Introduction to General Chemistry I Laboratory

General Chemistry I Laboratory (CHM151L) is designed to be taken by students enrolled in General Chemistry I Lecture (CHM151). The laboratory and lecture are separate courses and you will be assigned a separate grade for each. CHM151L will often reinforce lecture course topics, covering them at the same time or after, but the primary purpose is to provide you with instruction in common laboratory manipulations, laboratory safety, data collection, data interpretation, record keeping, common chemical concepts, and calculations. You will become familiar with some of the chemist's basic laboratory equipment and will learn why and when this equipment is used.

Mastery of the techniques, concepts, and calculations covered in the laboratory course will provide the foundation for future chemistry and science courses and future work and thinking after the university experience. Key techniques such as mass measurement, volume transfer, solution preparation, dilution, titration, and qualitative analysis must be done safely, balancing precision and speed. Concepts must then be applied to analyze and interpret data and final results using unit cancellation (dimensional analysis). Graphical analysis, and/or statistics will be applied as needed to complete any calculation, and/or determine the quantity of interest. The quality or precision of the data and results must be expressed using proper significant figures and evaluated using statistics such as mean, median, range, and correlation coefficients. Mastery of technique is done by "doing", therefore nearly all the work in this course is done individually. To excel in this laboratory course you must demonstrate mastery of all the key techniques and related concepts.

The data and results for each experiment are recorded in a laboratory notebook and will be evaluated to determine if techniques, concepts, and calculations have been mastered through the report sheet. Unknowns are used for each experiment to assist in the evaluation process. Each unknown has a unique number to be used only by you and must be recorded correctly on the report sheet. If you use the equipment properly, record observations accurately, and calculate correctly, you will obtain an "acceptable" answer (close to the true value) and receive a PASS. On the other hand, if an "acceptable" answer is not reported, you will receive a PARTIAL CREDIT or a REPEAT. If you make technique or calculation errors while doing the experiment you most likely will not get a "PASS". Calculation checks are available for most experiments to verify that computations are done correctly, but you will only know if the experiment techniques were done correctly when the value for your unknown is graded. An "acceptable" answer for an unknown is one that correctly identifies it or comes within a range of possible answers obtained by students. For best results, relax and work carefully.

You may repeat the unknown for an experiment any number of times to obtain the PASS grade (as lab space and time allows), but be sure to use a new unknown and a new report sheet each time you repeat an experiment. If you have to repeat an experiment, get help from your teaching assistant or instructor and have them check your technique. Save all graded unknown report sheets in case there are problems and make a backup copy of the report sheet before turning in your results. Lost work is the student's responsibility.

Each experiment will have pre and post lab work that will be completed in the lab notebook or will be done via a web based system. Your pre-lab preparation for each experiment will be tested in class by a pre-lab quiz and overall course mastery by a lab practical.

Learning Objectives

I. Technique - Laboratory Procedures and Equipment

A. The proper use of equipment for the measurement of various physical properties is very important. Considering the ease and speed of use and the desired precision and accuracy, you must be able to choose the right piece of equipment and follow proper technique to use it. This may include interpolation and estimating between the marks on a scale, and using the appropriate number of significant figures in reporting measured quantities. Mastery of the following techniques is expected:

1. Volume measurement: Quantitative volume transfer using pipettors and volumetric pipets and familiarity with graduated cylinders, pump dispensers, Mohr pipets and calibration. Quantitative dilutions using volumetric flasks and precise volume transfer. Use of a buret in titrations and safe use of beakers, erlenmeyer flasks, and test tubes to conduct reactions. (Experiments 1, 2, 3, 4, 6)
2. Mass measurement: Weighing technique and care of digital balances that includes "weighing by difference" with proper mass transfer. (Experiments 1, 2, 3, 4, 6).
3. Temperature measurement: Use of thermometer (Experiments 1, 3, 4).
4. Time measurement: Measuring the speed of a chemical reaction (Experiment 3).
5. Heating procedures: Use of Bunsen burner & hot plate (Experiments 2, 3, 5).
6. Qualitative analysis: Using flame tests, observing and describing the formation and dissolving of precipitates and gases (Experiments 2, 3, 5).
7. Quantitative techniques: Titration, pipetting, weighing (Experiments 1, 2, 3, 4, 6).
8. Proper cleaning of glassware, mixing of solutions, and use of reagents without causing cross-contamination (Experiments 1, 2, 5, 6).
9. Measuring emission spectra using spectrophotometer (Experiment 4).
10. Laboratory safety: Conduct a risk assessment using hazard codes, labels, safety data sheets (SDS), and other safety information to have awareness of lab hazards and respond with proper precautions. This involves the ability to use and dispose of chemical reagents and use lab equipment such as the fume hood safely and respond correctly in the event of an emergency. This also includes keeping work areas clean.
11. Collection of experimental data with correct significant figures and units.

B. Recognition of equipment found in your workstation and lab along with their use.

II. Calculations

A. The basic calculations used in this lab are important for future work in chemistry and other sciences. Mastery of the following calculations and methods is expected:

1. Percent by mass (Experiments 2, 6).
2. Density (Experiments 1, 2).
3. Mass by difference (Experiments 1, 2, 3, 4, 6).
4. Using a chemical formula to calculate molar mass (Experiments 2, 6).
5. Conversion from grams to moles or moles to grams using molar mass (Experiments 2, 6).
6. Use of concentration units such as molarity (Experiments 2, 3, 6).
7. Dilution calculations using $M_1V_1=M_2V_2$ (Experiments 3, 6).
8. Use of chemical equations in calculations (Experiments 1, 3, 4, 6).

9. Calculation of the median and the mean (average) from a set of data taken in the lab (Experiments 1, 2, 4, 6).
10. Graphing data and interpreting graphical information (Experiments 1, 3, 4)

B. Data recording: proper format and rules.
C. Significant figures should be understood and the appropriate number of digits should be used for recording data, doing calculations, and predicting precision when mathematical operations: mean (average), median, range, and error analysis are being done.
D. The use of unit cancellation or dimensional analysis will be used in all calculations to solve problems and check work in this lab course.
E. Graphing data and using linear regression and other functions to predict unknown values (Experiments 3, 4).

III. Concepts

A. Mastery of the following concepts is expected:
1. Atomic emission and emission spectrum (Experiment 2, 4, 5).
2. Concentration (Experiments 2, 3, 5, 6).
3. Density (Experiments 1, 2).
4. Energy (Experiment 4).
5. Stoichiometry (Experiments 1, 3, 4, 6).
6. Qualitative analysis (Experiments 2, 3, 4, 5).
7. Acid-base reactions as used in titrimetry (Experiment 6).
8. Use of an acid/base indicator (Experiment 6).
9. Significant figures and unit cancellation (Experiments 1, 2, 3, 4, 6).
10. Treatment of Data – Graphing and Statistics (Experiments 1, 3, 4).
11. Using net ionic equations to describe chemical reactions (Experiments 3, 5)

Safety in the Chemistry Laboratory

Laboratory safety is a core consideration before doing experimental work and involves the prevention of and response to laboratory emergencies. Good prevention is far better than someone getting hurt. This begins with always being aware of chemical and laboratory hazards. Hazard codes, chemical labels, and safety data sheets (SDS) or material safety data sheets (MSDS) are key sources of information that help us prepare to work safely in a laboratory. This information can be used to do a **risk assessment** on the experiment you are about to do. Certain rules need to be followed to keep you safe, and you must know what to do in case of an emergency. Chemical waste management is another important aspect of a safe laboratory and a key regulatory compliance issue.

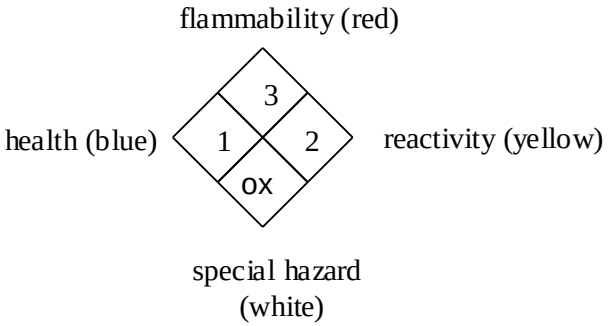
Risk Assessment

A risk assessment analyzes what hazards will be encountered during an experiment or lab procedure, how to mitigate them using precautions such as goggles, gloves, or a fume hood, and what should be done if something goes wrong. There may be physical or chemical hazards present that will be indicated in the experiment write up using hazard codes and other information. Labeling for reagent chemical bottles will always include hazard codes and/or special warning stickers. If a chemical has a higher hazard more information can be obtained by referring to the safety data sheet (SDS) and noting hazards and what precautions to use in response to these hazards. For every experiment outline the experimental procedure and write a risk assessment that includes hazards and precautions before you start lab work.

Becoming Informed: Chemical Labels, Hazard Codes, and Safety Data Sheets (SDS)

Label on Chemical Bottle: The first source of information is the label on a chemical bottle. Read the label carefully before using a chemical. A commercial chemical bottle will have extensive information on the label such as the chemical name and formula, physical properties, purity, molar mass, hazards, safety precautions, suggested protective equipment, hazard codes, and other information. **Chemical labels must include the chemical name and hazard(s).**

NFPA Code: The National Fire Protection Association (NFPA) uses a hazard code system that was adopted in 1975 to communicate hazards to emergency responders. This system uses a label that you may be familiar with since it appears on entrances to stores containing hazardous chemicals and on some chemical containers.



The positions on the NFPA diamond are defined as follows:

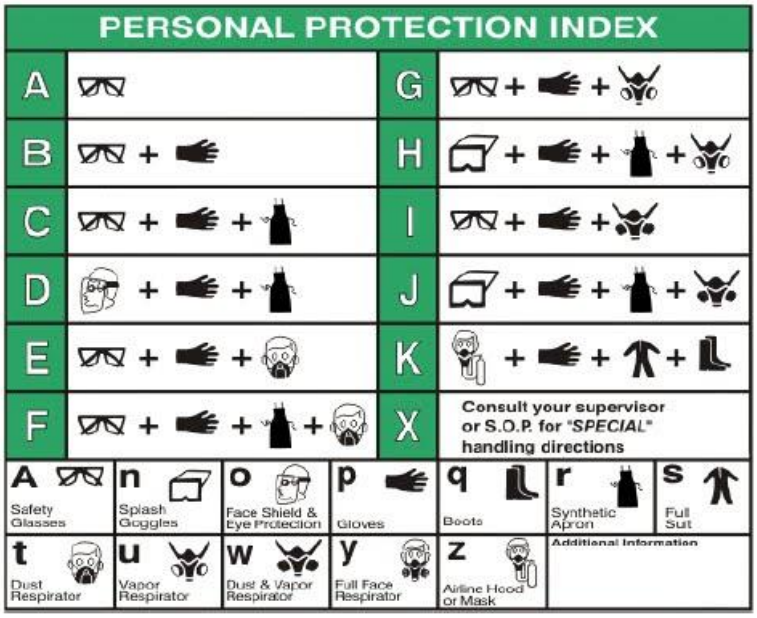
Health Hazard (Blue): Degree of hazard for short-term protection.
0. Ordinary combustible hazards in a fire
1. Slightly hazardous
2. Hazardous
3. Extreme danger
4. Deadly

Flammability (Red): Susceptibility to burning.
0. Will not burn
1. Will ignite if preheated
2. Will ignite if moderately heated
3. Will ignite at most ambient conditions
4. Burns readily at ambient conditions

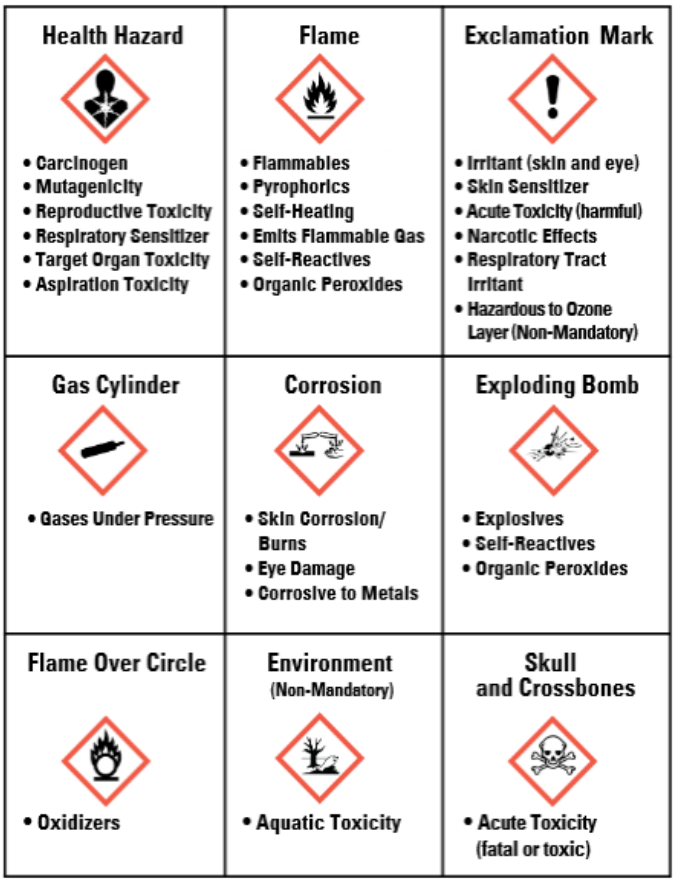
Reactivity, Instability (Yellow): Energy released if burned, decomposed, or mixed.
0. Stable and not reactive with water
1. Unstable if heated
2. Violent chemical change
3. Shock and heat may detonate
4. May detonate

Special Hazard (White position on diamond):
OX Oxidizer
~~W~~ Use no water, reacts!

HMIS Code System: The American Coatings Association uses the Hazardous Materials Identification System (HMIS) that is similar to the NFPA systems but includes a code for precautions to take for using a product or chemical. It also includes suggested personal protection for using chemicals or products. The code is often seen on paint and other products that might be found in a hardware store. The "*" indicates a chronic health exposure.



Globally Harmonized System (GHS): The Federal Government recently adopted the new Globally Harmonized System (GHS) hazard communication system. The GHS uses the nine hazard pictograms shown to the right to communicate chemical and product hazards. These are similar to DOT placards on the previous page. In this lab, course chemicals with the corrosive (Corrosion), oxidizers (Flame Over Circle), flammables (Flame), and toxins (Health Hazard and/or Exclamation Mark) may be encountered in lab. This system has three health hazard categories, 2-3 reactive categories, and two new additional areas: environment and gas cylinders. The SDS also uses an in-depth hazard coding system that is currently being implemented nationally and internationally.



The Safety Data Sheet (SDS)

The SDS is part of the GHS and should be read to obtain additional safety information before using hazardous chemicals. The SDS is required by OSHA for any workplace chemical hazards. If you are an employee, it is your right to have access to an SDS for any chemical product that you will likely encounter in the future. Every sheet is required to have 16 sections:

1. Identification (chemical or product)
2. Hazard Identification
3. Composition (chemical or product)
4. First-Aid Measures
5. Fire-fighting Measures
6. Accidental Release Measures
7. Handling and Storage
8. Exposure Controls and Personal Protection
9. Physical and Chemical Properties
10. Stability and Reactivity
11. Toxicological Information
12. Ecological Information
13. Disposal Considerations
14. Transport Information
15. Regulatory Information
16. Other Information

The signal words "Danger" (higher risk) and "Warning" (less risk than danger) are used in the SDS and labels. These sheets are available for all chemicals used in this course in the chemical hygiene plan notebook located in the "Right to Know Hazard Communication Station". These are to be kept in the lab at all times for reference. The internet is a great resource for SDS and other safety information. To get an SDS search the internet using the chemical name and SDS (or MSDS if SDS is not productive).

Precautions - How to Protect Yourself

1. **Eye Protection** MUST BE WORN IN THE LABORATORY AT ALL TIMES unless otherwise noted by the instructor or TA. Avoid rubbing your eyes in lab unless you wash your hands first. Use extra caution when using corrosive chemicals. Indirectly vented or nonvented goggles are the required eye protection for this lab course. Safety glasses or directly vented goggles are not acceptable. Do not modify or remove the vents on goggles. Write your name, course number, and section letter on your goggles.
2. **Skin protection** should be employed where appropriate; you may be required to wear long pants. Avoid wearing shorts. The use of a lab coat or plastic apron is recommended, but optional. Closed toed shoes must be worn at all times in the laboratory for protection against broken glass and spilled chemicals. Disposable gloves are available for the handling of hazardous chemicals. Avoid touching your face or personal items while wearing gloves. Always remove them before exiting the lab. After completing lab work for the day, wipe down your entire work area (or any area used including the balance, fume hoods, or reagent areas) with a clean damp sponge to clean up any spilled chemicals and other material. Rinse out the sponge several times and wring it out. Wash your hands as you exit the lab.
3. **Protection from fumes or fine powders:** Never allow hazardous chemical fumes or dust to escape into the open room; use fume hoods when necessary or specified. Be sure to use the fume hoods correctly, following the instructions provided by your TA or instructor. Avoid putting your head inside the fume hood, and close the sash or fume hood window when it is not in use.
4. **Protection from internal poisoning:** Never "pipet by mouth", eat, drink, or smoke in the laboratory. Do not keep food, beverage or personal items at your workstation. They must be kept in the designated area at the entrance to your lab. Wash your hands after you have completed lab work or leave the lab room.
5. **Protection from hot surfaces:** Use the appropriate types of tongs to handle hot objects. Test tube holders are too weak for carrying flasks.

6. **Protection from fire and explosion:** Never allow flammable vapors to escape into the open room (see No. 3). Hot plates/magnetic stirrers are an ignition source so keep away from flammables. Flammable liquids should be used in fume hoods and stored in solvent cabinets when possible. Long hair should be tied back to keep it away from open flames.
7. **Protection from cuts:** When manipulating glassware or ceramic ware, protect your hands with a cloth towel or gloves. Clean up broken glass immediately. Do not pick up broken glass with bare hands. Use a broom and dustpan to dispose of glass in the "Broken Glass Container".
8. **Protection from the unexpected:** Always read all labels noting the chemical name, formula, concentration, and warnings (including hazard codes) carefully, and double check to make sure you have the correct chemical and concentration. Follow directions in the experimental procedure exactly. Remove obstacles by keeping lockers closed, lab chairs pushed in, and backpacks and coats stored on coat rack. For unassigned lab work, you must have the approval of the instructor. Carefully follow hazardous waste disposal instructions given later.
9. **Safety Violations:** Any student who does not follow the above guidelines will be given one warning and will then be removed from the lab for the day for any subsequent violations. There may also be grade deductions or permanent removal from the lab for serious or repeated violations.

What to Do in Case of Accident

1. During your first lab period, locate the position of the fire extinguishers, eyewashes, safety shower, first aid kit, phone, fire alarm pull stations, exits, hallway showers, safety data sheets, and any other safety equipment.
2. In all cases of accident or injury, notify the TA and the instructor immediately.
3. For any serious fire or injury: Call the POLICE DEPARTMENT (3-3000) from any campus phone or 523-3000 on a cell phone. Campus security is in the best position to summon fire or ambulance service. Call the Flagstaff Fire Department (8-774-1414) or dial 911 if Security cannot be reached. Use the FIRE ALARM PULL STATIONS (red box by every stairwell entrance) to clear the building of personnel. THE LOCAL FIRE ALARM IN THE LAB BUILDING WILL SUMMON HELP, BUT ALWAYS CONTACT CAMPUS SECURITY FROM A SAFE LOCATION TO PROVIDE DETAILS AS TO THE NATURE OF THE EMERGENCY. Students must evacuate and stay with their lab TA if it is safe to do so.
4. In case of a small fire: Immediately get help from your TA or instructor. If a person's clothing is on fire, they should immediately stop-drop-roll, use the safety shower if it is close, or smother the fire with a lab coat or fire blanket. Cover beaker fires with a watch glass or larger beaker to remove oxygen and put out the fire. Cool minor burns in cold water immediately.
5. In case of chemical contact: If the area of contact is small, flush it under the nearest water tap for 15 minutes. Eyes must be flushed immediately using the eyewash at one of the sinks or the eyewash by the safety shower, keeping the contaminated eye(s) open. In case of large areas of contact, start rinsing the person using the safety shower and remove contaminated clothing. After decontamination, the person may be taken to a shower room by an employee where rinsing will continue for at least

15 minutes or until EMS arrives, if called. Immediately inform the instructor or TA in any case.

6. In the unlikely case of a mercury (Hg) spill: Notify your TA and he or she will collect the Hg using a special spill kit. This occurs most commonly in broken mercury thermometers. This is rare now since we now use alcohol thermometers..
7. Chemical spill: If only a few drops of chemical are spilled, immediately clean up the material with a damp sponge, rinse out the sponge well at a sink, and wipe down the area a second time with the rinsed out sponge, and rinse the sponge again. In case of a larger chemical spill, immediately notify your TA and ask for help. Sodium bicarbonate (baking soda) can be used to neutralize acid spills. If the substance spilled is flammable, turn off all burners, hot plates, or electrical devices and get help from your TA. For large spills notify the instructor, staff, or faculty. Clean-up materials are available in the lab or preparation stock.

Hazardous Waste Disposal

The Resource Conservation and Recovery Act (RCRA) mandates the proper disposal of hazardous waste. Disposal of many waste chemicals by putting them down the sink is illegal. Regardless of regulations, the proper management of hazardous waste is of particular importance to the people of Arizona where the contamination of groundwater by hazardous waste could have grave consequences. Please carefully follow the instructions below to protect our groundwater and keep your lab safe. Hazardous waste is determined by four properties:

TOXIC: A poisonous substance, potentially harmful to human health, can cause cancer, birth defects, or can contaminate, harm or kill wildlife.

FLAMMABLE: A substance which can explode, ignite, or emit toxic gases or fumes if exposed to a source of ignition.

REACTIVE: An unstable substance which can react spontaneously if exposed to heat, shock, air, or water. Reactions may include fires or explosions. The research director or instructor for the lab must neutralize any reactive substance before it can be accepted for disposal.

CORROSIVE: A substance that could corrode storage containers or damage human tissue upon contact. (For example, acids and bases, pH <5 or >10)

Used chemicals in this lab that are only acidic or basic (pH <5 or >10) will be collected in the "Corrosive Liquids" bucket and will be neutralized by staff. Used chemicals with other hazardous properties (such as toxic metals) cannot be added to the corrosive liquids bucket, or it will become a mixed hazardous waste and must be disposed of following EPA rules which is much more costly. Used chemicals that do not fit into the above categories may be flushed down the drain with **large** amounts of water, but check with the instructor or TA if you are uncertain regarding disposal.

Handling Reagents and Standard Procedures

The liquids, solids, and solutions used in a laboratory are called reagents. You must become well acquainted with these reagents, their containers, and their proper use. The reagents are kept on a separate bench or hood away from your work area. Some reagents must be kept in the fume hood because they generate flammable or toxic fumes. The reagents are grouped according to experiment, starting with Experiment 1 and ending with Experiment 6. When you need a reagent please follow these rules:

1. Be sure to use the correct reagent. Before using the reagent, carefully check the chemical name, formula, and concentration and double check to be sure you have the right one. Note the hazard code and warnings and take necessary precautions.
2. Do not take reagent containers to your work area, and take only what you need. Conserve!
3. Do not contaminate the reagents. Always use a clean spatula for solids and clean glassware for liquids. Never put a pipet or pipettor into a liquid reagent, instead pour what is needed into a clean, dry container and take it to your work area to pipet from there.
4. Put lids back on the reagent containers snugly and put them back in the correct locations. Clean up any reagents you spill with a wet sponge, rinse out the sponge at the sink, and then wash your hands.
5. NEVER return unused reagents, liquid or solid, to the reagent bottles. Discard or share any excess. Label any container you use to store a reagent with the chemical name and hazard or hazard code. The concentration and chemical formula along with your name, section, and date would also be good information to add to the label.
6. Use great care with corrosive chemicals (strongly acidic or basic solutions). Always wear safety goggles! Rinse your hands with tap water after using corrosive chemicals, especially if you feel a burning or slimy sensation on your skin. Wear the gloves provided in the laboratory if called for. Most strong acids and bases will be disposed of in the "Corrosive Liquids bucket", as noted in experimental procedures unless the used chemical has other hazardous properties.
7. Dispose of nonhazardous chemicals in the large sinks available in the lab. Be sure to follow the instructions in the experiments with regard to the disposal of chemicals.
8. **Pure water (PW)** is made using activated carbon filtration, reverse osmosis (RO), and ion exchange or distillation followed by UV treatment to remove any salts or organic compounds and kill any microbes that could contaminate your solutions. All pure water taps will be labeled with PW. When washing glassware, often all that is needed is to rinse well with hot tap water 4 or 5 times followed by one rinse with PW inside and out. If the glassware is really dirty use detergent or simple green, then rinse hot tap water. Then, rinse all glassware with PW from a wash bottle or carboy filled with PW before use or storage. Fill your plastic wash bottle with PW for this purpose. You do not need to dry the inside of glassware. Never store dirty glassware
9. At the end of every lab period you must clean your workstation bench space and any area you used by wiping it down with a clean, damp sponge. Rinse out and wring out the sponge when you are done. Your workstation drawer must be neat and complete with clean glassware and equipment for the next student. If you break glassware during lab, be sure to obtain a replacement from your TA before you leave. Do not store your goggles, solutions, or unknowns in your workstation. Instead place them in your student storage bin.

Data Recording

Recording Experimental Measurements

In this course, a report sheet is used as well as a laboratory notebook to provide more structure in data collection. You should be able to look at your lab notebook a year from now and be able repeat the experiment or calculations. Calculations should be shown in the lab notebook. Dimensional analysis (unit cancellation) must be used to do all calculations in this

course. If a spreadsheet or graph is used to do the calculations, staple a copy to the report sheet and lab notebook pages.

Before you start an experiment, key aspects of the laboratory procedure should be outlined in your lab notebook. Any procedures not in the lab manual including changes to procedures listed in the manual must be noted. Key data must also be recorded in the laboratory notebook, in case the report sheet is lost. Certain rules need to be followed when keeping a lab notebook:

1. Record all data and observations directly in the lab notebook.. This is by far the most important rule in recording data. Do not transcribe data from other pieces of paper, i.e., DO NOT record data on scraps of paper and then recopy the data into the lab notebook. Write down exactly what you are doing and your observations as you are doing the experiment. Errors in your procedure can be caught this way. Points can be taken off for writing raw data in places other than the lab notebook/report sheet.
2. Clearly identify all data, graphs, axes, and use correct units. Use unit cancellation.
3. A ball point pen must be used for all entries in a lab notebook. **A pen must be used for all measured data (mainly mass and volume data) and observations**. Do not white out, erase, any entry; simply cross out mistakes with a single line (the mistake should still be readable) and give a short note to explain the nature of the mistake, e.g., "misread." Sometimes you will find later that the entry was not a mistake after all and will want to retrieve the data. So never obliterate or destroy data no matter how bad it looks!
4. Before an experiment is started, the entire experimental procedure must be read. As you read it, note the objectives and key points of the experimental procedure in your lab notebook. This will prepare you for the pre-lab quiz and experiment before you come to lab.
5. Another important facet of scientific experiments involves the propagation of accuracy (or inaccuracy) of measurements through the calculations to the results. Use the correct number of significant figures, as outlined below, during the collection of data and calculations.

Recording Experimental Data Using Correct Significant Figures

It is important to take data and report answers such that both the one doing the experiment and the reader of the reported results know how precise the results are. The simplest way of expressing this precision is by using the concept of significant figures. A **significant figure** is any digit that contributes to the accuracy of an experimentally measured number or to a number calculated from experimentally measured numbers. Please refer to the chemistry lecture textbook for a discussion pertaining to the use of significant figures.

In this laboratory course, mass, volume, time, and temperature are experimentally measured and used to calculate density, concentration, percent by mass, and other values of interest. In CHM151L, mass in grams (g) is always measured using a top loading electronic balance with a precision of ±0.001g. Most mass measurements should be recorded to this precision even though the last digit may vary somewhat. For example, if the mass of an object on a balance reads 25.001, 25.000, 24.999 and moves between these values, 25.000 should be recorded. Recording 25, 25.0, or 25.00 would be wrong since these would not communicate the true precision of the number. If values on the balance change randomly from 25.000, 25.001, to 25.002 then 25.001g should be recorded.. For very precise mass measurements an analytical balance is used to ±0.0001g.

Time in seconds (s) is measured using a timer, stopwatch, or perhaps a clock so the precision of the measurement might vary from ±1 to ±0.01 seconds. Always record the number to the maximum precision. Temperature will be measured using an alcohol thermometer that can be read to a precision of ±0.2 °C so estimate to the tenth of a degree (i.e. 21.3 ℃).

Measuring volume in mL is a tradeoff between speed and the precision of the measurement and requires skill in choosing the right glassware for the task. When an approximate volume is needed, a beaker, Erlenmeyer flask, or graduated cylinder can be used, but when an accurate volume is needed, a pipet, pipettor, buret, or volumetric flask will be specified for use. Recognizing when to make an accurate measurement and when to be satisfied with an approximate measurement can save much time.

Frequently, the written directions will give clues to the needed precision by using the words "approximately" or "about" when the precision is not important and "exactly" or "precisely" when the precision is important. Another clue would be the number of significant figures used to write a number. It is also important to note that glassware used for accurate measurements is calibrated at a specific temperature, which is noted on the glassware. The precision of various types of glassware is shown in the following table:

Precision of Glassware for Volume Measurement

Equipment	Precision	Purpose of Glassware/Equipment
250 mL Beaker	±10 mL	Solution preparation, storage, reactions
125 mL Erlenmeyer flask	±6 mL	Solution preparation, storage, reactions
250 mL graduated cylinder	±1 mL	Volume transfer – moderate precision
25 mL graduated cylinder	±0.2 mL	Volume transfer – moderate precision
5 mL pump dispenser	±0.1 mL	Volume transfer – moderate precision
100 mL volumetric flask (class A)	±0.08 mL	Precise final volume for dilutions
10 mL measuring pipet (Mohr)	±0.05 mL	Volume transfer – good precision
5 mL pipettor	±0.025 mL	Volume transfer – very precise
25 mL buret	±0.02 mL	Precise volume delivery for titration
5, 10 mL volumetric pipet	±0.01 mL	Volume transfer – very precise

When a measurement is made, the question arises:"How many digits or figures should be recorded?" The answer is straightforward: **For a measured number record all digits, which are known with certainty, and the last digit, which is estimated**. Many of the measurements in this course involves estimation to the nearest one-fifth or one-tenth of a scale marking. For example, in Experiment 1 a 25 mL graduated cylinder, which has scale markings every 0.5 mL, should be read to the nearest 0.1 mL, estimation to the nearest one-fifth of a division. The graduated cylinder does not need to be used to this accuracy at all times; for example, if the instruction say “add about 25 mL of water” being within 1-2 mL of 25 would be ok.

NOTE: Whenever estimation between markings is being done and the reading is "on the mark," the last digit should be included to convey the idea of accuracy to the reader. For example, with a buret, which has markings every 0.1 mL, a reading on the mark of 11.3 mL would be recorded as 11.30 mL; otherwise, the reader will not know that the buret was really read to the nearest 0.01 mL. (You must estimate the last digit by looking carefully between the markings).

Sometimes approximate small amounts of liquid are needed. In this case instructions may indicate to measure out drops from a dropper bottle or eye dropper. One drop of water or a dilute solution on average is about 0.05 mL. This can also be a safer method because it does not involve pouring the liquid from one container to another.

Generally speaking, all the glassware in the table on the previous page is for transferring known volumes of liquid from one container to another except for the beaker and flasks. Beakers along with erlenmeyer flasks are generally used for conducting chemical reactions or other lab manipulations. The volumetric flask is used for preparing precise solutions or dilutions.

Calculated Values and Tracking Uncertainty Using Significant Figures

Reporting Answers in Addition and Subtraction

When experimental data has been recorded correctly, the uncertain or estimated digit is the last digit. The calculated sum or difference of experimental measurements must be carried out only to the place where the first digit of uncertainty enters the calculation. Example: Add 14.75, 1.475, and .001475 (all of which are experimental numbers). The digits of uncertainty are underlined.

$$\begin{array}{r} 14.7\underline{5} \\ 1.47\underline{5} \\ 0.00147\underline{5} \\ \hline 16.2\underline{2}\underline{6}47\underline{5} \end{array}$$

but report to 16.23

Since the answer may include only the first digit of uncertainty, it should be rounded off to that digit and reported as 16.23. It helps to line the numbers up by the decimal point.

Reporting Answers in Multiplication and/or Division

1. All measurements should be recorded to the appropriate number of digits as discussed in the section on recording experimental data.
2. All digits except zero are always significant.
3. Zeros may or may not be significant. Leading zeros are never significant (0.02562 has 4 significant figures because neither zero is significant). Using exponential form, 2.562×10^{-2}, clarifies this issue because only the numbers before the exponent multiplier count.
   a. Any zero to the right of the first non-zero digit is always significant if there is a decimal point (2.5070 has 5 significant figures since both zeros are significant).
   b. If there is no decimal point, zeros to the right of non-zero digits are ambiguous. For example, if all the zeros are significant in 25000 (five significant figures) it would be much better to write the number in exponential form as 2.5000×10^4 to convey the precision. If the number is known to less precision, say three significant figures, it should be written as 2.50×10^4 to remove any question about the precision.
4. In multiplication and/or division, the answer should be reported to the same number of significant figures as the value in the computation with the <u>least</u> number of significant figures

Example: Find the answer to the following multiplication/division problem to the correct number of significant figures.

$$\frac{(0.085)(.08206)(366)}{(0.782)(0.14200)}$$

0.085 has 2 significant figures; 0.08206 has 4; 366 has 3; 0.782 has 3; and 0.14200 has 5. A calculator shows the answer to be 22.989865, so the answer should be reported as 23 since the number with the fewest number of significant figures, 0.085, has 2 and dictates the precision of the result.

Just Remember: When adding and subtracting, look at the fewest number of decimal places when reporting the final answer. When multiplying and dividing, look at the fewest number of significant figures when reporting the final answer.

Interpretation of Data

Significant figures are excellent to express the precision of raw data but not as good to express the precision of calculated values. **As a general rule in this laboratory course you should always use at least four significant figures for calculated values to avoid rounding errors.** In order to interpret quality of your results, certain terms are useful. You will need to understand the following definitions.

1. Accuracy: The term "accuracy" describes the nearness of a measurement to its accepted or true value. In CHM 151L, the accuracy of your work becomes known when your unknown is graded. A PASS grade indicates good accuracy, a PARTIAL CREDIT grade indicates marginal accuracy, and a REPEAT grade indicates that your results had poor accuracy.
2. Precision: The term "precision" describes the "reproducibility" of results. It can be defined as the agreement between the numerical values of two or more measurements (trials) that have been made in an identical fashion. Good precision does not necessarily mean that a result is accurate.
3. Range: The "range" is one of several ways of describing the precision of a series of measurements. The range is simply the difference between the lowest and the highest of the values reported. As the range becomes smaller, the precision becomes better.

   Example: Find the range of 10.06, 10.38, 10.08, and 10.12.
   Range = 10.38 – 10.06 = 0.32

4. Mean: The "mean" or "average" is the numerical value obtained by dividing the sum of a set of repeated measurements by the number of individual results in the set.

   Example: Find the mean of 10.06, 10.38, 10.08, 10.12

   $$\frac{10.06 + 10.38 + 10.08 + 10.12}{4} = 10.16$$

   (Note that the value 10.38, which is far greater than the other values, has a large influence on the mean, which is larger than three out of the 4 individual values.)

5. Median: The "median" of a set is that value about which all others are equally distributed, half being numerically greater and half being numerically smaller.

   If the data set has an odd number of measurements, selection of the median may be made directly.

   Example: the median of 7.9, 8.6, 7.7, 8.0 and 7.8 is 7.9, the "middle" of the five.

   For an even number of data, the average of the central pair is taken as the median.

   Example: the median of 10.06, 10.38, 10.08, and 10.12 is 10.10 which is

the average of the middle pair of 10.08 and 10.12.

Notice in the example that the median is not influenced much by the value 10.38, which differs greatly from the other three values as in the example for the mean above. For this reason, the **median is usually better** to use in reporting results than the mean for small data sets.

6. Error: The absolute error of an experimental value is the difference between it and the true value. For example if the experimental value is 30.9 and the known true value is 26.5, the error would be

30.9–26.5 or 4.4.

7. Relative percent error would be the error divided by the true value times 100:

(4.4/26.5)x100%=16.6% or 17%.

Graphing and Analyzing Data

You will be graphing data using a program called Graphical Analysis. A linear fit is done for experiment one. The correlation coefficient from doing the linear fit indicates how linear the data is where 1.0000 would indicate perfectly linear data and smaller numbers such as 0.6000 would be a poor fit. You will also be using various mathematical algorithms to fit data in experiment 3. Instructions for using Graphical Analysis are provided at the end of experiment 1. A graph will also be in exp. 4. In some cases you may use excel or other software to graph data.

Laboratory Notebook

The laboratory notebook serves several purposes; the most important of which is to be the permanent, understandable record of data and observations taken during an experiment. You should be able to look at your notebook a year from now and be able repeat the experiment or calculations. Calculations should also be shown in the lab notebook using dimensional analysis or unit cancellation. If the same calculation is repeated several times, the calculation can be shown once, and the rest of the results can be listed in a table.

At the end of each class period the TA will put a line across the notebook page under the last entry, initial by the line and put the date and time.

Important Information:

- Pen Only
- ~~strikethrough~~ mistakes
- Do not tear out blue page: only yellow carbon copy
- Empty space must be crossed out with a single diagonal line.
- Place plastic cover sheet between pages so your writing does not "bleed" through the other carbon copies.

Below is a description of each section needed in a laboratory notebook:

***This is a general format for what should be included in your lab notebook for each experiment.**

Risk Assessment:

A Risk Assessment contains information about all potential hazards of the experiment and what precautions and personal protective equipment (PPE) should be used.

What should be included: ~half page or less length

- The hazard level of the experiment (low, medium, high)
- Hazardous chemicals with NFPA rating
- Personal protective equipment (PPE)

This information is found at the beginning of the experiment in your lab manual.

Outline: ~One page length

A sufficient outline should include enough step-by-step information about the experiment such that it could be conducted without a lab manual.

Your outline can be a list of steps/ bullet points / or in paragraph form.

Observations: ~Half page or less length

During your experiment you should include remarks, statements, and comments based off of what you see, hear, and feel.

Data / Graphs

Data tables are found in your lab notebook typically before your report sheet. Key data should be recorded in case the report sheet is lost.

Graphs should be labeled with key data including a detailed title, labeled axis, and annotations.

Calculations:

All calculations, especially ones indicated with an ***** on the report sheet, need to be competed with dimensional analysis (long hand).

Example:

$$\%EtOH = \frac{0.28505 \cancel{g\ CO2_2}}{1} \left| \frac{\cancel{1 mol\ CO_2}}{44.01 \cancel{g\ CO_2}} \right| \frac{46.068 \cancel{g\ EtOH}}{1\ mol\ \cancel{EtOH}} \left| \frac{100\%}{4.265 \cancel{g\ Cider}} \right| \frac{\cancel{1\ mol\ EtOH}}{\cancel{1\ mol\ CO_2}}$$

Post Laboratory Questions:

These questions are found on the experiment report sheet and are to be completed here. Use complete sentences and show all work when necessary.

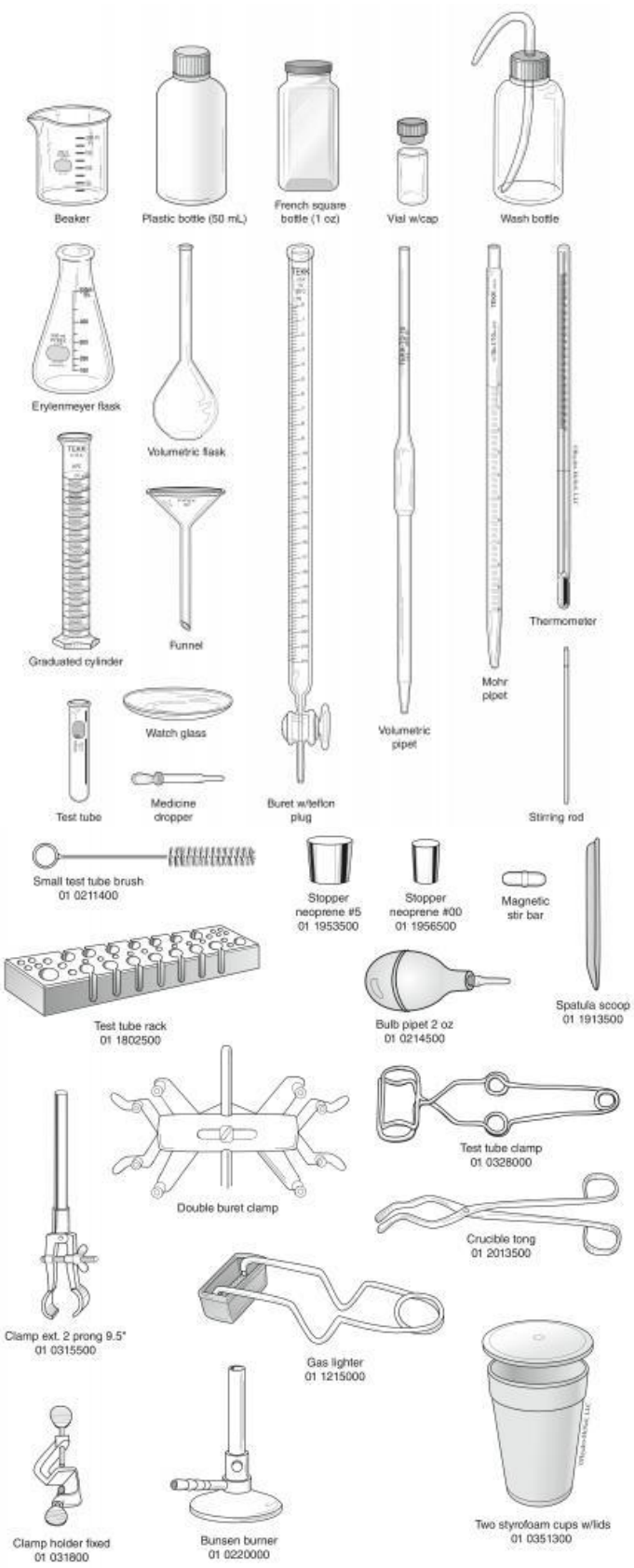
Grading Expectations

All laboratory notebooks will be graded based on the rubric below.

CHM 151L NOTEBOOK GRADING SHEET

TAs will provide exact point distributions. For certain experiments the point distribution may be changed or other requirements added. Duplicate pages of Lab notebooks are to be turned in at the same time as lab reports. Sheets are to be stapled on to the lab report sheets.

Experiment Number	1	Ferm	2	3	4	5a	5b	6
Procedure Outline/Changes	___/4	___/4	___/4	___/4	___/4	___/2	___/2	___/4
Risk Assessment	___/1	___/1	___/1	___/1	___/1	___/1	___/1	___/1
Observations	___/1	___/1	___/1	___/1	___/1	___/1	___/1	___/1
Data & Graphs	___/2	___/2	___/2	___/2	___/2			___/2
*Calculations	___/2	___/2	___/2	___/2	___/2	___/1	___/1	___/2


Beaker
Plastic bottle (50 mL)
French square bottle (1 oz)
Vial w/cap
Wash bottle
Erylenmeyer flask
Volumetric flask
Graduated cylinder
Funnel
Buret w/teflon plug
Volumetric pipet
Mohr pipet
Thermometer
Test tube
Watch glass
Medicine dropper
Stirring rod
Small test tube brush
01 0211400
Stopper neoprene #5
01 1953500
Stopper neoprene #00
01 1956500
Magnetic stir bar
Test tube rack
01 1802500
Bulb pipet 2 oz
01 0214500
Spatula scoop
01 1913500
Test tube clamp
01 0328000
Double buret clamp
Crucible tong
01 2013500
Clamp ext. 2 prong 9.5"
01 0315500
Gas lighter
01 1215000
Clamp holder fixed
01 031800
Bunsen burner
01 0220000
Two styrofoam cups w/lids
01 0351300

Experiment One:

Measurement of Mass, Volume, and Density

Purpose: In this experiment, you will learn fundamental techniques for measuring mass and volume and use these techniques to measure the density of metal samples including a metal of unknown density. Evaluating technique mastery by checking calibration using the average, median, range, and error and expressing data to correct significant figures using unit cancellation (dimensional analysis) for all calculations is fundamental. By the end of this experiment you should be able to choose glassware and equipment based on the precision and speed required for a measurement. Using these skills to scientifically and critically think about an experiment and the results will be used throughout this and future lab courses.

Required Techniques and Concepts: Mass measurement, quantitative volume transfer by pipettor, volumetric and mohr pipet, and graduated cylinder, checking calibration by using the mass and density of water at a measured temperature, density, precision by significant figures and range, average, unit cancellation (dimensional analysis).

Background: Density is a characteristic physical property of matter that can be used to help identify a substance. The density of any given substance or object refers to its mass per unit volume. It is mathematically expressed as

$$Density = \frac{mass\ of\ sample}{volume\ of\ sample} = \frac{mass\ of\ sample\ (g)}{volume\ displaced\ (mL)}$$

and commonly has units of grams per cubic centimeter (g/cm^3) or its equivalent, grams per milliliter (g/mL). For example, aluminum has a density of 2.70 g/cm^3 and nickel has a density of 8.90 g/cm^3, so measuring the density of a piece of metal would be one way to tell which metal it could be. Other properties, such as appearance, melting point, and chemical reactivity, could then be used to confirm the identification.

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The Experiment

Since the primary purpose of the experiment is to master key techniques and calculations used throughout this lab course you must do the experimental work and calculations by yourself, not in a group. To learn technique you must do it yourself! There are also videos available on using the balance, volumetric and mohr pipets, and pipettors you should view before starting this experiment that can be found on Bblearn.

Risk Assessment – low hazard: no hazardous chemicals in use.

Equipment and Supplies Needed –

- Electronic balance
- Calibration weights
- Cu and Al metal pieces
- Unknown metal bars
- 25 mL graduated cylinder
- Volumetric pipet (5 and 10 mL)
- 10 mL mohr pipet
- 50 and 100 mL beakers,
- 5 mL pipettor and tip
- Thermometer

Measurement of Mass

There are many different types of balances or scales available to measure the mass of an object. The selection of the balance depends on the mass of the object or sample and the precision needed for the measurement. In this course the measurement of mass will be done using top loading electronic balances. Our balances accurately measure mass to ±0.001 g or ±1 mg, so always record masses determined on these balances to this precision (three digits to the right of the decimal place in grams) even if the last digit is zero. All mass measurements will be done in grams, so make sure any balance you use is reading in grams (g). If not, see the TA immediately to get the mode changed back to "g". Please note that balances will change in the last digit ±0.002 g; this is to be expected.

There are many different types of electronic top-loading balances but they all use the same two simple procedures. To simply weigh an object, tare the balance to zero and then place the object on the balance to measure its mass. Weighing-by-difference is used to measure the mass of a sample being transferred from one container to another and will be used in experiment 6. A few rules need to be followed when using a balance.

Figure 1. Electronic balance

Balance Rules and Instructions

Figure 1 illustrates the electronic balance used in CHM 151L. Refer to this figure when following the steps and precautions for using the balance listed below:

1. Never pour or transfer chemicals on the balance. Spilled chemicals can damage the balances, which are very expensive to repair or replace. Never weigh warm or hot objects; if you can feel any heat, the weighing will not be accurate. Always use a container such as a vial, beaker, flask, or watch glass to weigh a solid or liquid chemical on the balance to protect the balance pan.
2. Make sure your hands are clean and dry before you handle containers or objects that are to be weighed. The outside of these containers or objects must also be clean and dry. Clean up any spills on the balance pan or lab bench around the balance immediately with a clean, damp sponge and dry with a kimwipe.

3. Prior to use it is important to make sure the balance is level. On every balance there is bubble level indicator and when the bubble is in the middle the balance is level.
4. First carefully slide open a door on the draft shield and check to make sure that the balance pan is clean. If the pan is dirty, have your TA show you how to clean it and gently place it back on the balance and close the balance by sliding the door closed.
5. Close the balance and zero it by pressing the zero >0< button. Wait 2-4 seconds for display to stabilize. It is normal for last digit to vary ± 0.001g. Let you TA know if the mass keep changing in one direction or another or if it has large jumps in mass.
6. Open the door and place the object to be weighed on the balance pan. Then close the balance. The weight display will stabilize and then record mass to ±0.001 g.
7. To tare a container mass such as a small beaker to zero place it on the balance and press the tare >T< button. Remove it from the balance and place the solid or liquid sample to be measured into it, place it back on the balance, and record its mass.
8. Remove the container, close the door, and press >0< to zero the balance.
9. Clean the balance and the counter around it when you are done and close the door(s). Never unplug the balance but be sure to turn it off at the end of the day.

Weighing Solids and Liquids

Since using the top loading electronic balance is so much easier than using the old triple beam balances or 1 mg mechanical analytical balances, very few errors are made measuring the mass of an object. Most errors are made when trying to measure the mass of solid or liquid transferred from one container to another (weighing-by-difference). The following are some helpful hints to keep in mind when weighing-by-difference.

1. Be very careful to avoid spilling material outside the target container.
2. If you are weighing the container that the material is being transferred from, do not use a spatula to transfer the material, but gently tap the container to slowly transfer the material into a new container.
3. Make sure the outside of the container is clean and dry before you weigh it for the first time and then touch it as little as possible until after the final weighing.
4. Set containers to be weighed on clean surfaces only.
5. Always cool containers or samples to room temperature before you weigh them.
6. It is sometimes helpful to pre-weigh the sample before it is transferred.

Some of these hints will be more important in future experiments (especially Experiment 6).

Balance Calibration Check

Skip this part of the procedure if it was done the first week of the semester. All of the balances are regularly checked for correct calibration by the stockroom. To insure that you are using the balance correctly and that it is properly calibrated, the mass of a calibration weight will be measured. Calibration weights are provided in small wooden boxes. Make sure your hands are clean and dry before you touch the weights. (Normally calibration weights are not touched with your hands). The balance pan should be clean and dry before calibration.

Select a calibration weight and note the "Known Mass" for the weight (stamped on the weight). Measure the mass on a balance. If the measured and known mass differ by more than 0.01 g reread the instructions for using the balance and measure the mass of the calibration weight again. If you get the same results again, see your instructor or TA.

Part A - The Density of a Metal Samples

1. Obtain an Aluminum (Al) metal sample from the reagent bench. You must return this metal sample to the box on the reagent bench as soon as you are done using it or before the end of the current lab period at the latest.
2. Make sure the metal sample is clean and dry. Weigh the metal sample on the balance and record the mass.

Note: Water is purified using various techniques to varying levels of purity measured by electrical conductivity. For this lab course we will use tap water for general washing and do a final rinse with pure water (PW), water purified by reverse osmosis (RO), carbon filtration, and deionization. The water is also treated with UV (to kill bacteria and other microbial impurities. There are pure water carboys by each sink in each lab. Fill the plastic wash bottle with pure water for use with your experiments. ***Never put anything but pure water in these wash bottles.*** *There may also be a rinse tub of pure water to give cleaned glassware a final rinse.*

3. Fill a 25 mL graduated cylinder approximately halfway with pure water. Read the volume of water accurately by estimating to the nearest ±0.1 mL. Record the results in your lab notebook.

Symbol	Metal	Density(g/mL)
Al	Aluminum	2.7
Cr	Chromium	7.2
Fe	Iron	7.9
Cu	Copper	8.9
Ni	Nickel	8.9
Ag	Silver	10.5
Pb	Lead	11.3
Hg	Mercury	13.9
Au	Gold	19.3

Table 1: Densities of Metals

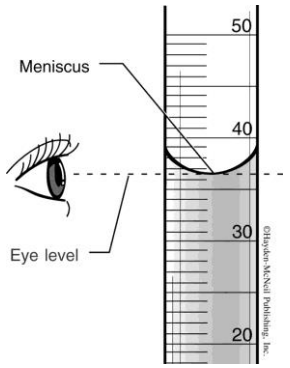


Figure 2: Graduated Cylinder Scale. Always read the bottom of the meniscus. This reading is 36.5 mL.

4. Tilt the graduated cylinder and then carefully lower the aluminum metal sample into the graduated cylinder without losing any water. Be sure that the water completely covers the sample and that the meniscus is still within the volume scale of the graduated cylinder. If not, start the procedure over using more or less water.
5. Set the cylinder on the lab bench and read the total volume of the contents in the cylinder and record it in your lab notebook
6. Repeat this procedure with one piece of the copper sample.
7. Record the data for each trial directly in your Lab notebook. Immediately return the metal samples to the reagent bench **(do not store them in your workstation drawer).**
8. Calculate the volume of each metal sample.
9. Calculate the density in g/mL of each sample. Compare the densities you measured with those listed above. The density for Al should be very close to the listed value (if not see your TA), but the density for Cu may differ from the listed value by a large margin.

Explain why the value for Cu is less accurate than that for Al. What measurement limits the precision or accuracy?

10. Now modify the procedure for measuring the density of Cu so that the density can be measured more accurately. Write your procedure in you lab notebook and use the procedure to measure the density of your copper sample again. A very common source of error in the experiment is from inaccurate reading of the graduated cylinder.

Part B - The Density of an Unknown Metal Bar

1. Check out a metal bar with an unknown density from your TA. Record the bar number in your report sheet/lab notebook.
2. Follow the procedure used for Al to determine the density of the unknown and do two trials. **Immediately return this bar to your TA when you are done and before the end of the lab period**. **Do not put it in your workstation drawer**.
3. Be sure to use the calculation check to make sure your density calculations are correct and print a copy of it to attach to the report sheet. Record the final results for the unknown in the lab notebook

Part C - Volume Measurement and Calibration:

You are now familiar with the graduated cylinder. In this part of the experiment the use of the volumetric pipet, the Mohr pipet, and pipettor will be mastered.

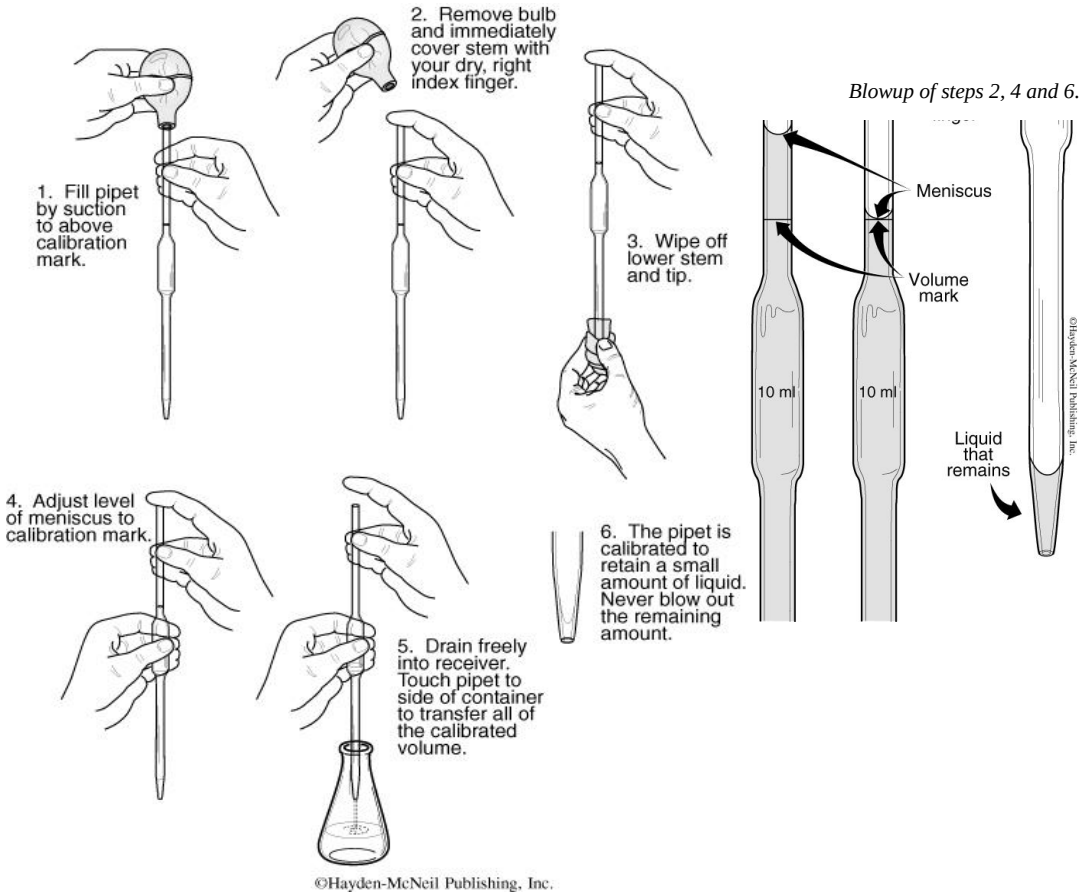


Figure 3. Using a Volumetric Pipet.

(1) The rubber bulb in your locker should have a pipet adapter or a disposable plastic pipet tip attached (if not, see your TA). The pipet is filled by placing a depressed rubber bulb assembly in the top and slowly releasing the bulb, thereby drawing liquid up into the pipet above the graduation line. Be careful ***not to draw the liquid into the bulb, as the bulb will contaminate the liquid****.*

(2) Remove the rubber bulb and immediately place your index finger on the top of the pipet.

(3) Wipe the outside of the pipet with a paper towel.

(4) While resting the tip of the pipet on the top inside portion of the container holding the solution, carefully raise your finger to release enough liquid so that the bottom of the meniscus is on the graduation mark.

(5) You are now ready to dispense a specific quantity of liquid; touch the inside upper wall of the target container with the tip of the pipet as you drain it. Hold the tip to the wall 5-10 sec. after the liquid has drained out. Note: If any droplets are found to be adhering to the inner walls of the pipet, it is dirty and should be cleaned. Try cleaning the pipet using hot soapy water. Draw the soapy water up into your pipet several times using your rubber pipet bulb. Then rinse the pipet several times with tap water and finally once with pure water. If the pipet is still dirty take it to the chemistry stockroom where it can be exchanged for a clean one. Be sure to view the video on the pipet.

Use the report sheet at the end of this experiment to record your results. Before you begin, view the videos on using this glassware and equipment.

CAUTION: Do not use your mouth to draw liquid into the pipet. **Use the pipet bulb and tip provided on the end of the bulb**.

Calibration of Volumetric Pipets

You will begin by calibrating your volumetric pipets with pure water. Record all data directly in the lab notebook.

1. First, be sure your pipets are clean (review figure 3 before using your pipets). The pipet bulb should have a plastic pipettor tip or adaptor that makes the bulb easier to use. If the bulb draws the liquid up slowly make sure the plastic tip or adaptor and bulb make a good seal. Take some time to practice using your pipets.
2. Start by using pure water and practice making 2 or 3 transfers with the 10 mL pipet.
3. Measure the temperature of the pure water and record it. Weigh a vial (or small beaker) to the nearest milligram and record the mass.
4. Using the correct size pipet, transfer the volume called for into the pre-weighed vial.
5. Weigh the vial with the water and record the mass. Subtract the two masses to get the mass of water transferred. The volume of water delivered is then calculated by dividing the mass of the pure water by the density.

$$Volume\ (mL) = \frac{mass\ (g)}{density\ of\ water\ (g / mL)}$$

The density of water can be obtained from the table below using the temperature of the water.

6. Use the density for the temperature closest to the temperature you measured and record it in you lab notebook.
7. **Calculate the error** by subtracting the volume actually delivered (calculated above using the mass and density) from the volume you tried to deliver (size of volumetric pipet used). The volume for each pipet should agree with the pipet size within ±0.05 mL. If the error in volume is greater than ± 0.05 mL, you have either made a pipetting error, your pipet is dirty or damaged, or possibly the calibration of your pipet is off. In any case repeat the calibration and get some help from your TA if you get the same result a second and third time.

Table 2.2 Density of Water

Temperature (Degrees Celsius)	Density (g/mL)	Temperature (Degrees Celsius)	Density (g/mL)
14	0.9993	25	0.9971
15	0.9991	26	0.9968
16	0.9990	27	0.9965
17	0.9988	28	0.9963
18	0.9986	29	0.9960
19	0.9984	30	0.9957
20	0.9982	31	0.9954
21	0.9980	32	0.9950
22	0.9978	33	0.9947
23	0.9976	34	0.9944
24	0.9973	35	0.9941

Calibration of the Mohr Pipet

The Mohr pipet and the buret (the buret will be used in experiment 6) are graduated or read from the top down instead of from the bottom up like the graduated cylinder. This often creates confusion when reading the Mohr pipet or buret, but this makes them valuable for transferring variable amounts of liquid with precision. Because of the design of most of our Mohr pipets, you don't completely drain them to transfer 10 mL. Instead, if you start at 0, the pipet is drained from the 0 to the 10 mL calibration marks on the graduated scale. Some Mohr pipets are calibrated

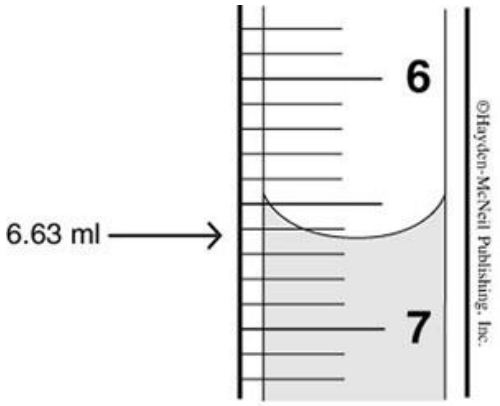


Figure 4 - Mohr Pipet; Illustrates a portion of the scale of a Mohr pipet (or a buret). Reading the scale from the top down, the bottom edge of the meniscus is resting on 6.63 mL and not 7.37 mL. To deliver a specific volume, fill the Mohr pipet to above the zero mark and drain such that the bottom of the liquid (meniscus) is on zero or below and note the volume. Then, deliver the required amount of solution and note the new volume on the scale. The volume delivered is the difference between the first and second readings. Practice using the Mohr pipet and make sure it is clean

all the way to the tip of the pipet. In this case, the graduations indicate that the pipet should be completely drained to deliver 10.00 mL. Both this type of Mohr pipet and our volumetric pipets are "To Deliver" or "TD" type pipet. This means that the tiny amount of solution left in the tip after a transfer is **not** blown out!

1. Transfer 10.00 mL of pure water using a 10 mL Mohr pipet to a preweighed vial and reweigh the vial with the water to complete the calibration.
2. Calculate the mass of water transferred, and then use the density to calculate the volume transferred. Subtract this volume from 10.00 to obtain the error.

Graduated Cylinder and Beaker

1. Measure out 10 mL of pure water with your 25 mL graduated cylinder.
2. Weigh the water transferred to the vial and calculate the volume transferred or "calculated volume" using the density of water as was done for your other pipets.
3. Calculate the error in volume by subtracting the volume calculated from 10.00mL. Record your results in your Lab Notebook.
4. Repeat this procedure transferring 10 mL of pure water using a 50 mL beaker.

Comparison of Glassware Accuracy

The terms "accuracy", "precision" and "range" are defined in the Introduction. The choice of glassware to measure volume is dependent on the goal of the experimental procedure, the volume size, the precision required for the final answer, and the time it takes to perform the manipulation. The measurement of volume is a tradeoff between speed and precision. More precise measurements are generally more time consuming. If a procedure called for 10.00 mL for one part of the experiment and about 10 mL for another part, different types of glassware would be used to measure the volumes. Let's look at the accuracy to which differing glassware can measure volume.

For each type of glassware you should have now calculated the volume delivered using the density of water and determined the error in volume delivered (volume to transfer minus calculated volume delivered). The error in these measurements will give an indication as to just how accurate each type of glassware is (a smaller error indicates higher accuracy). Answer the questions on the report sheet regarding glassware design (diameter at calibration markings) and volume errors.

Compare these errors to the precision listed for similar glassware in the table on page 11 in the significant figures section of the Introduction. Complete and print the calculation check for this part of the experiment.

Pump Dispensers

Pump dispensers are used to quickly and safely dispense liquids with some, but not exceptional precision. In this lab we will use these to dispense approximate amounts of liquids. **The following steps must be followed and the TA must sign off you have used the set up pump dispenser:**

1. Make sure the dispenser is set for the right volume. See your TA if it is not. DO NOT CHANGE SETTINGS ON THE PUMP DISPENSOR! LEAVE ALL ADJUSTMENT SCREWS UNCHANGED!
2. Make sure the dispenser has been primed and checked. See your TA if you are unsure about this.

3. Bring the container you want to transfer the sample into and hold it under the tip of the dispenser.
4. Pull the dispenser head up slowly until it stops. The more dense or viscous the solution is the slower you need to go and even hold it at the top.
5. Slowly press the dispenser head down with the container under the tip until it stops and wait until liquid stops coming out.
6. Check to make sure the volume transferred is about what you wanted.

Pipettors

Pipettors are the standard in research and industrial labs for transferring volumes from 0.0005 to 10 mL, and their use is a required skill for this lab. They are the best way to precisely transfer liquids quickly for volumes less than 2 mL. Volumetric pipets are still more precise for larger volume transfers but they are much slower to use and require a larger sample to use. The problem with pipettors is that the calibration or volume delivered is easily affected by misuse or solution properties. Since many students use the 5 mL pipettor at your work station, the calibration must be checked every lab period it is used. Another huge advantage of pipettors is that only the removable/disposable tip comes in contact with the solution transferred if the pipettor is used correctly. Since we are not worried about microbial contamination and are using only aqueous solutions (water as the solvent), we will reuse tips and wash them after every use.

Using a pipettor makes transferring precise volumes of liquids easy, but the procedure must be followed exactly. Always check the calibration of your pipettor with pure water to check technique and pipettor calibration before using one. The following are general steps for using a pipettor:

1. Select the correct pipettor that best matches the volume to be transferred. Never go above or below the working volume range for a pipettor (1-5 mL for 5 mL pipettor at your workstation).
2. Dial in the volume wanted, and snuggly place the correct and clean plastic tip on the pipettor. Be sure to clean the plastic tip for each new solution transferred. **Never use a pipettor without a tip!**
3. Depress the plunger button to the first stop, put the end of the tip in liquid, and slowly let the plunger button up to draw liquid into the tip. Wait for 5-10 seconds **(keep the end of the tip in liquid at all times while liquid is drawn into the tip)**. **Keep the pipettor tip pointed down at all times!** Remove the tip from the liquid. (Note: If at this point you notice droplets appearing and falling off the tip, stop the transfer, reset the tip on the pipettor, and start over. If it still leaks see your TA).
4. Point the tip into the container you want to transfer to. Now press the plunger button (not too fast, avoid splashing) all the way down (past the first stop) and wait for all the liquid to be dispensed (1-5 seconds). Go slower for very viscous or dense liquids.
5. Hang the pipettor on its holder or remove the tip before setting the pipettor down (**Always keep tip pointed down until it is removed from pipettor**).

To calibrate the pipettor we will do at least four trials. Place about 40 mL of PW in a 100 mL beaker. Working by a balance follow these steps to check the calibration of the pipettor:

1. Set the 5 mL pipettor on 5.00 mL and place a tip on it.
2. Place the 50 mL beaker on the balance and tare it to zero.

3. Take the 50 mL beaker off the balance, transfer 5 mL into the beaker as noted above and immediately place it back on the balance and record the mass in your Lab notebook. (There is no need to dump water out of the beaker.)
4. Tare the beaker on the balance to zero, remove it from the balance and transfer another 5 mL into it.
5. Place it back on the balance and record the mass.
6. Repeat steps 4 and 5 until you have at least four consistent masses of water recorded in your Lab notebook.
7. Measure the temperature of the water and calculate the volumes from the masses using the density of water at that temperature. Calculate the volume error by subtracting each of these volumes from 5.00 mL. If the error in volume is greater than ± 0.05 mL, you have either made a pipetting error, your pipettor is dirty or damaged, and/or the calibration of your pipettor is off. In any case, get some help from your TA. **Note**: The volume calculated from the mass is a slightly larger number by about 0.01.
8. When you check the calibration of your pipettor set at 5.00 mL later in the semester do one calibration and look at the mass. If it is within 4.95-5.05 g the pipettor is good to use as long as it is not leaking. If it is outside this range do more calibration checks and see your TA.

Record Key Data Below in Your Lab Note book

Record the information below for each trail

- Density of Unknown Metal Bar
- **Unknown #** (stamped on metal bar)
- Mass of metal sample
- Volume of water (mL)
- Volume of water & metal sample (mL)-
- Volume of metal sample (mL)-
- Density of metal sample (g/mL)
- Mean Density of Metal Bar (g/mL)
- Range

Record for each equipment/ and volume tested. Record the calculated volume and volume error.

- Graduated Cylinder
- Beaker
- Volumetric pipettes
- Mohr pipettor
- 5 mL pipettor: record the following for 3 trials
    - Mass of Water (g)
    - Calculated Volume of Water (mL)

Reference

1) Williamson, Kenneth. Macroscale and Microscale Organic Experiments. 2nd Ed. D.C. Heath and Company. 1994, 594-604.

Name Student ID# Dana ID_____

Lab Section____ Workstation #____ Date_____ **Unknown # __**_____ (on metal bar)

Experiment 1: Measurement of Mass, Volume, and Density

Experimental (all individual work, no group work or sharing data!)

Part A - Density Metal Samples Metal Sample Used: Al Cu Cu (write new procedure below)

Mass of metal sample (g)	_____	_____	_____
Volume of water (mL)	_____	_____	_____
Volume of water & metal sample (mL)	_____	_____	_____
Volume of metal sample (mL)	_____	_____	_____
Density of metal sample (g/mL)	_____	_____	_____

Which density is more accurate, Al or Cu?_____

Part B - Density of Unknown Metal Bar (checkout bar from your TA, return before the end of the lab)

Density of Unknown Metal Bar – **Unknown # _____** (stamped on metal bar)

Trials	1	2
Mass of metal sample (g)	_____	_____
Volume of water (mL)	_____	_____
Volume of water & metal sample (mL)	_____	_____
Volume of metal sample (mL)	_____	_____
Density of metal sample (g/mL)	_____	_____

Mean or Average Density of Metal Bar (g/mL) _____ Range_____

Please note that copies of calculation checks for "Density of Solids" (Density Metal Samples) & "Density of an Unknown Solid" (Unknown Metal Bar) must be completed, printed, & stapled to this report sheet.

Part C (Calibration Checks)

Temp. of Water _____(ºC) Density of Water _____g/mL (see water density table on p.27)
The density of the water is used to determine the "Calculated Volume" or actual volume delivered below.

Size of Glassware⟶	**10mL**	**5mL**	**10mL**	**25mL**	**50mL**
Type of Glassware⟶	**Volumetric Pipets**		**Mohr Pipet**	**Grad.Cylinder**	**Beaker**
Volume to Transfer⟶	**10.00 mL**	**5.00 mL**	**10.00 mL**	**10.0 mL**	**10 mL**
Mass Vial (g)	_____	_____	_____	_____	_____
Mass Vial & Water (g)	_____	_____	_____	_____	_____
Mass Water (g)	_____	_____	_____	_____	_____
Calculated Volume (mL)	_____	_____	_____	_____	_____
Volume Error (mL)	_____	_____	_____	_____	_____

Volume Error = Volume to Transfer - Calculated Volume The error shouldn't exceed ±0.05mL for volumetric pipets or ±0.2mL for the Mohr pipet; if too big repeat the procedure or see the TA.
Do the Error in Glassware calculation check for the data above, print it & staple it to this report sheet.

Pipettor Calibration: Temp. of Water _____(ºC) Density of Water _____g/mL

Use 5 mL pipettor set to 5.00 mL	Trial 1	Trial 2	Trial 3	Trial 4
Mass of Water (g)	_____	_____	_____	_____
Calculated Volume of Water (mL)	_____	_____	_____	_____
Volume Error of Water (mL) (5.00 mL minus Calculated Volume, should not exceed ±0.05 mL)	_____	_____	_____	_____

TA Sign Off of Pump Dispenser Test _____ Date _____

Post Lab Questions: To be completed in Laboratory Notebook

Part A

1. What measurement makes calculating the density of Cu less precise and likely less accurate? Why?
2. How would you modify the procedure to improve the measurement of Cu density? Now do it (see 3rd column above).

Part C

1. From your data for part C above, which glassware is most accurate? Least accurate?
2. Look at volume error. What effect does glassware diameter at calibrations have on volume error?

Assigned TA Signature _____ Date_____ (leave paper with TA)

DO NOT USE THIS SPACE

Fermentation

Purpose: The fermentation of apple juice to cider using related concepts and calculations Experiment One explored. Evaluating technique mastery by checking calibration using the average, median, range, and error and expressing data to correct significant figures using unit cancellation (dimensional analysis) for all calculations is fundamental. Using these skills to scientifically and critically think about an experiment and the results will be used throughout this and future lab courses.

Required Techniques and Concepts: Mass measurement, quantitative volume transfer by pipettor and graduated cylinder, checking calibration by using the mass and density of water at a measured temperature, density, precision by significant figures and range, average, unit cancellation (dimensional analysis), graphing and linear regression.

Background:

Fermentation is the reaction (oxidation) of certain types of carbohydrate, sugar in this case, to ethanol and carbon dioxide with yeast catalyzing the reaction as noted below.

$$C_6H_{12}O_6\ (aq) \xrightarrow{\text{yeast}} 2\ CH_3CH_2OH\ (aq) + 2\ CO_2\ (g)$$

Sugar Ethanol Carbon Dioxide

Yeast acts on the sugar using enzymes to catalyze several chemical reactions to produce ethanol. This reaction is of special interest beyond the production of beer, wine, and other alcoholic beverages in view of the limited nature of oil resources and the effects of global warming. Ethanol produced from fermentation can be used in place of gasoline refined from oil has been reported to have a smaller carbon footprint. There is currently much research aimed at creating microbes that can breakdown unused plant matter such as corn stalks (cellulose) to ethanol. The complete burning or oxidation of organic materials such as oil and coal to carbon dioxide producing huge amounts of energy has fueled the industrial revolution and our modern society.

$$C_6H_{12}O_6\ (aq) + 6\ O_2\ (g) \rightarrow 6\ H_2O\ (l) + 6\ CO_2\ (g) + \text{energy}$$

The oxidation of a specific group of organic chemicals, carbohydrates, to carbon dioxide via metabolism supplies the energy for oxygen-consuming life on earth. Understanding reactions such as these is central to our understanding of life as we know it. We will look at the fermentation reaction in this experiment and the relationship of yeast and carbohydrate (sugar) to the amount and rate of CO_2 production.

In 1815, after the mole concept was established, Gay-Lussac showed that one mole of glucose produces exactly two moles of ethanol and two moles of carbon dioxide. But the process of fermentation puzzled some great chemists.

It remained for Pasteur to show that fermentation was a physiologic action associated with the life processes of yeast. In his classic paper of 1857, he described fermentation as the action of a living organism. However, other chemists disputed his findings because the conversion of glucose to ethanol and carbon dioxide is a balanced equation. So a search was begun to find the substance in yeast that might cause the reaction. It took 40 years before a clever experiment by Eduard Buchner ended the search. He made a cell-free extract of yeast that still caused the conversion of sugar to alcohol. This cell-free extract contained the catalysts, which we now call enzymes that are necessary for fermentation. This discovery earned Buchner the

1907 Noble Prize. Clearly, the history of biochemistry is closely associated with the study of alcoholic fermentation [1].

When grain germinates, enzymes are produced that turn the starch into sugar. The process of malting involves letting the grain start to germinate and then heating and drying the sprouts to stop the process before the enzymes are used up. The color of the malt depends on the temperature of the drying. The darkest is used for stout and porter; the lighter, for brown, amber, and pale ale. At some point hops were added to beer when it was discovered that the resulting beverage did not spoil so rapidly [1].

In this experiment, alcoholic fermentation will be explored through a reaction similar to the traditional production of cider. This fairly simple method calls for picking apples, aging them for a week and then crushing them using a cider press to collect the juice. The freshly pressed juice is then fermented by immediately storing the juice in a wooden barrel and allowing wild yeast to ferment the juice. The fermentation starts in 1-2 days and continues for several weeks, during which time the barrel is topped off with more juice. Once fermentation is over, the barrel is sealed and matured for 5-6 months. The cider made in this experiment will be prepared using apple juice and bread yeast.

This part of the experiment involves the fermentation of apple juice to cider. The study of chemical reactions and the chemical equations that help describe them is central to the study of chemistry. We will test the hypothesis that the amount of product produced by a chemical reaction can be predicted using the chemical equation for the reaction knowing the amount of starting material. We will also look at how experimental parameters and limitations in measurements affect results. The fermentation will be completed during the first week of the next experiment.

The Experiment

Since the primary purpose of the experiment is to master key techniques and calculations used throughout this lab course <u>you must do the calculations by yourself, not in a group</u>. The only part of the experiment this does not apply is collecting the fermentation data which is done in groups of 2-4 students.

<u>Risk Assessment</u> – low hazard: no hazardous chemicals in use.

<u>Equipment and Supplies Needed</u> –

- Electronic balance
- 10 and 25 mL graduated cylinders
- 200 or 250 mL erlenmeyer flask
- Yeast,
- Apple juice
- Balloon
- Twist ties and/or rubber bands

Fermentation of Apple Juice to Cider – First Week (Group Work - data collection only)

We will look at fermentation by measuring the amount of carbon dioxide produced by measuring the mass change using varying amounts of apple juice and yeast. What do you think will happen during fermentation to the mass of the system (mass flask+yeast+apple juice) based on the chemical reaction for fermentation? What effect would changing the mass of apple juice or mass of yeast used have on the final mass of carbon dioxide produced? Keep these questions in mind as you analyze the final fermentation data.

Your TA will assign you to one of six lab groups of 2-4 students based on the lab bench you are on. Every student will record data for the fermentation in their lab notebook.

1. Each group should take a dry 250 mL Erlenmeyer flask out of the box on the reagent bench and label it with the section letter and group number.
2. Weigh the flask.
3. Obtain yeast from the reagent bench in a small, plastic tray. Preweigh the mass of yeast for your group to be within the range as noted in the table below into a vial (tare the vial mass to zero to help in weighing out the yeast).
4. Add the yeast in the vial to the empty flask and reweigh the flask.
5. Now measure the volume of apple juice indicated for your group in the table below using a 25 or 10 mL graduated cylinder and add it to the flask.
6. Make sure the outside of the flask is clean and dry and obtain the mass of the flask containing the juice and yeast.

Group Number	1	2	3	4	5	6	Control
Grams of Yeast	0.008-0.010	0.008-0.010	0.008-0.010	0.008-0.010	0.004-0.006	0.002-0.003	0.008-0.010
Volume of Apple Juice (mL)	20	15	10	5	5	5	5 mL of pure water

7. Place a balloon over the top of the flask, making sure the balloon stretches approximately 1 inch down the neck of the flask. A twist tie or rubber band is placed tightly around the neck of the flask to help seal the balloon on the flask. The setup will be kept in your lab section's storage space. Your TA will setup a control with the same conditions as group 4 but using pure water (PW) instead of apple juice (why might the mass of the control change?)
8. Using the measured masses subtract to obtain the mass of yeast and apple juice then calculate density of the apple juice using its mass and volume.
9. Look at the label of the apple juice bottle to determine the mass of carbohydrate per serving volume. If we assume that nearly all of the carbohydrate is present as sugar in the form of glucose, we can predict that for every mole of sugar, two moles ethanol and two moles of carbon dioxide will be produced. For example, if the label says that there is 28g of carbohydrate per 240 mL (standard serving size) that means 13.7 g carbon dioxide and 14.3 g of ethanol will be made if the reaction converts carbohydrates in the 240 mL into products. Using the chemical equation for fermentation, molar masses of sugar (assume glucose) and carbon dioxide, the mass of carbohydrate is 28.0 g per serving 8 fl. oz. or 240 mL (off apple juice label),

$$Predicted\ Mass\ CO_2 = \left|\frac{V_{AJ}\ \cancel{mL}}{}\right| \left|\frac{28\ \cancel{g\ Glucose}}{240\ \cancel{mL}}\right| \left|\frac{1\ \cancel{mol\ Glucose}}{180.156\ \cancel{g\ Glucose}}\right| \left|\frac{2\ \cancel{mol\ CO_2}}{1\ \cancel{mol\ Glucose}}\right| \left|\frac{44.01\ g\ CO_2}{1\ \cancel{mol\ CO_2}}\right|$$

and the volume of apple juice used by your group (V_{AJ}), the **predicted mass of carbon dioxide** that will be produced can be calculated using a simplified version of the formula above:

$$\text{Predicted Mass } CO_2 = 0.05701\ (V_{AJ})\ \text{g } CO_2$$

As you progress in your lecture course this semester you will learn how to do this calculation using dimensional analysis as applied to mass and mole calculations.

Fermentation of Apple Juice to Cider – Second Week (Group Work–data collection only)

After 1 week the fermentation should be complete.

1. Record observations and remove the balloon and rubber band or twist tie from the flask and immediately weigh it. Make sure the outside of the flask is clean and dry. You will notice that the mass is now different than the starting mass.
2. Next measure the volume of the cider with a 25 mL graduated cylinder (depending on the volume of cider).
3. When you are done for the day, wash all glassware used. Clean your work space and any other areas you used in the lab. Make sure your workstation drawer is complete and ready for the next student.
4. **Please note that all calculations are done individually and not as a group**. Calculate the mass of cider and its density by using its mass and volume. The mass of carbon dioxide made during fermentation can be determined by subtracting the "Mass(g) Flask+Yeast+Apple Cider" from the "Mass(g) Flask+Yeast+Apple Juice". Compare this value to the predicted mass of CO_2 made by answering the second post lab question.
5. Using the mass of CO_2 made, the percent alcohol (ethanol or EtOH) in the cider made can be determined. By first calculating the moles of CO_2 and then knowing that for every one mole of CO_2 made, one mole of ethanol will be made according to the chemical equation. The mass of ethanol made can then be calculated. Using the total mass of cider, the percent alcohol in the cider can be found and compared to values for alcoholic beverages found in the store or on the web. The concepts of stoichiometry needed to do this calculation will be covered later in lecture but for now the calculation can be done as follows:

$$\%EtOH = \left|\frac{M_{CO2}\ \cancel{g\ CO_2}}{}\right| \left|\frac{1\ \cancel{mol\ CO_2}}{44.01\ \cancel{g\ CO_2}}\right| \left|\frac{1\ \cancel{mol\ ethanol}}{1\ \cancel{mol\ CO_2}}\right| \left|\frac{46.068\ \cancel{g\ ethanol}}{1\ \cancel{mol\ ethanol}}\right| \left|\frac{100\%}{M_{Cider}\ \cancel{g\ cider}}\right|$$

Doing the math to simplify the calculation above and knowing that M_{CO2} is the mass of CO_2 made and M_{Cider} is the total mass of cider made, the percent ethanol can be determined:

$$\text{Percent Ethanol in Cider} = 104.7\left(\frac{M_{CO_2}}{M_{Cider}}\right)$$

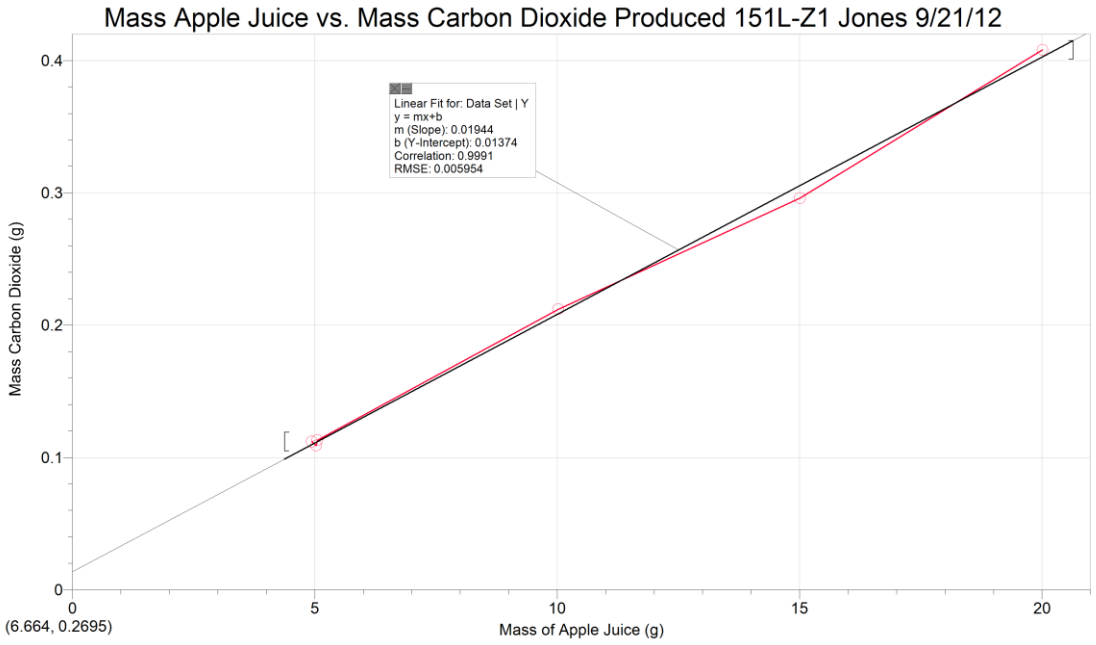
6. Each group will decide on values to report for class data for their work to further investigate the effect of mass of apple juice and mass of yeast on the fermentation reaction and compare the densities of apple juice and apple cider for each group. The TA

will have a spreadsheet up on the computer connected to the projector for each group to enter agreed values on the class spreadsheet for your lab section.

7. The fermentation report sheet will be stapled to the printouts of graphs, and your laboratory notebook pages. Sheets containing optional work must be done individually for extra credit and stapled to the report sheet.
8. As an optional part of this experiment to explore the rate of reaction, you can weigh the flask setup now, at least twice during the week, and then on your next regular lab period, recording the date when the mass was measured and recorded. Record these masses when other sections are meeting. See the syllabus for lab times. Immediately return the flask setup to the cabinet for your section when you are done weighing it and taking observations. For another optional challenge, calculate the volume of CO_2 in mL that should have been collected using the mass of CO_2 made and compare to the estimated volume of gas collected in the balloon.

Instructions for Graphical Analysis (Note - all graphing work is done individually):

"Graphical Analysis", a program by Vernier, is loaded on all publicly available computers in the chemistry department as well as Cline library. You can also use excel to graph data for this experiment if you choose. To start graphical analysis click on the "windows icon" in the lower left of the desk top, then "All programs", then "chemistry applications", and finally "graphical analysis". The program is easy to use. From the class data table simply enter values in the "Data Set" table on the left side of screen. For the first graph you will enter the mass (g) of apple juice in the x column (for x axis) going from lowest to highest mass of apple juice and entering the corresponding mass (g) of carbon dioxide lost in the y column for groups 1-4 where the mass of apple juice changes and the mass of yeast is held constant. The data will be plotted as you enter the x-y pairs.



Once the data is entered, a linear regression (or fit) is done by highlighting all of the x,y points in the "Data Set" table on the left. Next click on the "Linear Fit" icon (second from right on top function bar) and the linear fit data will appear on the screen with m (slope), b (y-

intercept), and Correlation (correlation coefficient for the linear regression). Record these values in your post lab questions. The closer the correlation coefficient is to one the more linear the data. Next double click on the graph to enter a graph title that will include what was plotted and your name, section, and date. To label each axis with a label and units, double click on the "x" or "y". Print the graph.

Now enter data using the mass of yeast for groups 4, 5, and 6 instead of apple juice again entering the lowest mass of yeast first with its corresponding value of mass (g) of carbon dioxide lost in the y column. These are the trials where the volume of apple juice is constant and the mass of yeast changes. Workup the graph as was done for the previous one.

Record Key Data Below in Your Lab Notebook

All fermentation data should be immediately recorded by each group member.

Reference Williamson, Kenneth. Macroscale and Microscale Organic Experiments. 2nd Ed. D.C. Heath and Company. 1994, 594-604.

Fermentation

Name _____ Student ID# _____ Dana ID_____

Lab Section_____Workstation # _____Date_____ Your Group Number _____

Experiment 1: Fermentation Data, Results, and Post Lab

Group Data – Collected Raw Data as a group:
***This number is a calculated value; it must be done individually using unit cancellation to show work:**

Mass Range of Yeast - p. 25	
Volume of Apple Juice Used (mL) - p. 25	
First period of experiment 1	
Mass Flask (g)	
Mass Flask + Yeast (g)	
Mass Yeast (g) *	
Mass Flask + Yeast + Apple Juice (g), no balloon	
Mass Apple Juice (g) *	
Density (g/mL) of Apple Juice (mass/volume) *	
Predicted Mass of CO_2 made (calculated, p. 25)*	
Second period of experiment 1	
Mass Flask + Yeast + Apple Cider (g), no balloon	
Volume Apple Cider (mL)	
Mass Apple Cider (g) *	
Density(g/mL) Apple Cider *	
Mass CO_2 Made (g): mass lost making cider * (Mass Flask + Yeast + Apple Juice) – (Mass Flask + Yeast + Apple Cider)	
Percent Alcohol (see p.31 for equation) *	

Class Data - Results From Groups 1-6:

Your Group Number	1	2	3	4	5	6	Control (water)
Mass Yeast (g) *							
Mass Apple Juice (g) *							
Density (g/mL) of Apple Juice (mass/volume) *							
Density Apple Cider (g/mL) *							
Mass CO_2 Made: mass lost (g) * (Mass Flask + Yeast + Apple Juice) – (Mass Flask + Yeast + Apple Cider)							

1. Using the class data for the densities of ***apple juice,*** show calculations for:

Average:_____

Median:_____

Range:_____

2. Using the class data for the densities of ***apple cider***, show calculations for:

Average:_____

Median:_____

Range:_____

Post Lab Questions: To be completed in Laboratory Notebook

1. Compare the average density of apple juice to apple cider. Are they different and why? Be sure to consider that hard cider was made (contains ethanol with a density of ~0.79g/mL) and that the cider was most likely cloudy

2. What is a possible explanation for why the control (which does not contain apple juice) produces CO_2?

3. Use data for groups 1-6 for the following (Use graphical analysis to plot data):
   a. Graph or plot data for groups 1-4 (mass of yeast is constant) "Mass of CO_2 Made" (y-axis) versus "Mass Apple Juice" (x-axis), do a linear fit (regression), label each axis and add a title that includes the data plotted, your name, and section, print the graph, and record the following information:
      Slope, Y-Intercept, Correlation Coefficient.
      Are these values good or bad? Explain

   b. Graph or plot for groups 4-6 "Mass of CO_2 Made" (y-axis) versus "Mass of Yeast" (x-axis), do a linear fit (regression), label each axis and add a title that includes the data plotted, your name, and section, print the graph, and record the following information:
      Slope, Y-Intercept, Correlation Coefficient.
      Are these values good or bad?Explain

   c. Based on the correlation coefficients from above, what should be done in the experiment to increase the "Mass of CO_2 Made"?

   d. Using y=mx+b, the slope (m), and the y-intercept (b) from 5a above, predict the "Mass of CO_2 Made" (y) using the workstation number as the mass of apple juice used (x). (Use 100 if last two digits are "00", hint: solve for y)

Assigned TA Signature _____ Date_____ (leave paper with TA)