hydroxide, and acetic acid and sodium hydroxide. The general trend observed in temperature change is an approximate average of 6.0°C for the hydrochloric acid reaction and approximately 6.0°C for the acetic acid. The heat capacity is also recorded for each group. These values ranged from 19.8J/K to 95.6 J/K. The heat of neutralizationwas recorded with the average being appoximately 55.5 kJ/mol for the HCl and 56.6 kJ/mol for the acetic acid.*

Example Lab Report – See D2L for an example

Investigation 1: Intermolecular Forces(IMFs) of Liquids

> **a)** Can the magnitude of intermolecular forces in a compound be used to identify a set of unknown compounds?
> **b)** What compound almost killed Max?

Content Connection:

Intermolecular Forces

Narrative:

Who tried to kill Max…what are these unknown liquids? Max has made someone angry…or was it an accident and Max ingested something from the chemistry lab because he had his drink open and was taking sips during the experiment? Max ended up in the hospital for ingestion of a suspicious substance. A vial labeled with the letter D was found in his bag. He thought he had just consumed too many wine coolers the night after his chemistry class. Your mission…analyze the unknown liquids using the indicated methods. These methods focus on the presence or absence of IMF's, as well as the extent of these forces.

Max's Symptoms: nausea, pain in belly area (abdomen), fruity odor on breath

Pre-lab assignment(s)

1) Draw Lewis structures for the unknown liquids, and indicate the number of H-bonds one molecule could form with other molecules of itself in a pure liquid sample.
2) Indicate if each unknown is polar or nonpolar. Given this information and that glass is polar, which unknowns should be attracted to glass?
3) Determine how surface tension is measured, describe the method and compare this to the penny drop method. What unit is surface tension measured in?
4) Determine how capillary action is measured and describe the method. There is a formula that relates surface tension, density, and radius of a capillary tube, find that and list here.
5) Describe the Leidenfrost effect. In which test might you observe this?

Safety Precautions:

Follow all lab safety procedures and wear goggles. Wash your hands before leaving the laboratory. No open flames.

Materials available

Possible Unknown Liquids
Toluene
n-Butanol
Hexane
ethylene glycol
Acetone
hydrogen oxide

Hot Plates
Aluminum Foil
Burets
Friction Rods
Balloons
Dropping Ball Apparatus

Pennies
Stop Watches

Suggested Method(s):

There are five stations set up for you. Read the descriptions of these stations below and be ready to discuss the procedures with your classmates to ensure consistency.

Station#1:

Effect of a charged rod on a stream of liquid: Use this test to determine polarity of the unknown liquid. Can a compound be induced to respond to a charged rod if the charge is great enough? Report your observations as to whether or not the stream of liquid responded to the charged rod and to what degree.(maybe on a scale of 1-10)

Station#2:

Rate of Evaporation and the connection to volatility: Use a hot plate to determine to the rate of evaporation of the unknown liquids. Cover the surface of the hot plate with aluminum foil and apply a number of drops of the substance to the hot plate. How many drops should you use…how hot should it be…use small amounts and be consistent with the class. Report your answer in seconds.

Station#3:

Surface Tension-number of drops on a penny: Use this test to determine the relative surface tension of the liquid. Report your answer in number of drops that ***stayed*** on the penny.

Station#4:

Viscosity: Speed of a falling ball: Use this test to determine the relative viscosity of the unknown liquid. Time and record the number of seconds it takes for the ball to travel through a specified distance. Report your answer in meters per second.

Station#5:

Capillary action and polarity: Use this test to determine the extent of attraction for each liquid to glass. Record the height in millimeters the liquid rises.

Team Table Layout

Each group will do all assigned unknowns but only record your assigned unknown in the team table.

Group Name	**Unknown Substance**	**Station #1: Observations**	**Station #2(sec)**	**Station #3 (# drops)**	**Station #4(m/sec)**	**Station #5(mm)**
	A					
	B					
	C					

Post Analysis:

Research the literature for the known surface tension, viscosity, heat of vaporization, and relative polarity for each substance to help you identify the unknowns and corroborate your findings. P**resent** this information in a table. This identification should be based on IMF's and physical properties. Include this in your results and discussion section. Relative values are indicated using the numbers 1-6, 1 being the most, and 6 being the least.

Substance	Observations at Buret	Polar/ Nonpolar	Volatility (sec)	Relative Volatility	Surface Tension (Ave # drops)	Relative Surface Tension	Time for Falling Ball(sec)	Relative Viscosity	Identity of Unknown with Explanation
A									

Lab Report Checklist - IMFs Activities.

___/7 Pre-lab Assignment/questions:

1) Draw Lewis structures for the unknown liquids, and indicate the number of H-bonds each can participate in with another molecule of itself.
2) Find the relative polarities of the possible unknown liquids given in the materials section below.
3) Determine how surface tension is measured, describe the method and compare this to the penny drop method. What unit is surface tension measured in?
4) Determine how capillary action is measured and describe the method. There is a formula that relates surface tension, density, and radius of a capillary tube, find that and list here.
5) Describe the Leidenfrost effect. In which test might you observe this?

___/2 Reagent Table / Toxicity/Interesting Fact:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/1 Header: Make sure to fill out each header area.

___/3 Procedure:

Cite the source of your procedure. Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/3 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and observed. Include physical observations of all chemicals, molarities and anything you did in the lab.

___/3 Summary:

Type a narrative of what you did and observed. Include reference to any graphs drawn(page #), and/or calculations(page #) done to arrive at the result(s) you are reporting. Use subscripts and superscripts for chemical formulas.

Research the literature for the known surface tension, viscosity, heat of vaporization, and relative polarity, for each to help you identify the unknowns and corroborate your findings and **present** in a table. This identification should be based on IMF's and physical properties. Include this in your results and discussion section. Relative values indicate using the numbers 1-6, 1 being the most, and 6 being the least. How does this compare to your predictions from the pre-lab?

____/2 Table(s)

Include a table of your results embedded in summary and of team table, include caption(s)

Substance	**Observation at Buret**	**Polar/ Non**	**Volatility (sec)**	**Relative Volatility**	**Surface Tension(Ave # drops)**	**Relative Surface Tension**	**Time for Falling Ball(sec)**	**Relative Viscosity**	**Identity of Unknown with Explanation**
A									

____/3 Conclusions:

In conclusion, this experiment was performed in order to ….then explain why you did it and if it answered the hypothesis or question posed. If it did not, then what experiment could you perform to answer that question(s). Address error here.

___/1 Signed

Each page as you did it and instructors signature after you finish

___/5 Post Questions:

Look for these on D2L Announcements!

Investigation 2: Rate of evaporation and Intermolecular Forces?

a) Can the change in temperature upon evaporation of a liquid be measured and what insights can this provide about intermolecular forces and the identity of a substance?
b) Can the *rate* of evaporation of a solvent be measured, and if so, how does this relate to the extent of IMFs present in a substance?

Content Connection:

Intermolecular Forces and evaporation

Narrative

Intermolecular forces have an effect on many physical properties, such as boiling point, melting point, and evaporation. Evaporation occurs below the boiling point of a substance, and is affected by air movement and temperature. In this investigation, we will look at the effects of intermolecular forces on the rate of evaporation of various liquids.

Pre-lab assignment(s)

1) Draw **Lewis structures** for the unknown liquids given in the materials section.
2) **Prediction Table**
   For each molecule. predict, based upon structure, if the molecule is polar or nonpolar, can participate in hydrogen bonds, and if so how many hydrogen bonds *per molecule* if it was hydrogen bonding with another molecule of itself. Include the boiling points and heat of vaporization for each substance. Cite your source(s) of information.
3) **Explain** the effect of molar mass on intermolecular forces.
4) **Predict** which compound you would think would have the highest rate of evaporation. Explain.
5) **Predict** which compound you would think would have the greatest temperature change upon evaporation. Explain.

Safety Precautions:

Follow all lab safety procedures and wear goggles. Wash your hands before leaving the laboratory. No open flames.

Materials available

Unknown Liquids
n-pentane
n-butanol
ethylene glycol
acetone
tertiary-butanol
Hydrogen oxide
n-hexane
n-propanol
methanol
ethanol

Temperature Probes
filter paper
Lab Quests
Twist ties

Suggested Method(s)

1. Use a temperature probes and a LabQuest to monitor the temperature change upon evaporation of a solvent from solvent-soaked filter paper wrapped around a temperature probe.

2. We will be using the time-based mode of data collection. Set your lab quest to collect data for at least 300 seconds. Do multiple runs so a graph can be printed of all runs on one graph for comparison.

3. Wrap the temperature probe with ***narrow strips*** pieces of filter paper secured by twist ties. Does the size of the filter paper affect the time or rate of evaporation? Roll the filter paper around the probe tip in the shape of a **cylinder** to ensure maximum contact to the probe. We want to measure how much heat the substance is using from the surroundings upon evaporation as well as how **fast** the temperature change occurs.

4. Stand the probe with its wrapped filter paper in the solvent you are measuring for at least 15 seconds to ensure the paper is fully saturated. Start data collection, then **remove** the probe to let the solvent evaporate.

5. You can tape the probe to your counter with masking tape, and you may do two probes at once.

6. Collect the data for all liquids in multiple runs so that you may overlay all these graphs one on top of each other. This is done by selecting the new run icon, which resembles a filing cabinet in the upper right corner of you screen when you are viewing graph. Print your graph showing all runs and label each curve as to unknown letter.

7. Data collection will stop after 5 minutes. Examine the graph of temperature vs time to determine the maximum temperature, $\mathbf{t_1}$, and minimum temperature, $\mathbf{t_2}$, reached by each process of evaporation.

8. For each liquid, determine the change in temperature(Δt) and the rate of evaporation. The magnitude of this can further help us identify the unknowns relative to each other. Make sure to divide by the number of seconds it took to ***evaporate***, not by the entire time the temperature was measured. Record this in the team table.

9. Draw picture of your apparatus.

Team Table Layout

Each group do all of the unknowns. Report the data of one unknown per group for corroboration.

Group	Unknown	Change in temperature upon complete evaporation (°C)	Time to reach lowest temperature (sec)	Rate of Evaporation (°C/s)	Physical observations of liquid and evaporation process

Lab Report Checklist-Evaporation and IMFs.

___/5 Pre-lab assignment/questions:

a. Draw **Lewis structures** for the unknown liquids given in the materials section.

b. **Prediction Table**

For each molecule. predict, based upon structure, if the molecule is polar or nonpolar, can participate in hydrogen bonds, and if so how many hydrogen bonds *per molecule* if it was hydrogen bonding with another molecule of itself. Include the boiling points and heat of vaporization for each substance. Cite your source(s) of information.

c. **Explain** the effect of molar mass on intermolecular forces.

d. **Predict** which compound you would think would have the highest rate of evaporation. Explain.

e. **Predict** which compound you would think would have the greatest temperature change upon evaporation. Explain.

___/2 Reagent Table / Toxicity/Interesting Fact:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Choose one chemical to research further and report an interesting fact about it. cite sources

___/1 Header: Make sure to fill out each header area.

___/3 Procedure:

Cite the source of your procedure. Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/3 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and observed. Include observations of all chemicals, molarities and anything you did in the lab.

___/1 Calculations:

Rate of Evaporation

___/3 Summary:

Type a narrative of what you did and observed. Include reference to any graphs drawn(page #), and/or calculations(page #) done to arrive at the result(s) you are reporting. Use subscripts and superscripts for chemical formulas.

____/2 Table(s)

Include a table of your results embedded in summary and of team table, include caption(s)

____/4 Conclusions:

In conclusion, this experiment was performed in order to ….then explain why you did it and if it answered the hypothesis or question posed. If it did not, then what experiment could you perform to answer that question(s). Address error here.

___/1 Signed

Each page as you did it and instructors signature after you finish

___/5 Post Questions:

Look for these on D2L Announcements!

Investigation 3: Freezing Point Depression and Molecular Weight

a. Can freezing point depression phenomena alone be used to identify an unknown?
b. If not, what other tests are necessary to identify an unknown?
c. What substance killed Max?

Content Connection:

Colligative Properties, freezing point depression, physical and chemical tests to determine an unknown

Narrative:

Now, on to the experiment…when a solute is dissolved in a solvent, the freezing temperature is lowered in proportion to the number of moles of solute added. This property, known as freezing-point depression, is a *colligative property*; that is, it depends on the ratio of solute and solvent particles, not on the nature of the substance itself. The following equation describes this relationship

$$\Delta T_f = \text{i}\, K_f m$$

Where ΔT_f is the measured freezing point depression in degrees Celsius, K_f is the freezing point depression constant for a particular solvent, m is the molality of the solution (in mol solute/kg solvent), and i is the van't Hoff factor. The van't Hoff factor describes the ability of a solvent to separate into more than one particle upon dissolution in a solvent. Ionic compounds will dissociate in water into more than one ion, which compounds the colligative effect by a factor of how many particles into which it dissociates.

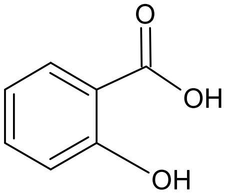
What really killed Max …what are these substances…again. Your mission…analyze the unknown substances using the phenomenon of freezing point depression. This will enable the determination of the molar mass of the compound. You will also use various physical property to narrow the identity of the unknown. The compounds listed below were known to have been in Max's apartment. Max seemed to act drunk but did not smell like alcohol. His girlfriend was using these substances in her chemistry lab at medical school. She was working as a TA and had access to all these and liked to bring samples home to show Max…unknown # 7 bottle was completely empty.

Max's Symptoms: nausea, vomiting, convulsions, stupor, coma and death.

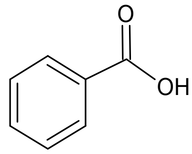
Pre-lab assignment(s)

1) Look up the freezing points and freezing point depression constant(K_f) values for each **solvent** listed in the materials below and present in a table.
2) Determine the molecular formula, molecular weight, melting point and van't Hoff factor of each unknown substance and present this in a table.
3) Write 2-3 sentences for each about the how you would experimentally determine the melting point of a solid, the density of liquid, and the solubility of the unknowns in the solvents cyclohexane, tert-butanol, and water. Cite any outside sources.
4) For the unknown assigned to you, determine the minimum *mass* required to decrease the freezing point of **each solvent** by 1.5°C. Assume you will use 10.0 g of solvent. Present this in a table. Be prepared to put this in the board se we can work as a group.

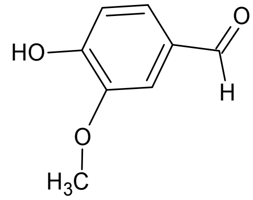
Possible Unknown Substances:



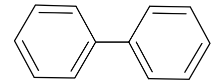
Salicylic Acid



Benzoic Acid



4-Hydroxy-3-methoxy-benzaldehyde



Biphenyl

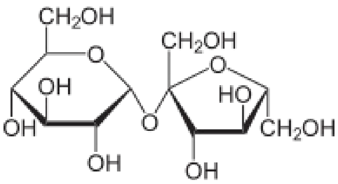
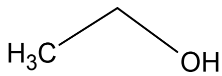
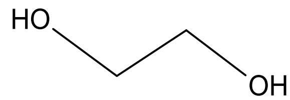


Table Sugar



Ethanol



Ethylene Glycol

NaCl
Sodium Chloride

Safety Precautions:

Follow all lab safety procedures and wear goggles. Wash your hands before leaving the laboratory. No open flames.

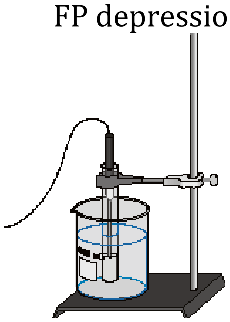
Materials available

Possible Solvents for FP depression experiment:	**Other Materials**
Water	Rock salt/ice-to make an extremely cold bath
t-butanol	Lab quest and temperature probes
cyclohexane	Mel-Temps and capillaries
	Large test tubes for FP depression

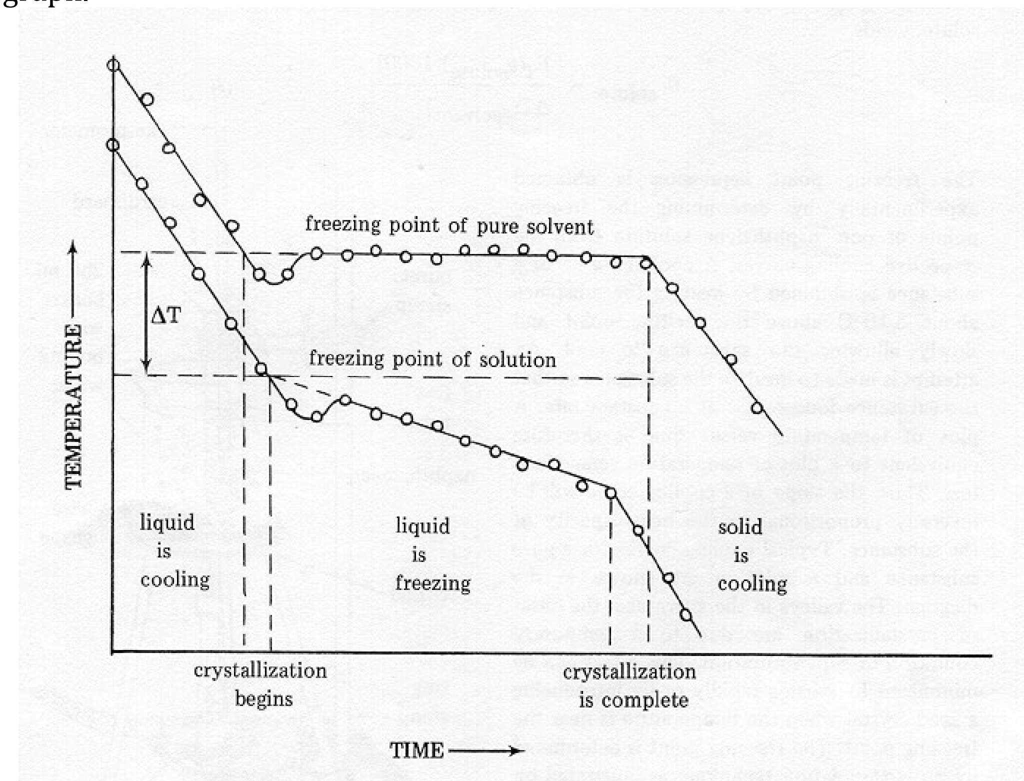
Suggested Method(s)

- Test the solubility of your unknown in cyclohexane, water, and t-butanol to decide what solvent to use for your freezing point depression experiment. Only use **small amounts** of unknown and solvent for solubility tests.

- Before you can determine the freezing point(FP) *depression* on a solvent caused by your unknown, you must determine the freezing point of the pure solvent. Obtain 10.0 g of your solvent. Use the **large** test tubes provided on the cart, a labquest, and a temperature probe to set up an apparatus to determine the freezing point of the pure solvent. Do not let the probe touch the glass of the test tube. Clamp it as in illustration. Generate a graph with the lab quest and save it. Make sure to measure and record the mass of solvent you are using. Save this solvent for the FP depression experiment.



- Thaw your frozen solvent. Choose to do a new run, so you can **print** them all on the same graph. Add an amount of your unknown to the solvent you just thawed, how much should this be? Check your pre-lab calculations to help you decide. Start with a small amount, because remember, the more solute the **lower** the freezing point, but if you add too much the FP becomes too low to reach. Do a run to see if a FP depression has occurred and if it is significant(large) enough to do a calculation of your unknowns molecular weight. See the following graph.



- Add some more of your unknown and run the thaw/freeze cycle again to determine if a FP depression has occurred and if it is significant enough, do another calculation of your unknown's molecular weight. Take the average of the two molecular weights you determined.

Physical Characteristic Tests

- If you have a solid unknown, perform a melting point determination. If you have a liquid, perform a density determination.
- Record physical observations of ***all*** unknowns in your notebook!

Team Table Layout:

Tabulate your data as a class for each unknown for corroboration. Each group test only one unknown. However, you must use class data to identify all the unknowns and to determine what killed Max.

Experimental Team Table

Group	UK #	UK Solubility in H_2O	UK Solubility in C_6H_{12}	UK Solubility in $C_4H_{10}O$	Solvent Grams	Freezing Point Pure Solvent	Grams Solute	Melting Point or density

Calculated Team Table

Group	UK #	Trial 1: ΔT_f(°C)	Grams Solute	Moles solute	Calculated MW (g/mol)	Trial 2: ΔT_f(°C)	Grams Solute	Moles solute	Calculated MW (g/mol)	Average MW (g/mol)	Notes/ Characteristics

Lab Report Checklist- Freezing Point Depression and Molecular Weight

___/4 Pre-lab Assignment:

1) Look up the freezing points and freezing point depression constant(K_f) values for each **solvent** listed in the materials below and present in a table.
2) Determine the molecular formula, molecular weight, melting point and van't Hoff factor of each unknown substance and present this in a table.
3) Write 2-3 sentences for each about the how you would experimentally determine the melting point of a solid, the density of liquid, and the solubility of the unknowns in the solvents cyclohexane, tert-butanol, and water. Cite any outside sources.
4) For the unknown assigned to you, determine the minimum *mass* required to decrease the freezing point of **each solvent** by 1.5°C. Assume you will use 10.0 g of solvent. Present this in a table. Be prepared to put this in the board se we can work as a group.

___/2 Reagent Table/Toxicity/Interesting Fact:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/0.5 Header: Make sure to fill out each header area.

___/3 Procedure:

Cite the source of your procedure. Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/3 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and observed. Include physical observations of all chemicals, molarities and anything you did in the lab.

___/4 Calculations:

Do the calculation for the molecular weights of ***each*** unknown to check your classmate's work. Show All Work. If there were two trials do both and take the average.

___/3 Summary:

Type a narrative of what you did and observed. Include reference to any graphs drawn(page #), and/or calculations(page #) done to arrive at the result(s) you are reporting. Use subscripts and superscripts for chemical formulas.

____/2 Table(s)

Include a table of your results embedded in summary and of team table, include caption(s)

_____/4 Conclusion Table

Create a table of all unknowns with their calculated molar masses, known molar masses, density , boiling/melting point, possible identifications, and the explanations for the identifications

____/3 Conclusions:

In conclusion, this experiment was performed in order to ....then explain why you did it and if it answered the hypothesis or question posed. If it did not, then what experiment could you perform to answer that question(s). Address error here

___/0.5 Signed

Each page as you did it and instructors signature after you finish

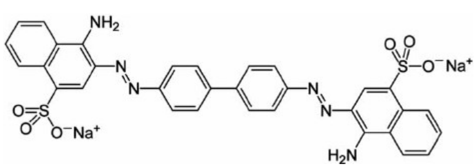
___/1 Post Questions:

Investigation 4: Getting rid of the evidence!

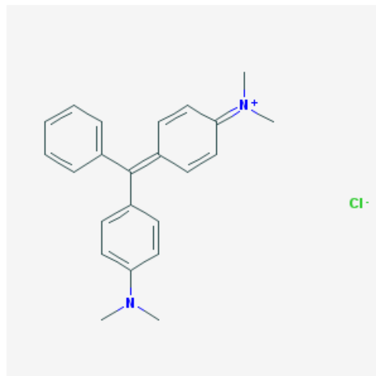
a) How is a rate law and its associated rate constant determined?
b) How is Beer's Law used to determine concentrations of substances in aqueous solutions?
c) How does a graphical representation of the progress of a reaction indicate order?
d) Which dye will disappear the fastest?

Content Connection:

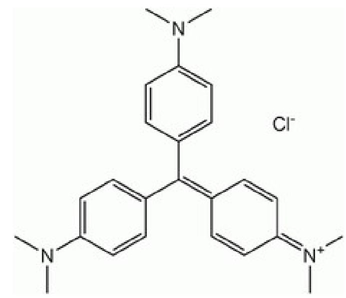
- Use of Beer's law to determine concentrations
- Determining rate laws and rate constants



Congo Red(CR)



Malachite Green(MG)



Crystal Violet(CV^+)

Narrative:

Kinetics is the study of how rapidly, or slowly, a reaction occurs. This experiment studies the rate of the reaction of the bleaching of dyes, by either sodium hypochlorite or sodium hydroxide.

$$NaOCl + Dye \rightarrow \text{Colorless products}$$
$$NaOH + Dye \rightarrow \text{Colorless products}$$

In this activity, the goal is to determine the "rate law" for the reaction above. Once we have the rate law, we can predict the rate of the reaction for a wide range of experimental conditions. The rate law has this form:

$$\text{Rate} = k[\text{dye}]^m[\text{bleaching agent}]^n$$

and contains two types of information:

- The order of the reaction, *n* and *m*, with respect to the concentrations of the reactants. The rate of this reaction is proportional to the concentration raised to the "order" for that reactant. For first order, the rate is proportional to concentration raised to the first power, and **doubling** the concentration of that reactant **doubles** the rate. For a second order, **doubling** the concentration quadruples the rate, and for a zero order reaction, altering the concentration of a reactant has no effect on the rate.
- The rate constant, *k*, is the proportionality constant that is specific for the reaction being studied. It is like a fingerprint, and provides information about the mechanism of the reaction as well as the order of each reactant. This will also tell us how fast this reaction goes in general, when compared to other reactions.

To determine the rate law, we will measure the rate of the reaction of a dye with either bleach or sodium hydroxide. This will be measured by monitoring the disappearance of color during the reaction. We will determine the rate constant from the graphs generated for the individual experiments after determining the rate law.

What is really being measured in this experiment is the concentration of the species in solution over time, indirectly through absorbance. The behavior of the reaction points to the order of each reactant in the rate law with respect to that substance. The dyes have a color when dissolved in water that can be measured spectrophotometrically, therefore the behavior of the dye as it undergoes its reaction with the bleaching agent can be followed and analyzed. This leads to the order of reaction with respect to the dye. The bleach or sodium hydroxide does not have a color, but the *effect* of the bleach(or sodium hydroxide) on the rate of reaction, and hence *its* order, can be indirectly determined by its effect on the reaction at varying concentrations of itself.

Pseudo rate orders

Any reaction that has more than one reactant can be difficult to follow, since changes in both reactant concentrations are occurring simultaneously (and potentially with different reaction order.) Many reactions falls into this category. In such situations, chemists often will instead find the *pseudo rate law* for one reactant. In this method, one of the reactants is present in large excess relative to the other. For example, consider the reaction

$$A + B \rightarrow \text{Products}$$

Suppose that the initial concentrations of A and B are 0.0001 M and 0.2000 M, respectively. We see that [B] >>[A]. If the reaction goes to completion, all of A is consumed as it is the limiting reactant, and the concentrations of both reactants will have decreased by 0.0001 M. The final concentration of B at the end of the reaction is then 0.2000 M – 0.0001 M = 0.1999 M, a decrease of only 0.05 %. Therefore the concentration of B remains essentially constant during the reaction, and can be factored out of the calculations.

Determining the order of reaction for the dye

If a trial is run such that the [bleaching agent] >> [dye], the rate law now takes the form:

$\text{Rate} = k'[\text{dye}]^m$ where $k' = k[\text{bleaching agent}]^n$ (This is the factoring out spoken of above)

Since this pseudo-rate law only contains one species, a graphical method can be used to determine both the numerical value of k' as well as the value of the exponent, m, the order of reaction with respect to the dye. This is assuming the absorbance is proportional to [dye].

The graphical method involves running a trial with a specific concentration of dye and an excess of bleach, then preparing three plots from this data. These are absorbance vs. time, ln(absorbance) vs. time, and 1/absorbance vs. time. Only one of these graphs will produce a straight line. The treatment that produces a straight line will indicate the value of the exponent for the dye, and the absolute value of slope will = k'.

Determining the order of reaction for the bleaching agent

The absolute value of the slope of each linear plot tells you the value of k' for that trial. By comparing the three values of k' with the concentrations of bleaching agent for each trial, the order of the reaction for the bleaching agent can be found.

Since $k' = k[\text{bleaching agent}]^n$

We can analyze experimentally what happens to k' (slope) when [bleaching agent] is altered.

- If k' does not change from one reaction to another when the bleach is doubled, the reaction is zero-order in bleaching agent and n = 0.
- If k' doubles when the bleaching agent is doubled, the reaction is first-order in bleaching agent and n = 1.
- If k' quadruples when the bleaching agent is doubled, the reaction is second-order in bleaching agent and n = 2.

Finding k

Once you know the value of n and k'(which is the slope) and $k' = k[\text{bleaching agent}]^n$ you can solve for the value of k for each of the three trials based on the bleaching agent concentration. Substitute in the known value of bleaching agent, its exponent and k' to calculate the rate constant for the reaction, k.

Voila!

So, what do we need to do to determine the rate law again…?

A. Determine the wavelength that will be used to monitor the reaction. This is different for each dye and is called the analytical wavelength.

B. Determine if Beer's law is obeyed for this species. Beers law, which is the simply the fact that an absorbance versus concentration study of varying concentrations in an aqueous solution will produce a straight line(y=mx +b), must be obeyed to perform any rate studies using absorbance. Absorbance measurements are most accurate and sensitive in the range 0.2–1.0 M. Therefore, we must create a plot of absorbance at the varying concentrations within these values. If we get a straight line, Beer's law is obeyed, and we can use this technique to study the rate of reaction.

C. Do a rate study by

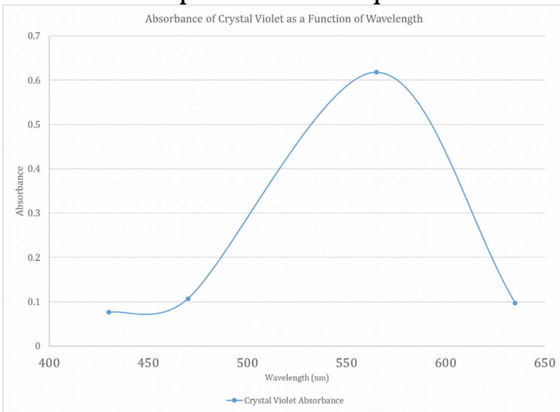
   a. Analyze various graphical treatments of the reaction of the dye with the bleaching agent at a specified concentration of both. Only one experiment is run here and various treatments graphically are created. This will indicate the order of the reaction with respect to the dye.

   b. Vary the concentration of the bleaching agent and keep the concentration of the dye constant. Analyze the variation of the pseudo-rate constant k' with these concentration changes. This will infer the order for the bleaching agent(NaOCl or NaOH).

D. Use the experimentally determined rate law to calculate the rate constant. From this determine which reaction will be the fastest.

Pre-lab assignment(s)

1. Dyes that are dissolved in solution will absorb some wavelengths and transmit others. A visible *absorption* spectrum of a colored compound in an aqueous solution is given below.

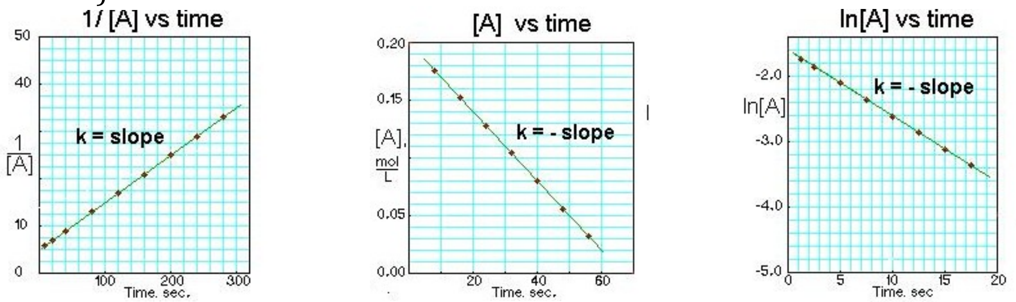


From this graph of absorbance versus wavelength, determine the analytical wavelength of absorption for this compound. This would be used for generating a Beer's law calibration curve for this substance and it is the wavelength of *greatest* absorbance in the above figure.

2. To determine if Beer's law is obeyed, you will prepare a graph of absorbance(at the analytical wavelength) versus concentration of your assigned dye. Using a 25 micromolar(μM) solution as the stock solution, complete the following table to show how you will prepare 20, 15, 10, 5 and 2.5 μM(micromolar) solutions of one of the dyes. Use a final solution volume of 10.0 mL in all cases.

	Stock Solution	A	B	C	D	E
Concentration(M)	2.5×10^{-5} M(25 μM)	2.0×10^{-5} M	1.5×10^{-5} M	1.0×10^{-5} M	5.0×10^{-6} M	2.5×10^{-6} M
Water (mL)	0					9.0
Stock Solution (mL)	10.0					1.0

3. In order for the reaction to not occur too quickly, the bleaching agent will have to be diluted.
   a. Commercial bleach is 6% NaOCl m/m. Given that the density of 6% NaOCl is 1.163 g/ml, determine the molarity of commercial bleach. In your calculation, assume 1000 g of solution.
   b. For a rate study, a 5%, 10%, and 20% concentration of stock bleach is usually effective. What molarity of bleach does this correspond to? (Hint: Take these percentages of the molarity you found in a. above)
   c. List the molarities of the sodium hydroxide from the materials section here.
4. You will be running the reaction between a dye and a bleaching agent. Various permutations of the graph of the concentration of dye([Dye]) versus time may result.
   a. Identify each of the following graphs as to the order with respect to the dye(Zero, First, or Second)



5. What does it mean to create a "pseudo first order" reaction? Why would this be necessary?

Materials and Equipment

(caution: all these may leave permanent marks on clothes)

- 5%, 10% and 20% of stock bleach solution
- Sodium Hydroxide(0.100 M, 0.050 M, 0.0250 M)
- Congo red (25.0µM)
- Malachite Green(25.0µM)
- Crystal Violet(25.0µM)

Colorimeters
LabQuest
Plastic Cuvettes

Chemical Disposal

All chemicals and solution may be disposed of down the drain

Suggested Procedures

A. Determining analytical wavelength to study the concentration of Congo Red(CR), Crystal Violet(CV) and Malachite Green(MG)

i. Connect a spectroVis plus to a labquest. Fill a cuvette with the stock concentration of your assigned dye and run a wavelength scan of the absorbance of your dye versus wavelength(nm). Find the wavelength of greatest absorbance. This will be the analytical wavelength to study absorbance for your assigned dye.

B. Creation of a Beer's Law Calibration Curve: Determination if Beer's law is obeyed.

i. For your assigned dye, create each solution according to the information in pre-lab question #2. Set the mode in your LabQuest to be "**Events with Entry".** Using the optimum wavelength for your assigned dye determined in part A and the colorimeter that only measures 4 wavelengths, measure the absorbance of each solution you created. Choose the wavelength that is closest to what you determined in part A. Construct a Beer's Law graph. You should have 6 data points in the graph. After you are finished creating your graph, find the equation for the line.

	25µM	20µM	15 µM	10 µM	5 µM	2.5 µM
Absorbance Crystal Violet						

ii. Determine if Beer's law is obeyed. If it is, move on to the kinetics study of your assigned dye.

iii. Determine the absorbance of an unknown solution of your dye and use your equation to determine the concentration. This calculation needs to be shown.

C. Determining the order of reaction with respect to the dye

As described above, since there are two reactants in this reaction, we will need to have one in a significant excess in order to be able to apply the pseudo rate law concepts. Since we are following the extent of reaction by color, then it must be the dye that is the limiting reagent and the bleach, or sodium hydroxide, in excess (otherwise the color wouldn't change appreciably.) To test the rate of discoloration of **Congo Red** we will be using **bleach**. For the rates of discoloration of **Malachite Green** and **Crystal Violet** we will use **Sodium Hydroxide**. The concentrations of the green, blue and red dyes are provided on the bottle (i.e. the stock solutions, all 25 µM).

In order to measure the absorbance of the solution, you will need to:

- Zero the spectrometer using a blank. The Congo Red will use a 20% bleach and the other two dyes will use sodium hydroxide diluted with an equal volume of water as a blank. This will approximate the residual materials left in your cuvette after the reaction has completed.

- Change the mode on the labquest to Time Based. Your data collection will be for 10 minutes (600s).
- Do the two steps below in 5 seconds or less:
  - Begin collecting data
  - Mix 5 mL of the bleach solution (or sodium hydroxide) and 5 mL of your dye solution in a 50 mL beaker. Quickly swirl this to mix the solutions, then transfer a portion of the liquid to your cuvette. Insert the cuvette in the spectrovis plus.
- Save the data. On the table of data, scratch all the data that was saved from the beginning of the data collection up until the first sign of dye decomposition. This is to scratch all the zeroes that you will have at the beginning as well as any data recorded during the insertion of the cuvette. The initial data point that you keep must be the highest reading recorded by the colorimeter.
- Do a graphical analysis of this data to determine the order of the [dye]. If the reaction order is **zero** then a plot of [Dye] vs time will be linear. If the reaction order is **first** then a plot of ln[Dye] vs time will be linear. If the reaction order is **second** then a plot of 1/[Dye] vs time will be linear. Do all three treatments and take a picture of each one of these graphical treatments to include in your report, as evidence.

D. Determining the order of reaction with respect to the bleach
Run three trials as outlined in the table below. Do multiple runs so we can overly them on each other. Save the graph to print or take a photo to insert in report.

- Mix 5 mL of the bleach solution (or sodium hydroxide) and 5 mL of your dye solution in a 50 mL beaker. Quickly swirl this to mix the solutions, then transfer a portion of the liquid to your cuvette.
- Begin collecting data.
- Save the data

Experimen t	[Dye]	[NaOCl] or [NaOH]	k'(from slope of appropriate graph)
1	25 mM	5% or 0.025 M	
2		10 % or 0.050 M	
3		20 % or 0.100 M	

E. Determine k.
Remember that the slope of the straight line that you get in your graph to determine the correct order is related back to the value of k'**.** The value of k' will be used to determine the actual rate constant k.

Calculations: Results (Graphs, calculations and tables)

In a calculation sections, do a recap of any calculations that were done to explain how you arrived at the order of the reaction with respect to the dye and bleach, and how you determined k' and k. **Once you know what k is; you can determine which dye will disappear first.**

Team Table:

Tabulate your data (determined rate law rate for the unknown trial, and concentration of unknown) as a class for the unknown for corroboration. Put this information in your notebook.

Group Names	Assigned Dye	Analytical wavelength (nm)	Beer's Law equation	Unknown concentration (M)	Rate law	Rate constant(k) (include units)

Lab Report Checklist: Chemical Kinetics to Dye For!

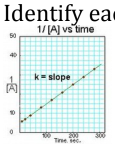
___/5 Pre-lab assignment/questions:

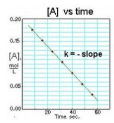
1. From this graph of absorbance versus wavelength, determine the analytical wavelength of absorption for this compound. This would be used for generating a Beer's law calibration curve for this substance.

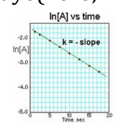
2.

	Stock Solution	A	B	C	D	E
Concentration(M)	2.5×10^{-5} M(25 μM)	2.0×10^{-5} M	1.5×10^{-5} M	1.0×10^{-5} M	5.0×10^{-6} M	2.5×10^{-6} M
Water (mL)	0					9.0
Stock Solution (mL)	10.0					1.0

3. In order for the reaction to not occur too quickly, the bleaching agent will have to be diluted.
   a. Commercial bleach is 6% NaOCl m/m. Given that the density of 6% NaOCl is 1.163 g/ml, determine the molarity of commercial bleach. In your calculation, assume 1000 g of solution.
   b. For a rate study, a 5%, 10%, and 20% concentration of the stock bleach is usually effective. What molarity of bleach does this correspond to? (Hint: Take these percentages of the molarity you found in a. above)
   c. List the molarities of the sodium hydroxide from the materials section here.
4. You will be running the reaction between a dye and a bleaching agent. Various permutations of the graph of [Dye] versus time may result.
   a. Identify each of the following graphs as to the order with respect to the dye(Zero, First, or Second)







5. What does it mean to create a "pseudo first order" reaction? Why would this be necessary?

___/2 Pre-lab -Reagent Table / Toxicity:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/1 Header:

Make sure to fill out each header area.

___/3 Procedure:

Cite source. Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/2 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and saw. Include observations of all chemicals, molarities and anything you did in the lab.

___/4 Calculations –

Concentrations of unknown solution and rate law and rate constant

___/3 Summary:

Summary of what you did and observed.

___/2 Table(s)

Include a table of your results embedded in summary and of team table, include caption(s)

___/4 Conclusions:

- *In conclusion, this experiment was performed in order to*....then explain why…

___/1 Signed

Each page as you did it and instructors signature after you finish

___/3 Post Questions:

Look for these on D2L Announcements!

Investigation 5: LeChatelier's Principle

a. How well can I speak "chemistry"?
b. Can I write a procedure and associated observations in as few words as possible… representing steps and observations mainly using chemical equations?
c. Can it be determined what is taking place chemically at each step?

Content Connection:

Interpretation of Le Chatelier's Principle and equilibrium

Narrative:

The understanding and application of the equilibrium of chemical reactions can create a world power, or destroy one.

The equilibrium state of a chemical reaction is dictated by the equilibrium constant of that specific reaction, at that temperature. To truly understand and follow what is occurring in an equilibrium state, the equilibrium created must be identified and tracked. The question is, how can one know that a system is in equilibrium at all? Answer? If it can be made, by the alteration of various parameters, to shift its position from one side of the equilibrium to the other, or vice versa. This shift can be visualized by a change in color or the appearance or disappearance of a precipitate. This experiment's goal is two-fold, 1) to identify what is chemically happening at each step and 2) to write your procedural and observational steps as succinctly as possible, using chemical equations, symbols and pictures wherever possible, including molarities of each solution used and phase labels. Make physical observations at each step before, during and after in the observations section of your notebook across from the equations representing those steps as well as the chemical formulas for any products you made, or think you made. See symbol table below.

Symbol	Meaning
+	Added To
$\rightarrow$	Yields or produces
$\rightleftharpoons$	In equilibrium or reversible(i.e. an $\rightleftharpoons$ of AgCl)
(s)	Solid
$\downarrow$	Precipitate formation
$\downarrow$ NaCl	Decrease in concentration of NaCl(any substance could be here)
(aq)	Aqueous solution or dissolved in water
An Arrow w/ a Δ above	Adding heat to the forward reaction
(l)	Liquid
(g)	Gas
$\uparrow$	Gas formation
$\uparrow$ $NaNO_3$	Increase in sodium nitrate concentration(any substance could be here)
gtt.	Abbreviation meaning drops (from the Latin "guttae", drops). One of a number of hallowed abbreviations of Latin terms that have traditionally been used in prescriptions. Retrieved from medicinenet.com
tt	Test tube
cc	Color change (i.e. cc red)
mL	Milliliters

- If you use your own abbreviations, make sure to define them.

Example Notebook Entry:

Procedure:	Observations
1) $NaCl(aq) + AgNO_3(aq)$	1) Clear, colorless-before

(0.1 M) (0.1 M) supernatant cloudy after mixing
How much? white ↓ - possibly AgCl ?

Pre-lab assignment(s)

1) We will be creating and shifting the position of the following equilibrium

$$[Cu(H_2O)_6]^{2+}{}_{(aq)} + 4NH_{3(aq)} \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+}{}_{(aq)} + 4H_2O_{(l)}$$

Light blue dark blue

Go to this [fabulously helpful chemistry]() site and research the colors of the following complex ions:

$[Cu(H_2O)_6]^{2+}{}_{(aq)}$

$[Cu(NH_3)_4(H_2O)_2]^{2+}{}_{(aq)}$

$[CuCl_4]^{2-}{}_{(aq)}$

2) We will be creating the following equilibrium

$$[Co(H_2O)_6{}^{2+}]_{(aq)} + 4Cl^-{}_{(aq)} \rightleftharpoons [CoCl_4]^{2-}{}_{(aq)} + 6H_2O_{(l)}$$

pink blue

Go to this [fabulously helpful chemistry site]() and research the colors of the following complex ions:

$[Co(NH_3)_6]^{2+}$

$[CoCl_4]^{2-}{}_{(aq)}$

Which of these do you think would form if excess concentrated hydrochloric acid were added and what color would your solution be?

3) We will be creating an equilibrium between silver ions, carbonate ions, and solid silver carbonate. We will do this by combining 0.01 M silver nitrate and 0.010 M sodium carbonate.
   a. Starting with 2.0-ml of 0.01 M silver nitrate, **calculate** the appropriate volume of 0.010 M sodium carbonate that would completely react with the silver nitrate. Show all work.
   b. Write the equilibrium between silver ions, carbonate ions, and solid silver carbonate that would result, putting the solid as the reactant.

Safety Precautions:

Follow all lab safety procedures and wear goggles. Wash your hands before leaving the laboratory. No open flames.

Materials available

0.1 M Copper(II) Sulfate ($CuSO_4$)
0.1 M Sodium Carbonate(Na_2CO_3
0.01 M Silver Nitrate($AgNO_3$)
15 M ammonium hydroxide(NH_4OH)
0.1 M Potassium Iodide(KI)
0.1 M $CoCl_2$ in 12 M Hydrochloric Acid(HCl)
0.1 M Hydrochloric Acid(HCl)
1 M Hydrochloric Acid(HCl)
6.0 M Nitric acid(HNO_3)
Sodium Chloride(NaCl)

Suggested Method(s)

1) The $[Cu(NH_3)_4(H_2O)_2]^{2+}/[Cu(H_2O)_6]^{2+}$ equilibrium:

Using the copper(II) source of copper(II) sulfate(what color is this?) and a source of ammonia, create equilibrium(A) with 1-mL of the 0.1 M copper sulfate and the 15 M ammonium hydroxide, ***dropwise***. The resulting solution should be dark blue, but transparent. This will be your reference test tube. Record everything you did, how much you used, and what each solution looked like before and after additions.

Equilibrium(A) $[Cu(H_2O)_6]^{2+}{}_{(aq)} + 4NH_{3(aq)} \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+}{}_{(aq)} + 4H_2O_{(l)}$

Light blue dark blue

a) Create a new $[Cu(NH_3)_4(H_2O)_2]^{2+}/[Cu(H_2O)_6]^{2+}$ equilibrium in another test tube. Shift this equilibrium by adding hydrochloric acid dropwise. Which concentration of HCl would be the best based on the ammonia concentration you used to create the equilibrium, and how much should you add? Clear your choice with your instructor before you continue. Record everything you did and observed, including concentrations and colors.

b) Continue to add this hydrochloric acid until you see another color change. A new equilibrium is being created between a new complex of copper and the $[Cu(H_2O)_6]^{2+}$ complex ion. What equilibrium was created here? Hint: This one involves chlorine and a copper chlorine complex. (let's call it equilibrium(B)). Write that in your notebook now. Clear with your instructor before you continue.

c) Add water to the same test tube until you see another color change. Which way did equilibrium (B) shift?

d) Add ammonium hydroxide to this same test tube until you see a color change. Which equilibrium was re-established?

e) Create a new $[Cu(NH_3)_4(H_2O)_2]^{2+}$/$[Cu(H_2O)_6]^{2+}$ equilibrium (A) in another test tube with as little ammonium hydroxide as possible. Add water to this until it is at least 5 times its volume. Heat and cool this solution you just created. What color change is observed? What does this indicate about the thermochemical nature of equilibrium (A)?

f) Create another equilibrium(A) in another test tube. Can this equilibrium by shifted by just adding water? Try adding water until you see a shift of equilibrium (A) to the reactants, then add a drop or two of ammonia again. Record everything you did and observed, including concentrations and colors.

g) Using a sample of just $[Cu(H_2O)_6]^{2+}$ source, add an excess of solid sodium chloride. What equilibrium was created here? Add water slowly until a color change occurs. Which way did ***this*** equilibrium shift?

h) To the test tube from g), slowly add 1-3 drops of 15M ammonium hydroxide. Which equilibrium has been re-established at this point?

2) The $Co(H_2O)_6^{2+}]_{(aq)}$ /$[CoCl_4]^{2-}_{(aq)}$ equilibrium:

With 1-mL of 0.1 M $CoCl_2$ in 6 M Hydrochloric Acid(HCl) as your source of the following equilibrium:

Equilibrium (C)	$[Co(H_2O)_6^{2+}]_{(aq)} + 4Cl^-_{(aq)} \rightleftharpoons [CoCl_4]^{2-}_{(aq)} + 6H_2O_{(l)}$ pink blue

a) Investigate the effect of temperature on this equilibrium using ice water and hot water. Is the equilibrium endothermic or exothermic as written?

b) Shift this equilibrium by adding concentrated hydrochloric acid dropwise. Record everything you did and saw, including concentrations and colors.

c) Again, with a new 1-ml sample of the original equilibrium(C), shift it by adding water. Record everything you did and observed, including concentrations and colors.

3) Create the following equilibrium(D) as indicated in your pre-lab question 4). Record everything you did and observed, including concentrations and colors.

Equilibrium (D)	$Ag_2CO_{3(s)} \rightleftharpoons 2Ag^+_{(aq)} + CO_3^{2-}_{(aq)}$ tan solid

a) Shift this equilibrium by adding nitric acid(HNO_3). Be careful and always start dropwise, especially with the concentrated solutions. Record everything you did and observed. Acids react with carbonates to form carbonic acid(H_2CO_3). This then decomposes to carbon dioxide and water. Think about which way this equilibrium shifted and why.

b) At this point your test tube contains silver ions and nitrate ions. (What happened to the carbonate?) Add a few drops of 0.10 M HCl as a source of chloride ions.

   This creates a new equilibrium(E) of a solid in equilibrium with its ions. What solid was created? Write the chemical equation of the equilibrium of this solid with its ions in your notebook. Clear with your instructor before continuing. Record everything you did and observed.

c) To the same test tube, add a source of ammonia dropwise until you see the solid disappear. Make sure to agitate completely between each addition. This creates a new equilibrium(F), which is a silver-ammonia complex in equilibrium with the silver ion and a neutral molecule…what is this equilibrium? Write the chemical equation of this equilibrium in your notebook. Clear with your instructor before continuing.

d) Add HNO_3 to the same test tube to shift the equilibrium from step c) above. How does an addition of an acid shift the equilibrium in the previous step? What is the solid (re)created? Record everything you did and observed. What equilibrium was re-established? Clear with your instructor before continuing.

e) Recreate the initial equilibrium in another test tube. Investigate the effect of temperature. Is the original equilibrium endothermic or exothermic as written? Record everything you did and saw.

Lab Report Checklist._ LeChatelier's Principle

___/6 Pre-lab questions/assignment.

1) Colors of: $[Cu(H_2O)_6]^{2+}{}_{(aq)}$ $[Cu(NH_3)_4(H_2O)_2]^{2+}{}_{(aq)}$ $[CuCl_4]^{2-}{}_{(aq)}$
2) Colors of: $[Co(NH_3)_6]^{2+}$ $[CoCl_4]^{2-}{}_{(aq)}$
   Which of these do you think would form if excess concentrated hydrochloric acid were added? What color would your solution be?
3) We will be creating an equilibrium between silver ions, carbonate ions, and solid silver carbonate. We will do this by combining 0.01 M silver nitrate and 0.10 M sodium carbonate.
   a. Starting with 1.0-ml of 0.01 M silver nitrate, **calculate** the appropriate volume of 0.10 M sodium carbonate that would completely react
   b. Write the equilibrium between silver ions, carbonate ions, and solid silver carbonate that would result, putting the solid as the reactant.

___/2 Reagent Table / Toxicity/Interesting Fact:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/1 Header: Make sure to fill out each header area.

___/5 Procedure:

Cite source Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment- and using as much chemistry short-hand as possible.

___/5 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and observed. Include physical observations of all chemicals, molarities and anything you did in the lab.

___/10 Summary/Discussion/Conclusion

For each equilibrium studied:

a) Write one or two sentences about how it was created and give the equilibrium equation.
b) then create a table to describe the observations and interpret the shift.

For Example: The equilibrium between the tetraaquacopper(II) ion and the tetraaquaammonia ion was created by combining…(then state that here)…

Equilibrium equation: $Cu(H_2O)_6{}^{2+}]_{(aq)} + 4NH_{3(aq)} \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+}{}_{(aq)} + 4H_2O_{(l)}$

Table of results of equilibrium shifts

Substance/amount added	Observation	Shift
• 12 M HCl – 3 drops	turned from dark blue→light→pale blue	To the right

c) Conclusion: Final recap as to how Le Chatelier's principle was illustrated in this experiment

___/1 Signed

Each page as you did it and instructors signature after you finish

Investigation 6: Acid-Base Titration

Can Acid/Base Titration be used to identify a weak acid from a strong and its molarity?

Content Connection:

Acid/Base titration

Narrative:

Acid base chemistry is one of the most important topics in general, organic, and analytical chemistry. Acids and bases play a role in so many natural, and un-natural processes that the understanding of what they are, what they do, and the prediction of their behavior is paramount to understanding many chemical processes. The concept of acid-base titration is also central to an understanding of the analytical nature of chemistry.

This investigation is three-fold; 1) you are tasked with determining the nature of your unknown acid(is it strong or weak), 2) the identity of the acid (acetic or hydrochloric acid), and 3) the identity of another acid that as a nature opposite of your unknown. You will be using a pH meter coupled to a LabQuest to monitor your titration and produce a titration graph that will allow you to calculate the molarity of the unknown.

The nature of the acid, strong or weak, is reflected in the shape of the titration curve that results when it is titrated with a strong base. Research the shapes of the titration curves of a strong acid being titrated by a strong base and a weak acid being titrated by a strong base.

The molarity of the acid can be calculated from the equivalence point. The equivalence point is the point at which the acid has been completely neutralized. This means that the exact amount needed to react with the acid present in the solution has been reached. If the molar ratio between the acid and base is known, then the number of moles of acid can be determined. If the volume of the sample is also known, the molarity of the acid can be calculated. (Molarity = moles/Sample Volume)

Each student group will run a slooooowwww, accurate titration of an unknown acid with a standard sodium hydroxide solution. Then each student will determine all the unknown identity and molarity of their unknown acid, as well as one other acid from the collaborative team table.

You will have one of the following acids:

Acetic acid
Sulfuric acid
Nitric acid
Hydrochloric acid.

You know you are titrating with sodium hydroxide(NaOH) and you know its standardized molarity. What is the concentration and identity of all these unknowns? You will have to work as a class!

Pre-lab assignment(s)

1) Go to this site and answer the questions below: (let me know if you cannot access this site) Look at this to watch how a titration works and what a titration graph looks like.
   i. In your note book, write the reaction for the titration, draw the curve that results after titration is complete and label the equivalence point.
   ii. Label the point on the graph which corresponds to the "half-titration" point.
   iii. Calculate the molarity of the unknown acid in the simulation. Show all work.
   iv. Given that the greatest change in pH occurs at the instant stoichiometric amounts of reactants are combined, at what point in the titration would have been a good place to add the titrant *dropwise*. Explain your answer.
2) Sketch a titration graph for the titration of acetic acid(weak) and sodium hydroxide(strong). Label the following areas on the graph: initial pH, before equivalence point, equivalence point, after equivalence point, half equivalence point. Cite your sources. Where on these graphs does a buffer solution occur? If Any? Explain.
3) Sulfuric acid is a diprotic acid. Explain what that means. How many equivalence points should be present in a titration of sulfuric acid with sodium hydroxide? Research this and sketch a titration curve of sulfuric acid with sodium hydroxide. Cite your sources.

Safety Precautions:

Follow all lab safety procedures and wear goggles. Wash your hands before leaving the laboratory. No open flames.

Materials available

Standardized NaOH solution
Unknown acid solutions labeled 1-8
pH meters
Calibration solutions for pH meter(pH 4,7,10)
Unknown acid/base indicator solutions labeled 1-12
Lab Quest
1.0 M $CaCl_2$

Suggested Method(s)

1) Calibrate your pH meter with standard buffer solutions of pH = 4, 7, and 10. Do this by rinsing off your pH meter, then submerging it into the buffer solution. Under the sensor's menu, tap calibrate sensor. Follow the prompts from there to do a two-point calibration using two buffer solutions. Record how you did this in your notebook.
2) Use the labquest with events with entry as your mode of data collection. The entry will be the volume in millliters.
3) Use 15-25 ml of your unknown acid and an amount of water that will bring the volume to 50-60ml(Why is this necessary or is it?) Use a 250-ml beaker. Record the initial pH of your unknown solution. Record color of the solution.
4) Start data collection and the "Keep" button will appear. Tap keep and enter your first point as zero, since no base has yet been added.
5) Add small amounts of base to create a titration curve that has a vertical region like that seen in your pre-lab graphs. Collect pH/Volume data in your notebook as the titration progresses.
6) Continue your titration all the way into the basic region(>12)
7) Sulfuric acid can be difficult to determine. The sulfate anion can be detected by precipitation with calcium. Do a precipitation test on your unknown to detect sulfate(SO_4^{2-}) in your acid.

Should this test be performed on the pure acid or the resulting solution after titration? Does it matter?

Calculations:

1) Calculate the molarity of your unknown from the equivalence point of your titration.
2) Determine if it is a strong or weak acid from the initial pH data and the shape of the curve.
3) Label the point on your graph where the *half-equivalence* point would be, this is the point where $pH = pK_a$. From this calculate the K_a of your acid and compare it to the "true" value.(Can you do this for the strong acid?)
4) If you had a weak acid, label the area that correlates to the buffer region being formed.
5) From the team table information, choose another unknown to calculate the concentration of. Choose one that was opposite of yours, meaning if you had a weak, choose a strong and vice versa. Identify your unknown and your chosen one from the team table and determine the K_a of the weak.
6) Compare the K_a of the weak acid with the literature value by calculating the percent error.

Team Table Layout:

Name	UK #	Acid Sample Size(ml)	Initial pH of unknown acid	ml of added NaOH added at equivalence point	pH at equivalence point.	pH at ½ equivalence point	Titration Graph Shape

Post Questions:

1) Explain the variation in pH of the different acids at the equivalence point. W**hy** does the effect occur?
2) Explain how the fact that sulfuric acid is diprotic affect molarity calculations?

Lab Report Checklist.- Acid-Base Titration

___/4 Pre-lab questions/assignment.

1) Go to this site and answer the questions below: (let me know if you cannot access this site)
   Look at this to watch how a titration works and what a titration graph looks like.
   i. In your note book, write the reaction for the titration, draw the curve that results after titration is complete and label the equivalence point.
   ii. Label the area on the graph which is the "half-titration" point.
   iii. Calculate the molarity of the unknown acid in the simulation. Show all your work, not just what you see when you click around to find the correct answer.
   iv. At what point in the titration would have been a good place to add the titrant *dropwise*.
2) Sketch a titration graph for the titration of acetic acid(weak) and sodium hydroxide(strong).
   Label the following areas on the graph: initial pH, before equivalence point, equivalence point, after equivalence point, half equivalence point. Cite your sources. Where on these graphs does a buffer solution occur? If Any? Explain.
3) Sulfuric acid is a diprotic acid. Explain what that means. How many equivalence points should be present in a titration of sulfuric acid with sodium hydroxide? Research this and sketch a titration curve of sulfuric acid with sodium hydroxide.

___/1 Reagent Table / Toxicity/Interesting Fact:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/1 Header: Make sure to fill out each header area.

___/3 Procedure:

Cite source Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/3 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and observed. Include physical observations of all chemicals, molarities and anything you did in the lab.

___/8 Calculations:

1) Calculate the molarity of your unknown from the equivalence point of your titration.
2) Determine if it is a strong or weak acid from the initial pH data and the shape of the curve.
3) Label the point on your graph where the *half-equivalence* point would be, this is the point where $pH = pK_a$. From this calculate the K_a of your acid and compare it to the "true" value.(Can you do this for the strong acid?)
4) If you had a weak acid, label the area that correlates to the buffer region being formed.
5) From the team table information, choose another unknown to calculate the concentration of. Choose one that was opposite of yours, meaning if you had a weak, choose a strong and vice versa. Identify your unknown and your chosen one and determine the K_a of the weak.
6) Compare the K_a of the weak acid with the literature value by calculating the percent error.

___/4 Summary:

Type a narrative of what you did and observed. Include reference to any graphs drawn(page #), and/or calculations(page #) done to arrive at the result(s) you are reporting. Use subscripts and superscripts for chemical formulas.

____/1 Table(s)

Include a table of your results embedded in summary and of team table, include caption(s)

____/2 Conclusions:

In conclusion, this experiment was performed in order to....then explain why you did it and if it answered the hypothesis or question posed. Identity and molarity of all the unknowns, acid and indicator. If it did not, then what experiment could you perform to answer that question(s). Address error here.

___/1 Signed

Each page as you did it and instructors signature after you finish

___/2 **Post Questions:**

Look for these on D2L Announcements!

Investigation 7: Acid-Base Indicators

Can Acid/Base Titration be used to differentiate one indicator from another?

Content Connection:

Acid/Base indicators

Narrative:

Indicators are used in so many applications in our everyday life, from fish tank testing strips to diabetic testing strips.

Pre-lab assignment(s)

1) Research the colors of the indicators at various pH's and color a table in to reflect this, also label the colors with words. Hand in first thing on a white piece of paper. Cite source

pH	Methyl Violet	Thymol Blue	Methyl Yellow	Bromphenol blue	Methyl Orange	Methyl Red	Litmus	Bromthymol Blue	Phenol Red	Phenolphthalien	Thymolphthalien	Alizarin Yellow
0												
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												

2) We will be titrating a sample of 0.1 M HCl with 0.1 M NaOH. Will this titration span all the pH's we need to determine the colors of the indicators. Calculate the pH of both of these solutions to determine if this will be enough to test ALL the color changes the indicators could undergo.
3) Suggest a concentration of hydrochloric acid and sodium hydroxide that would change the indicators at all pH level. Back your answer up with a calculation.

Safety Precautions:

Follow all lab safety procedures and wear goggles. Wash your hands before leaving the laboratory. No open flames.

Materials available

The indicators:

- phenolphthalein — bromothymol blue — Thymolphthalien
- methyl orange — thymol blue — Methyl yellow
- methyl violet — litmus — bromophenol blue
- methyl red — phenol red — alizarin yellow

Concentrated HCl and NaOH – to determine the color of the indicator at the extremes

Suggested Method(s)

1) Calibrate your pH meter with standard buffer solutions of pH = 4, 7, and 10. Do this by rinsing off your pH meter, then submerging it into the buffer solution. Under the sensors

menu, tap calibrate sensor. Follow the prompts from there to do a two point calibration using two buffer solutions. Record how you did this in your notebook.

2) Use the labquest with events with entry as your mode of data collection. The entry will be the volume in millliters.
3) Run a very *careful* titration, titrating alkali into acid making sure to add your unknown indicator. This will determine the color of the indicators at various pH's. Record all pH's, volumes and colors.
4) Use-15-25 ml of an acid sample and an amount of water that will bring the volume to 50-60ml. Use a 250-ml beaker. Determine initial pH of your solution.
5) Add enough indicator to get a dark enough color for you to visualize your color changes.
6) Start data collection and the "Keep" button will appear. Tap keep and enter your first point as zero, since no base has yet been added.
7) Continue your titration all the way into the basic region(>12)
8) After your first careful titration, start a new run on the lab quest and completely and carefully **back titrate** the solution to see the color change again and verify the pH's at which the indicator changed color(aka. the endpoint of the indicator). Record your color changes in the team table.
9) Use a solution of high molarity of acid or base to test your indicator at the extremes of pH.
10) Do one unknown indicator per group.
11) Identify **all** of the unknown indicators by collaboration, discussing your reasoning for each identification.
12) Print your titration graphs for your indicator coloring them to show the colors during the titration.

Team Table Layout:

Tabulate your data(color of each unknown at each pH) as a class for each unknown for corroboration.

	Colors															
Group	UK #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Post Questions:

1) Indicators are weak acids. For your indicator, look up its chemical structure and find the difference in the structure at the different pH's that cause it to change color. Finally, Research a modern use for your indicator
2) An indicator is a weak acid, generally represented by HIn.
   i. Write the chemical reaction showing the how this indicator (HIn) would be in equilibrium with its ions. Write the K_a expression for this equilibrium.
   ii. The K_a of a certain indicator is 2.0×10^{-6}. The color of HIn is yellow and the color of In^- is red. A few drops of the indicator are added to an HCl solution. What color should show up?
   iii. The solution is titrated against an NaOH solution. At what pH range will the indicator change color?(Hint: Calculate the pK_a and what the pH would be at a base/acid ratio of 0.1 and 10.)
   iv. What color would this indicator be during the titration if [HIn] = [In^-] What condition is this known as in a weak acid/strong base titration?

Lab Report Checklist.- Acid Base Indicators

___/6 Pre-lab questions/assignment.

1) Research the colors of the indicators at various pH's and color a table in to reflect this, also label the colors with words. Hand in first thing on a white piece of paper. Cite source
2) We will be titrating a sample of 0.1 M HCl with 0.1 M NaOH. Will this titration span all the pH's we need to determine the colors of the indicators. Calculate the pH of both of these solutions to determine if this will be enough to test ALL the color changes the indicators could undergo.
3) Suggest a concentration of hydrochloric acid and sodium hydroxide that would change the indicators at all pH level. Back your answer up with a calculation.

___/2 Reagent Table / Toxicity/Interesting Fact:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/1 Header: Make sure to fill out each header area.

___/4 Procedure:

cite source Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/4 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and saw. Include observations of all chemicals, molarities and anything you did in the lab.your acid should have been based on this concentration. Show all work.

___/4 Summary:

Type a narrative of what you did and observed. Include reference to any graphs drawn(page #), and/or calculations(page #) done to arrive at the result(s) you are reporting

___/3 Table(s)

Table of your results and team table embedded in summary with catptions

___/2 Conclusions:

- *In conclusion, this experiment was performed in order to* ....then explain why you did it and if it answered the hypothesis or question posed. If it did not, then what experiment could you perform to answer that question(s). Address error here. Identify all the unknowns.

___/1 Signed

Each page as you did it and instructors signature after you finish.

___/3 Post Questions:

1) Indicators are weak acids. For your indicator, look up its chemical structure and find the difference in the structure at the different pH's that cause it to change color. Finally, Research a modern use for your indicator.
2) An indicator is a weak acid, generally represented by HIn.
   i. Write the chemical reaction showing the how this indicator (HIn) would be in equilibrium with its ions. Write the K_a expression for this equilibrium.
   ii. The K_a of a certain indicator is 2.0×10^{-6}. The color of HIn is yellow and the color of In^- is red. A few drops of the indicator are added to an HCl solution. What color should show up?
   iii. The solution is titrated against an NaOH solution. At what pH range will the indicator change color?(Hint: Calculate the pK_a and what the pH would be at a base/acid ratio of 0.1 and 10.)
   iv. What color would this indicator be during the titration if [HIn] = [In^-] What condition is this known as in a weak acid/strong base titration?

Investigation 8: What Salt is This?

a) Can the behavior of a salt, upon its addition to water, be used to identify it?
b) Can the K_a or K_b of an ion undergoing hydrolysis be determined by subsequent titration of the solution.

Content Connection:

Acid-base properties of salts, titration, acid-base dissociation constants, identification of unknowns

Narrative:

To continue this fabulous opportunity of inquiry, Jill wants to know how salts affect the pH of her soups. She wants to try all the gourmet salts on the market, but she is a poor college student and only has access to the salts she has been stealing from the chemistry stockroom. Even though she is poor, and a thief, she does not have a death wish. This compels her to study the nature of these substances.

A salt consists of a cation portion, and an anion portion. If a salt is soluble in water, the cation and anion will separate and may or may not react with the solvent, which is water in this case. If a salt dissolves in water, and the pH changes, then it would appear there was a reaction with the water. The reaction with water is called ***hydrolysis***.

1) Acidic solutions can form in two ways;

   a) If the cation has a hydrogen to donate to water and is derived from a weak base, it itself is a stronger acid than water and will react;

   $$HCation^{+} + HOH \rightleftharpoons H_3O^{+} + Cation^{0}$$

   This occurs when salts derived from a weak base and a strong acid and are dissolved in water.

   b) If the cation is a charged metal cation;

   $$M^{+} + HOH \rightleftharpoons H_3O^{+} + [M(H_2O)_5(OH)]^{(\text{charge on cation -1})}.$$

   The extent of this reaction depends on the charge on the metal cation. The higher the charge and the smaller the cation the greater the extent of the reaction.

   Since this situation produces an acidic solution, a titration can be performed with a strong base to determine the shape of the titration curve, which can aid in the identification of the unknown.

2) Basic solutions form if the anion reacts with water to remove a hydrogen and form hydroxide and the conjugate acid;

   $$Anion^{-} + HOH \rightleftharpoons HAnion^{(\text{charge on anion +1})} + OH^{-}$$

   This occurs when salts derived from a strong base and a weak acid are dissolved in water. The weak acid from which the salt came from creates a strong conjugate base(stronger than water) so it will react.

   Since this situation produces a basic solution, a titration can be performed with a strong acid to determine the shape of the titration curve, which can aid in the identification of the unknown.

3) A neutral solution will result if the salt is derived from a strong acid and a strong base.

$M^+ + HOH \rightarrow$ No significant reaction
$X^- + HOH \rightarrow$ No significant reaction

Pre-lab assignment(s)

1) Copy this table into your lab notebook. For each of the unknown salts, input the indicated information. Examples are given for sodium nitrate and sodium cyanide. Show an example calculation for how you determined the mass required.

Salt	Mass required to create a 0.1 M solution	Hydrolysis equation of ion reacting with water to create pH other than 7 * .	Acidic, basic or neutral salt	K_a or K_b expression of ion undergoing hydrolysis	Literature K_a or K_b
$NaNO_3$		$Na^+ + HOH \rightarrow$ none $NO_3^- + HOH \rightarrow$ none	neutral	none	none
NaCN		$Na^+ + HOH \rightarrow$ none $CN^- + HOH \rightarrow HCN + OH^-$	basic	$K_b = \frac{[HCN][OH^-]}{[CN^-]}$	$K_b = 2.0 \times 10^{-5}$
KCl					
NH_4Cl					
$NaC_2H_3O_2$					
$AlCl_3$					
LiCl					
$ZnCl_2$					
NaCl					
Na_2CO_3					
$KAl(SO_4)_2$					

* If reaction is not significant enough to create enough hydroxide or hydronium to affect the pH, enter none.

2) Assuming 50mL of water as your solvent; determine the mass of each salt needed to make a 0.1M solution. Present this information in the column in the table above.

3) Practice: If a student dissolves 0.130 g of $NH_4Cl(s)$ in 50.0 ml of water, what would be the resulting solutions pH? Write the hydrolysis reaction that occurs in this case. Show all work.

4) Research the following qualitative tests and find a general procedure:

a. A qualitative test for chloride is the addition of the silver ion to produce silver chloride. Write the chemical equation for this reaction.

b. A qualitative test for sulfate is precipitation with calcium. Write the chemical equation for this reaction.

c. A qualitative test for carbonate is production of carbon dioxide gas upon its reaction with acid. Write the chemical equation for the reaction of sodium carbonate with vinegar.

5)

Materials available

Nine unknown salts labeled 1-9, which consist of:

Potassium chloride	Aluminum chloride	Zinc chloride
Ammonium chloride	Lithium Chloride	Sodium chloride
Sodium acetate	Potassium aluminum sulfate	Sodium carbonate

1.1 M HCl – for titration of a basic solution

0.1 M NaOH – for titration of an acidic solution

pH meters and labquests.

Calibration solutions for pH meters (pH 4, 7, and 10)

Boiled Distilled Water to make salt solutions

Long range pH paper

1.1 M Silver nitrate

1 M aqueous calcium chloride

Suggested Method(s)

1) Calibrate your pH meter with standard buffer solutions of pH = 4, 7, and 10.
2) Create a salt solution with your unknown salt, keeping in mind the calculation you did in the pre-lab concerning the mass that should be used to achieve an approximate 0.1 molarity. In other words, don't add too much, or you will be titrating forever. Record everything, how many grams of salt, the volume of the water used, physical observations, etc. Measure the pH of the water before and after you create your salt solution. Use your pH meter **and** long range pH paper.
3) After dissolving your salt, perform a titration with the appropriate solution. How can you tell what that will be? Sometimes that is difficult, especially with a neutral salt. Use the lab quest with events with entry as your mode of data collection. The entry will be volume(ml). Do a titration with both acid and base if you suspect a neutral salt. This will be evidence of that. No matter which titrant you are using, make sure to titrate until you reach the pH of the HCl or NaOH, then you will know you are finished.
4) Start data collection and the "Keep" button will appear. Tap keep and enter your first point as zero, since no titrant has yet been added.
5) Add small amounts of titrant and collect pH/Volume data in your notebook as well as the labquest.
6) Continue your titration to create a complete titration curve. Sketch this graph in your notebook.
7) Save your graph to print or take a photo to insert in your lab report summary. Also have your instructor take a photo to post for the class.
8) Think about other methods(precipitation tests, flame tests…etc) to identify the anion and cation in your unknown salt. Run at least one extra test to help you identify your salt.

Team Table Layout

Tabulate your data as a class for each unknown for corroboration. Each group do one salt.

Group	UK #	grams unknow n salt	volume of water salt	Initial pH of boiled DI Water	pH after addition of salt	Nature of Salt(Acidic/ Basic/Neutr al)	Equival ence point for	pH at 1/2 equiv. point	Titration Curve Shape	Observations /Other Tests

Calculations

1) Calculate the K_a or K_b of the ion that underwent hydrolysis. This can only be done for ions resulting from weak acids/bases, as the conjugate is stronger than water and reacts with it. If the half-equivalence point can be determined, pH=pK_a. See team table and graphs for this data.
2) Now that you have identified the unknowns, write the reaction of the ion(s) with water and the equilibrium constant expression, if any ,and input in a summary table
3) Compare your K_a to known value by calculating the percent error. Use this to corroborate your unknown choice

Suggested Results Table Layout

Grou p	UK #	Nature of Salt (Acidic, basic, neutral)	Identity of Salt	Hydrolysis Reaction of ion with water to create pH other than 7	Ka or Kb Expression	Numerical Value of K_a or K_b	Literature Value of K_a or K_b	Percent error from literature value

Conclusions:

1) Determine the identity of all the unknowns. Discuss your reasoning for your unknown identifications.
2) Your goal is to identify **all** the salts, by whatever means possible, but use all the information you and your classmates gathered. If a piece of data does not corroborate your identification, then indicate it, and try to explain why.
3) See titration curves given below for some of the salts we used. Compare these to what you got to help with identification. How well did we do titration wise?

View the graphs below to aid in the identification of the unknown salts.

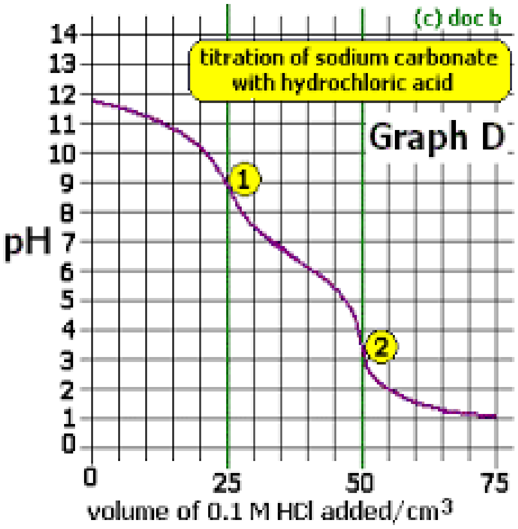


Figure 1:Titration curve of carbonate and hydrochloric acid

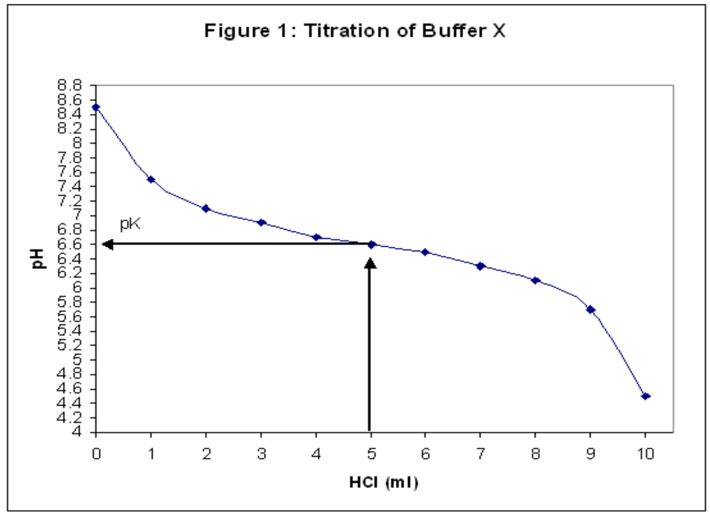


Figure 3:: Titration of acetate with hydrochloric acid

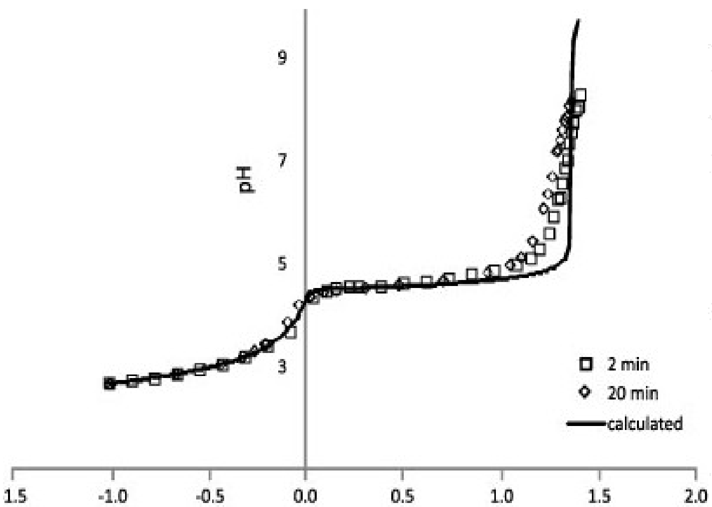


Figure 2: Titration curve of Aluminum Chloride with sodium hydroxide

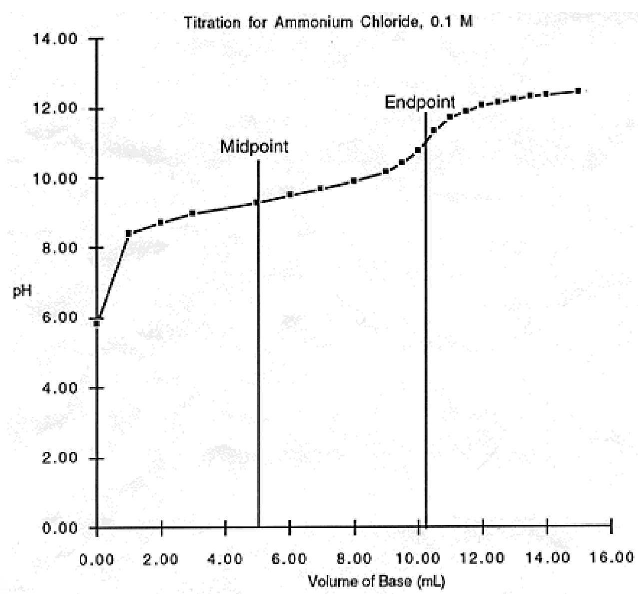


Figure 4: titration curve of ammonium chloride with sodium hydroxide

Lab Report Checklist.- What Salt is This?

___/5 Pre-lab questions/assignment.

1) Pre-Lab Table of unknown information
2) Assuming 50mL of water as your solvent; determine the mass of each salt needed to make a 0.1M solution. Present this information in the column in the table above.
3) Practice: If a student dissolves 0.130 g of $NH_4Cl(s)$ in 50.0 ml of water, what would be the resulting solution pH? Write the hydrolysis reaction that occurs in this case. Show all work.
4) Write out and finish the following reaction, circle the hydronium or hydroxide ion formed and then indicate whether this is an acidic or basic cation. Read the Chemical Mystery in your textbook called "Decaying Papers", and explain how this reaction contributes to the problem of disintegrating paper. Al^{3+} + HOH →

___/2 Reagent Table / Toxicity/Interesting Fact

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/1 Header: Make sure to fill out each header area.

___/3 Procedure:

Cite source Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/3 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and observed. Include physical observations of all chemicals, molarities and anything you did in the lab.

___/5 Calculations

1) Write the reaction of the ion(s) with water and the equilibrium constant expression, if any and input in a summary table
2) Calculate the K_a or K_b of the ion that underwent hydrolysis. This can only be done for ions resulting from weak acids/bases, as the conjugate is stronger than water and reacts with it. If the half-equivalence point can be determined, $pH=pK_a$. See team table for this data.
3) Compare your K_a to known value by calculating the percent error. Use this to corroborate your unknown choice.

___/2 Summary:

Type a narrative of what you did and observed. Include reference to any graphs drawn(page #), and/or calculations(page #) done to arrive at the result(s) you are reporting. Use subscripts and superscripts for chemical formulas.

____/1 Table(s)

Include a table of your results embedded in summary and of team table, include caption(s)

____/5 Conclusions:

In conclusion, this experiment was performed in order to ....then explain why you did it and if it answered the hypothesis or question posed. If it did not, then what experiment could you perform to answer that question(s). Address error here. Identify all the unknown salts.

___/1 Signed

Each page as you did it and instructors signature after you finish

___/2 Post Questions:

Look for these on D2L Announcements!

Investigation 9: How to make and dissolve a kidney stone?

a) What does the Ksp of a salt tell me about dissolution?
b) What can dissolve an insoluble salt?

Content Connection:

Solubility product constants, chelating agents, acid-base properties

Narrative:

A kidney stone is a urologic disorder caused by a precipitate formed as a product of the reaction of soluble ions present in our blood and urine. There are more than 2.7million hospital visits and 600,000 emergency room visits due to kidney stones. Researchers have encountered kidney stones in a 7000 year old mummy. This problem is still very common in our times and it is one of the most common disorders of the urinary tract. As a matter of fact, gymnast Simone Biles recently competed at the World Championships in Doha while trying to pass a kidney stone.

In order to improve the quality of life of patients, you have been assigned to investigate the formation of kidney stones and suggest ways to dissolve and prevent them. Your goals for this lab is to prepare 5g of artificial kidney stones, research chemical and household remedies and figure out a way to prevent kidney stones.

Pre-lab assignment(s)

1) The kidney stones you will be making in lab are $Ca_3(PO_4)_2$ and CaC_2O_4. You will be using Na_3PO_4, $CaCl_2$ and $Na_2C_2O_4$ to synthesize your kidney stones. Calculate how much of each reagent you will need to make 5g of each stone.
2) Find the Ksp values for $Ca_3(PO_4)_2$ and CaC_2O_4. Which “stone” should be easier to dissolve?
3) Research chelating agents. What do they do? Why would we use a chelating agent?
4) Research methods to dissolve kidney stones, both laboratory and household remedies. Could we also use physical means? How can you know if your method is effective?
5)

Materials available

Calcium chloride | Sodium Oxalate | Sodium Phosphate

1M HCl

1M Acetic Acid

0.05M EDTA

Vinegar

Olive Oil

Lemon Juice

Celery seed tea

Suggested Method(s)

Making Kidney Stones

1) Measure the respective amounts of calcium chloride, sodium phosphate, calcium chloride and sodium oxalate solids.
2) Place in separate containers (you will need 4 total containers)
3) Dissolve each salt with the smallest amount of deionized water possible.
4) Combine containers to make an insoluble salt.
5) Gravity filter, label and leave to dry until the next lab period.

Dissolving Kidney Stones

1) Measure at least 4 small amount of your kidney stone.
    a. You will do at least 4 tests so make sure that you have enough of each kidney stone for the tests
2) Try dissolving using the following
    a. A strong acid
    b. A weak acid
    c. A chelating agent
    d. A household remedy
    e. A physical method
3) Add small amounts of titrant and determine if/how much of your kidney stone has dissolved

Team Table Layout

Tabulate your data as a class for each unknown for corroboration. Each group do one salt.

Group	Kidney Stone Tested	Chemical Method	Chelating Agent	Household remedy	Physical Method

Calculations

1) Calculate the theoretical yield, experimental yield, and percent yield for both kidney stones made by your group.
2) For each dissolving process you used,
   a. Calculate the theoretical and experimental amount of the dissolved salts
3) Write down equilibrium equations for the solubility reactions

Conclusions:

1) Discuss the difference in percent yield for each compound.
2) Discuss the contributions of the Ksp of kidney stones, Ka of the weak acid, and concentration of strong acid in the solubility of kidney stones. Give the equation for Ksp and Ka of the kidney stones and weak acid you analyzed.
3) Which of the different dissolving methods is more efficient and why? Always consider safety and cost effectiveness in your reflection
4) Which of the methods you tried could be applied to humans? What evidence do you have for making this claim?
5) If you have to do the dissolving process again, how would you make it better?
6) Discuss how you can prevent kidney stone formation.

Investigation 10: Qualitative Analysis of Household Substances

Can chemical tests be used to identify the components in a common household substance?

Content Connection:

Qualitative Analysis; chemical testing of Unknown Substances

Narrative

One of the most important aspects of chemistry is the testing, analysis, and subsequent identification of unknown substances. As the physical and chemical properties of millions of substances were determined, the identification of unknown substances became more routine. In this modern age, the availability of quick and routine tests for elements, compounds, or ions in a sample is commonplace. This is evident in the testing kits in medical offices, environmental monitoring stations, and forensic labs.

Your goal for this experiment is to determine the identity of common household substances using ***qualitative*** chemical tests.

Many substances found in our everyday lives contain elements, compounds, or ions that react in characteristic patterns which can be instrumental in identifying the constituents contained therein. Qualitative analysis is a method of using chemical tests and the characteristic observations that result, to identify unknown substances.

In this experiment you will run tests on known and unknown substances to become experienced in chemical testing of the qualitative nature.

Pre-lab assignment(s)

1) Each unknown is a common household substance, from the kitchen, medicine, or craft cabinet. Research each of the substances as to their chemical makeup. Present the components of these in a table.

Table salt-non-iodized	Epsom Salts	Calcium Carbonate
Salt Substitute	Plaster of Paris	Baking Soda
Table Salt-Iodized	Flour	Powdered Sugar
Double-Acting Baking Powder	Self-Rising Flour	Cornstarch

2) Make a table of the flame colors for the alkali and alkaline earth metal cations present in the unknowns. Outline how to perform a flame test using a nichrome wire.
3) A precipitation test is a method that utilizes the **solubility** trends of ionic compounds to differentiate between metal cations and certain anions. List the solubility rules of the alkali and alkaline earth metals, the sulfates, phosphates, carbonates, hydroxides, ammonium compounds, and halides. Using this solubility information, how could a precipitation test be used to differentiate between table salt and baking soda?
4) Research the iodine test for starch. Write the chemical equation(s) that describe this and indicate the physical evidence of a positive test. Which substance(s) have starch as an ingredient? What types of starch will give a positive test?
5) Why should distilled water be used when conducting these chemical tests?

Safety Precautions:

Follow all lab safety procedures and wear goggles. Wash your hands before leaving the laboratory. No open flames. Do concentrated sulfuric acid tests and flame tests in the hood!

Reagents available

1M hydrochloric acid	Household vinegar	1.0 M sodium hydroxide
1.0 M sodium sulfate	1.0 M sodium carbonate	1.0 M sodium phosphate
1.0 M calcium chloride	0.2 M barium chloride	0.1 M lead(II) nitrate
0.1 M silver nitrate	3.0 M nitric Acid	Nichrome Wires
Bleach	Mineral oil	iodine-potassium iodide
18.0M Sulfuric acid	concentrated calcium hydroxide(CO_2 Test)	
Conductivity apparatus	Blue/red litmus paper	

Solid substances for knowns

potassium chloride	sodium chloride	sodium Iodide
sodium carbonate	sodium sulfate	potato

Suggested Methods:

Solubility

Solubility can be a descriptor of the type of compound present, such as ionic vs covalent, polar or nonpolar. Test the solubility in of your unknown in water. Use small amounts of your unknown to determine the solubility in water of the unknown.

Precipitation

To perform these tests, dissolve a small pea-sized amount of your unknown in water, and choose an aqueous cation or anion to react with it from the materials list as described below.

If your substance is soluble in water, you can test for the presence of:

a) carbonate, sulfate, chromate, sulfide, or phosphate anions by the addition of a cation that would form a precipitate with it. This is a general test and only indicates there may be a cation that would form a precipitate with these anions. Consult your solubility rules. Choose an aqueous cation for this purpose from the materials list.

b) an alkaline earth metal cation by the addition of an anion that would form a precipitate with it. Choose an aqueous anion for this purpose from the materials list.

c) a halide(Cl^-, Br^-, I^-) by the addition of a cation that would form a precipitate with it. Choose an aqueous cation for this purpose from the materials list. Make sure your solution is acidic with a few drops of 3.0 M nitric acid, so that insoluble hydroxides, which may be formed in a basic solution, do not give a false positive.

Flame Test:

Flame tests are traditionally used to detect the *possible* presence of a specific metal cation. If your substance is soluble in water, make an aqueous solution of your unknown and dip a nichrome wire in the solution to extract a sample to perform a flame test. If your sample is insoluble in water, you can use a small solid sample on the end of a scoopula to perform a flame test.

Halogen Displacement

Many common substances contain chloride and iodide, which will both precipitate with certain cations. The halide present can be more specifically determined using a halogen displacement reaction. Bleach can be used as a source of chlorine to displace another, more inactive halide, such as bromine or iodine. This test is performed with household bleach as the source of chlorine, which displaces the halide from the compound.

$$Cl_{2(aq)} + MX_{(aq)} \rightarrow X_{2(aq)} + MCl_{(aq)}$$

In a test tube dissolve a small amount of your unknown in a 1-2 mL of water and 2-3 drops of 6 M nitric acid, then add 5 drops of chlorine water. Flick the test tube to mix the solutions ***vigorously***. Observe for a change in color. Discard the solutions in the **correct** waste containers. If ***chloride*** is present you will get a ***negative*** result for this test, as chlorine will not replace chloride.

Reaction with Concentrated Sulfuric Acid

Concentrated sulfuric acid has the capability to react with solid compounds in such a way as to cause their decomposition. This changes the compound into several compounds, some of which can be detected by other means, and therefore can give an indication of the elements present. Concentrated sulfuric acid is an acid, which means it will react with carbonates to liberate carbon dioxide gas. It will react with a chloride salt to liberate hydrogen chloride gas, and an iodide salt to liberate iodine fumes. Analyze each of the reactions below to understand these reactions. (Hood!)

$H_2SO_4 + NaCl_{(s)} \rightarrow Na_2SO_{4(aq)} + HCl_{(g)}$ - production of an acidic gas

$H_2SO_4 + NaI_{(s)} \rightarrow Na_2SO_{4(aq)} + I_{2(g)}$ - production of a purple vapor

$H_2SO_4 + Na_2CO_{3(s)} \rightarrow Na_2SO_{4(aq)} + H_2O + CO_{2(g)}$ - production of bubbles

$H_2SO_4 + Na_2SO_{4(s)} \rightarrow Na_2SO_{4(s)} + H_2SO_4$ (Isn't that the same thing?)

(HOOD!) $H_2SO_4 + C_{12}H_{22}O_{11(s)} \rightarrow C(s) + 11\ H_2O_{(l)} \rightarrow CO_2 + SO_2$

Check out this link about this reaction

To run this test, use a small, pea-sized amount of your solid unknown in a test tube, add 1-3 drops of concentrated sulfuric acid. Do this reaction in the HOOD. If you suspect a specific anion from this test, run a known sample for comparison.

Evidence of carbonates

Carbonates are substances that contain the carbonate anion, or the bicarbonate anion. These substances react vigorously with acids to produce carbon dioxide gas. Any acid(including vinegar) will cause this reaction.

$Na_2CO_3 + HCl \rightarrow CO_2(g) + H_2O(l) + 2NaCl(aq)$

What physical observation should be expected for this reaction?

Choose an acid from the materials list to test for the presence of a carbonate in your unknown and a run a known for comparison.

Evidence of starch

Iodine-iodide is the indicator of choice for starch, as it will form the intense blue-black complex of the triiodide anion. This can be seen if the iodine-iodide reagent is simply dropped onto a potato. If starch is suspected, add 1-3 drops of the iodine-iodide solution directly onto the solid. Try this with a sample of a dissolved starch containing compound also and note the differences. Use this test if you suspect your unknown has starch.

Evidence of a hydrate

A hydrate is a solid substance that has water molecules as part of its crystal structure. These water molecules can be easily liberated by heating the solid and observing the condensation of the water at the mouth of a test tube. Care must be taken to be very observant and not to overheat the test tube, as this will cause the evaporation of the water as it condenses.

Heating your test tube slightly beforehand is also a good idea, as that will "dry" the test tube. Do this test on a known hydrate as well as your unknown.

Identity of a specific gas

Common gases produced in chemical reactions include carbon dioxide, hydrogen sulfide, hydrogen chloride, iodine vapor, and ammonia vapor.

Some of these gases are acidic or basic upon reaction with water and can be identified by a change in the color of pH paper. These would include ammonia vapor and hydrogen chloride vapor. Therefore, if moist litmus paper is held over the test tube where the gas producing reaction is occurring, a change in color of the litmus paper can provide evidence of its presence. Blue litmus paper would be used for hydrogen chloride and red litmus for ammonia.

Gases that are not acidic or basic can be detected by their reaction with another substance. This is seen in the reaction of carbon dioxide gas with an aqueous alkaline earth metal, that subsequently forms a carbonate precipitate(from the carbon dioxide). You can use calcium cations in this capacity. For this reaction to be observed, the suspected carbon dioxide gas must contact a solution of the concentrated calcium ion. To perform this test, put a sample of your unknown in a test tube and add an acid to release the suspected CO_2. Collect a sample of the gas in a disposable pipet. Bubble the collected gas through a solution of saturated calcium hydroxide. A cloudiness indicates a positive test for carbon dioxide gas.

These tests can be performed on any gas produced from a chemical reaction to provide further evidence of the gas's identity, and subsequently the identity of the solid that the gas came from.

Conductivity

Conductivity has been traditionally used to determine if a substance is ionic or covalent. Dissolve a small pea-sized amount of your unknown in excess water, and measure the conductivity, or lack thereof, of the resulting solution.

- You must provide at least four tests to corroborate your conclusion as to the identity of your unknowns.
- Each student(group) will do two unknowns. But only report on 1 of them in the team table.
- If you suspect the presence of a specific ion, run that same test on a sample that you **know** contains that ion to see a true positive to compare to your unknown results. You should see the same results on the known sample.
- Record ALL of this in your observations

Team Table Layout

Tabulate your data as a class for your assigned unknown. Put this information in your notebook. Each student must identify all the unknowns individually from their peer's information

Name	Unknown #	Solubility in Water	Conclusive Tests Observations			
			1	2	3	4

Lab Report Checklist – Quantitative Analysis of Household Substances

___/7 Pre-lab assignment/questions:

1) Each unknown is a common household substance, from the kitchen, medicine, or craft cabinet. Research each of the substances as to their makeup. Present the components of these in a table.

Table salt	Epsom Salts	Calcium Carbonate
Salt Substitute	Plaster of Paris	Iodized Table Salt
Baking Soda	Flour	Self-Rising Flour
Double-Acting Baking Powder	Cornstarch	Powdered Sugar

2) Make a table of the flame colors for the alkali and alkaline earth metal cations present in the unknowns. Outline how to perform a flame test using a nichrome wire.
3) A precipitation test is a method that utilizes the solubility trends of ionic compounds to differentiate between metal cations and certain anions. List the solubility rules of the alkali and alkaline earth metals, sulfates, carbonates, ammonium compounds, and halides. How could a precipitation test be used to differentiate between table salt and baking soda?
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5) Why should distilled water be used when conducting these chemical tests?

___/3 Reagent Table / Toxicity/Interesting Fact:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/0.5 Header: Make sure to fill out each header area.

___/4 Procedure:

Cite the source of your procedure. Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/4 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and observed. Include physical observations of all chemicals, molarities and anything you did in the lab.

___/3 Summary:

Type a narrative of what you did and observed. Include reference to any graphs drawn(page #), and/or calculations(page #) done to arrive at the result(s) you are reporting. Use subscripts and superscripts for chemical formulas. Include a summary of the reactions you ran on the knowns with balanced chemical equations to represent them. Do the same for the reactions you ran on the unknowns with balanced chemical equations to represent them.

____/4 Table(s)

Include a table of your results embedded in summary, team table, results table showing identification of all unknowns: include caption(s)

Unknown	Identification	Reasoning
1	Provide substance name	Provide reasoning, include all test results

____/4 Conclusions:

In conclusion, this experiment was performed in order to….then explain why you did it and if it answered the hypothesis or question posed. If it did not, then what experiment could you perform to answer that question(s). Address error here. Write a narrative of your reasoning surrounding the identification of **all** the unknowns.

___/0.5 Signed

Each page as you did it and instructors signature after you finish

Investigation 11: Electrochemical Cells

a) Does the Mass of an Electrode really change during the operation of an electrochemical cell?
b) Can I kill an electrochemical cell by getting it really cold?

Content Connection:

Electrochemistry

Narrative:

Electrochemistry is an area of study that concerns the interconversion of electrical energy(the flow of electrons) and chemical energy(the energy exchanged upon the alteration of a chemical species). This is the basis for all the batteries we use today. You have been learning about *voltaic*, also known as *galvanic,* electrochemical cells. According to the chemical theory of these types of cells, a spontaneous reaction occurs between two substances, one being oxidized and the other reduced, based upon the location of these substances in an activity series. This is a result of the fact that there are substances that would rather be reduced(accept electrons) or oxidized(donate electrons) when in contact with each other.

According to the nature of these reactions, the substance that is being oxidized(losing electrons) is normally being converted from an elemental solid state to the ionic aqueous state. This would result in a decrease in mass of that sample. The substance that is being reduced(gaining electrons) is normally being converted from an ionic aqueous state to the elemental solid state, which results in an increase in mass of the substrate on which it is occurring.

The electrical energy produced by these voltaic cells are affected by various parameters, such as the concentration of the elements in solution and temperature.

In this investigation, you will build a voltaic cell, measure the voltage produced, measure the change in the masses of each electrode, and investigate the effect of temperature on cell voltage, then try to kill it with cold.

Pre-lab assignment(s)

1. See this Kahn Academy video for a mini-lecture and answer the following questions.
   a) Sketch the zinc-copper electrochemical cell. What is the EMF of this cell if both solutions are 1.0 M?
   b) Write the spontaneous chemical reaction occurring in this cell.
   c) Which electrode should be gaining mass? Which should be losing? Explain.
   d) Which electrode is acting as the anode and write the oxidation half-reaction that occurs?
   e) Which electrode is acting as the cathode and write the reduction half-reaction that occurs?
   f) Write the cell diagram for this cell.
   g) Indicate the electron flow on your drawing in a).
   h) Optional Extension: Go to this site to build a cell and see its operation.
2. Research the temperature of a dry-ice acetone mixture. How can we use this to get our apparatus REALL, REALLY COLD! Cite Sources.
3. Calculate the theoretical emf for each of the following cells.
   $Pb^0,Pb^{2+}_{(aq)}/Cu^{2+}_{(aq)},Cu^0$ $Sn^0,Sn^{2+}_{(aq)}/Cu^{2+}_{(aq)},Cu^0$ $Pb^0,Pb^{2+}_{(aq)}/Sn^{2+}_{(aq)},Sn^0$

Materials available

LabQuest	1M $Pb(NO_3)_2$	Ice
Temperature Probe	1M $SnCl_2$	glass U-tubes
Voltage Reader	0.1M KNO_3	cotton
Clamps	1M $Cu(NO_3)_2$	Agar
Lead(Pb), Sn and Cu strips	Alligator clips	Dry Ice

Safety Precautions:

Follow all lab safety procedures and wear goggles. Wash your hands before leaving the laboratory. No open flames.

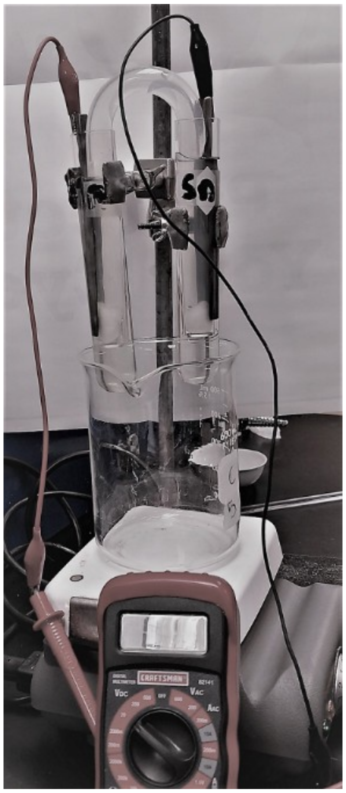
Suggested Method(s)

Building a salt bridge

1. Mass 1.000 g of agar and dissolve it in 100.0 mL of boiling 0.1 M KNO_3, stirring constantly until all the agar dissolves.
2. Invert a **U-tube** and fill it with the solution, plugging the ends with agar soaked solution. Leave it to cool and harden. Make sure there are no empty spaces in the salt bridge.

Build your assigned electrochemical cell

1. In two separate large test tubes, place 30mL each of 1 M metal nitrate solution to match your cell electrodes.
2. Obtain two solid, elemental metal electrodes for the galvanic cell you are building. Clean the surfaces using steel wool and mass the electrodes.
3. Insert the elemental metal electrodes into their corresponding metal ion solution and clamp the prepared test tubes to a ring stand.
4. Set up a hot plate and beaker that will be placed underneath the two test tubes such that the apparatus can be raised and lowered into an alternate temperature bath.
5. Use your salt bridge to connect the test tubes. Be careful not to break the salt bridge as you adjust the apparatus.
6. Obtain a voltmeter and attach the leads to the metal electrodes.
7. Record this voltage and temperature. If your voltage is negative; reverse the wire connection.
8. Run your cell for 30 minutes and monitor the voltage.
9. Dismantle the cell and determine if the mass of the electrodes have changed.
10. Change the temperature of your electrochemical cell by lowering your apparatus into a Alternate temperature bath. Monitor the voltage during these temperature changes.


Example set-up for the electrochemical cell

Team Table Layout:

Tabulate your data as a class for comparison.

Group Names	Chosen Cell	Mass of cathode before running cell(g)	Mass of cathode after running cell(g)	Mass of anode before running cell(g)	Mass of anode after running cell(g)	Time cell was run	EMF and T 1	EMF and T 2	EMF and T 3	EMF and T4

Lab Report Checklist Voltaic Cells

___/5 Pre-lab questions/assignment

1. See this Kahn Academy video for a mini-lecture and answer the following questions.
    a) Sketch the zinc-copper electrochemical cell. What is the EMF of this cell if both solutions are 1.0 M?
    b) Write the spontaneous chemical reaction occurring in this cell.
    c) Which electrode should be gaining mass? Which should be losing? Explain.
    d) Which electrode is acting as the anode and write the oxidation half-reaction that occurs?
    e) Which electrode is acting as the cathode and write the reduction half-reaction that occurs?
    f) Write the cell diagram for this cell.
    g) Indicate the electron flow on your drawing in a).
2. Research the temperature of a dry-ice acetone mixture. How can we use this to get our apparatus REALL, REALLY COLD! Cite Sources.
3. Calculate the theoretical EMF for each of the following cells.
    $Pb^0,Pb^{2+}{}_{(aq)}/Cu^{2+}{}_{(aq)},Cu^0$ $Sn^0,Sn^{2+}{}_{(aq)}/Cu^{2+}{}_{(aq)},Cu^0$ $Pb^0,Pb^{2+}{}_{(aq)}/Sn^{2+}{}_{(aq)},Sn^0$

___/2 Reagent Table / Toxicity/Interesting Fact:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/1 Header: Make sure to fill out each header area.

___/4 Procedure:

Cite the source of your procedure. Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/4 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and observed. Include physical observations of all chemicals, molarities and anything you did in the lab.

___/4 Summary:

Type a narrative of what you did and observed. Include reference to any graphs drawn(page #), and/or calculations(page #) done to arrive at the result(s) you are reporting. Use subscripts and superscripts for chemical formulas.

___/2 Table(s)

Include a table of your results embedded in summary and of team table, include caption(s)

___/4 Conclusions:

In conclusion, this experiment was performed in order to ....then explain why you did it and if it answered the hypothesis or question posed. If it did not, then what experiment could you perform to answer that question(s). Address error here.

___/1 Signed

Each page as you did it and instructors signature after you finish

___/3 Post Questions:

Look for these on D2L Announcements!

Investigation 12: Lab Practical

How well did I take notes and understand the lab experiments we did this Semester?

Content Connection:

Lab Practical and the importance of a lab notebook.

Narrative:

A "Lab Practical" is a way to assess proficiency in the methods and analysis typically done in a laboratory setting. Throughout the semester, you performed various techniques; from boiling point, melting point, using a spectrometer, and titration to determine concentrations. You also learned various chemical methods to determine the identity of unknown substances.

You will be assigned certain tasks to complete. You will only have your lab notebook to guide you. These assignments will be based on the techniques/experiments you have practiced throughout the semester and will involve identification of unknowns.

Assigned Tasks

1) correctly identify the an unknown solid salt(cation and anion)
2) correctly identify an unknown acid or base **and** its concentration in molarity.
3) correctly identify the **concentration** of an unknown dye solution.

The tools at your disposal are found on the cart as well as your observations from previous experiments. You will have a maximum of 2.75 hour to **finish** all tests and **clean up**. If your chemical runs out before you have finished testing your unknown you will have to use whatever tests you have already done as there will not be any refills. You will be graded on accuracy and appropriate use of laboratory techniques.

Remember to include all procedures in your lab notebook as this will count toward the final grade.

Hand in a lab report of what you did as well as the identification of your unknowns and rational for the identification, as well as your observation/procedural notebook sheets. You must provide at least 3 reasons for your identification of unknown(s).

Investigation 13: Breaking Bad scenario…

What are the challenges in creating a pure organic substance?

Content Connection:

Organic Chemistry Synthesis

Narrative:

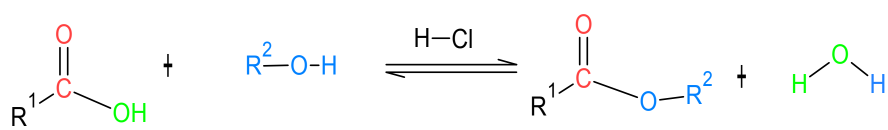
Chemistry, which is the study of matter and the changes it undergoes, spans a diverse array of matter types, which we know as compounds. As the characterization of chemical substances continued to increase, the need for specialization arose. *Inorganic* chemistry traditionally focuses on the properties and behavior of substances that include minerals, metals, and ionic and covalent compounds that do not contain carbon to any great extent.

Organic chemistry constitutes the study of the structure, properties, composition, reactions, and preparation of carbon-containing compounds, which can include hydrocarbons, pharmaceuticals, petrochemicals, food, explosives, paints, and cosmetics. Organic compounds also can include other elements such as nitrogen, oxygen, halogens, phosphorus, silicon, and sulfur. This branch of chemistry was originally limited to compounds produced by living organisms but now includes synthetic substances such as plastics.

In this investigation, you will learn how to synthesize a small organic molecule, namely aspirin and wintergreen. This synthesis will give you a taste of the challenge's organic chemists, or "cooks" face.

Pre-lab assignment(s)

1) The synthesis of aspirin involves an esterification reaction.
An example of a general esterification reaction is given below. The letter R stands for the "rest" of the molecule.



Write this reaction in your notebook and label each molecule in the reaction as to its functional group using the following word bank. Not all the words are used.

Word Bank:	an ester	water	an alcohol
	acid catalyst	carboxylic acid	an anhydride

2) Research the esterification reaction to create aspirin out of salicylic acid and acetic anhydride. Write the reaction and cite your source. Use the same word bank above to label each reactant and product. Circle each functional group in each molecule in your esterification reaction to create aspirin.
3) Research and write the esterification reaction to create methyl salicylate(wintergreen) using salicylic acid and methanol as starting materials. Use the same word bank above and circle each functional group in each molecule in your esterification reaction to create wintergreen.
4) Phenols are a class of compounds that contain an –OH group attached to a benzene ring. Circle the phenols in both your reactions you wrote in 2) and 3).
5) Phenols react with the iron(III) cation to create coordination complexes that have distinct colors. Research and write a reaction between a phenol and iron(III) cation to create a colored complex. Would a positive test result if the aspirin synthesis goes to completion? Explain.
6) Assuming a 3.00 g starting amount of salicylic acid and an excess amount of acetic anhydride, calculate the theoretical yield of aspirin.

Safety Precautions:

Follow all lab safety procedures and wear goggles. Wash your hands before leaving the laboratory. No open flames. Do concentrated sulfuric acid tests and flame tests in the hood!

Materials available

Acetic anhydride	absolute ethanol	1%$FeCl_3$ solution
Methyl alcohol	salicylic acid	concentrated H_2SO_4

Suggested Methods

Synthesis of Aspirin

1. Start a hot water bath heating.
2. Place about 3g of salicylic acid in a 125mL Erlenmeyer flask
3. Add 6mL of acetic anhydride.
4. Working in the hood, cautiously Add 5 drops of CONCENTRATED H_2SO_4, swirling to combine the reagents.
5. Heat the flask in a hot water bath (80-90°C) for 20 minutes. Remove the flask from heat and allow it to return to room temperature.
6. Add 40mL of distilled water to this flask and cool the mixture by placing in an ice bath. Crystals of crude acetylsalicylic acid should form at this point
7. Mass a piece of filter paper that fits inside a Buchner funnel. Place the filter paper in the funnel, and attach to the vacuum. Moisten the filter paper with a small amount of water. Once crystallization is complete, vacuum filter the crude crystals, continuing to allow air to be drawn through to dry the solid.
8. Obtain the mass of the crude crystals.

Determination of Phenolic Impurities

1. In a test tube, dissolve a few crystals of stock salicylic acid in 5mL of H_2O and add a drop of 1% ferric chloride. Note the color.
2. In another test tube, dissolve a few crystals of **your crude aspirin** in 5mL of H_2O and add a drop of 1% ferric chloride. Note the color. Should a color change occur if the reaction has run to completion?

Recrystallization

1. Dissolve 6g of ***your crude aspirin*** in about 20mL of absolute ethanol (if you have less than 6g, scale the amount of ethanol needed based on this ratio).
2. Warm the ethanol in a water bath (**DO NOT USE A FLAME)**.
3. When the aspirin has dissolved, add 50mL of H_2O, scaling this amount if you had more or less than 6 g crude product. If any crystals form, heat up your solution.
4. Cover your flask and let the solution cool slowly for 10-15 minutes. Submerge the flask in an ice bath for a further 5 minutes.
5. Mass a piece of filter paper that fits inside a Buchner funnel. Place the filter paper oin the funnel, and attach to the vacuum. Moisten the filter paper with a small amount of ethanol. Once crystallization is complete, vacuum filter the crystals, continuing to allow air to be drawn through to dry the solid.
6. After your crystals have successfully dried, obtain and record the mass of the filter paper/product. Determine the mass of purified crystals obtained and calculate percent yield.
7. In another test tube, dissolve a few crystals of **your purified aspirin** in 5mL of H_2O and add a drop of 1% ferric chloride. Note the color.

Synthesis of Methyl Salicylate

1. Place 1g of salicylic acid and 5 mL of methyl alcohol in a large test tube.
2. Working in the hood, add 3 drops of concentrated sulfuric acid and place the test tube in a newly prepared water bath(70°C) for about 15min. **DO NOT PLACE IN THE HOT WATER BATH AT 80-90°C.**
3. Note the odor.
4. Add a drop of 1% $FeCl_3$ to the test tube and note any color change. Should a change occur if the reaction has run to completion?

Lab Report Checklist - Synthesis of Aspirin and Wintergreen

___/6 Pre-Lab Questions:

1) The synthesis of aspirin involves an esterification reaction.
An example of a general esterification reaction is given below. The letter R stands for the "rest" of the molecule.
Write this reaction in your notebook and label each molecule in the reaction as to its functional group using the following word bank. Not all the words are used.

Word Bank:			
	an ester	water	an alcohol
	acid catalyst	carboxylic acid	an anhydride

2) Research the esterification reaction to create aspirin out of salicylic acid and acetic anhydride. Write the reaction and cite your source. Use the same word bank above and circle each functional group in each molecule in your esterification reaction to create aspirin.
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5) Phenols react with the iron(III) cation to create coordination complexes that have distinct colors. Research and write a reaction between a phenol and iron(III) cation to create a colored complex. Would a positive test result if the aspirin synthesis goes to completion? Explain.
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___/2 Reagent Table / Toxicity/Interesting Fact:

Look up the main routes of exposure, the toxicity, the formula, and the molar mass of each chemical you are using. Present this information in a table. Chose one chemical to research further and report an interesting fact about it. cite sources

___/1 Header: Make sure to fill out each header area.

___/4 Procedure:

Cite source Full Credit will be given for procedures, coupled with notes/observations, that I could use to repeat your experiment.

___/4 Notes/Observations:

Full Credit will be given for notes and observations that describe everything you did and observed. Include physical observations of all chemicals, molarities and anything you did in the lab.

___/2 Calculations:

Calculation of theoretical and percent yield

___/3 Summary:

Type a narrative of what you did and observed. Include reference to any graphs drawn(page #), and/or calculations(page #) done to arrive at the result(s) you are reporting. . Use subscripts and superscripts for chemical formulas.

____/2 Table(s)

Table of your results

____/2 Conclusions:

___/1 Signed

Each page as you did it and instructors signature after you finish.

___/3 Post Questions:

Look for these on D2L Announcements!