Experiment 1G

WBH 07/21/22 FV

PHYSICAL AND CHEMICAL PROPERTIES

MATERIALS: 100 mL beaker (1), 50 mL beaker (1), 10 mL graduated cylinder (1), 25 mL graduated cylinder (1), 5.00 mL volumetric pipet (1), buret (1), plastic dropper (1), small bottle with cap (2), buret clamp (1), ring stand (1), copper shot (instructor hood), zinc metal pieces (instructor hood), brass pieces (instructor hood), 7 M hydrochloric acid dropper (instructor hood), 7 M nitric acid dropper (instructor hood)

PURPOSE: The purpose of this experiment is to become familiar with the common types of laboratory glassware and equipment, make observations, and analyze data.

LEARNING OBJECTIVES: By the end of this experiment, the student should be able to demonstrate the following proficiencies:

1. Understand the safety issues when working in the laboratory.
2. Know how to correctly use a buret, a pipet, and a graduated cylinder.
3. Know how to use an analytical and top-loading balance.
4. Determine the density of a liquid and a solid.
5. Construct an Excel spreadsheet and graph with trendline using laboratory data.
6. Record laboratory data and observations.

BACKGROUND:

Laboratory glassware. There are two major categories of laboratory glassware: (1) those that contain a certain volume (volumetric flasks) and (2) those that deliver a certain volume (pipets, burets, and graduated cylinders). "To Contain" glassware (labeled TC) is typically used for preparing solutions of known volume. "To Deliver" glassware (labeled TD) is used to transfer known volumes between containers. Some glassware is designed and marked for high accuracy/precision measurements (burets, pipets, and volumetric flasks), while other glassware is not intended for such work (beakers, Erlenmeyer flasks, and graduated cylinders).

In high accuracy/precision work, the glassware must be clean. Not only does clean glassware avoid unwanted chemical contamination, but it also assures that delivered volumes of liquids will be correct. A dirty spot on the inside wall of a buret or pipet, for example, even if the spot itself does not occupy a significant volume, can cause a droplet of water to adhere to the wall, causing an error in the recorded volume of delivered liquid (less volume delivered).

Measuring and recording data. The generally accepted rule for measuring volumes is to estimate one more digit beyond the digit associated with the closest spaced markings.

Portion of a buret

4 significant figures

Correct reading: 16.16 mL

3 Certain Digits

1 Uncertain Digit (different people may read different values for this digit)

For measurements obtained from devices which provide digital output, such as an electronic mass balance or a Spectronic 20 spectrophotometer, all digits should be recorded, including any trailing zeroes, with the understanding that the last digit is within "one" unit of the correct value.

Example readings from an analytical balance: 1.234 g (no trailing zeros) 0.0450 g 4.000 g (trailing zeros reported)

Appendix E (posted under "Laboratory Resources" on the Plebe Chemistry website) gives more detailed information about the precision (uncertainty of measurement) associated with the various types of glassware to be investigated in this experiment.

Properties. Any characteristic that can be used to describe or identify matter is called a *property*. Properties can be classified in a variety of ways; most broadly, we may distinguish *physical* properties from *chemical* properties. *Physical* properties, like color or mass, are those which can be determined without changing the chemical composition of the material. Weighing an object does not change it, so mass is classified as a physical property. *Chemical* properties, on the other hand, can only be determined by carrying out a chemical change. For example, iron metal has a natural tendency to react with oxygen to form rust. This characteristic of iron is classified a chemical property because it involves a chemical reaction that changes the chemical composition of the sample.

Extensive and Intensive Properties. Properties of matter may be further classified as either extensive or intensive properties. An extensive property is one that depends upon the amount of sample being observed, where as an intensive property is one that is independent of amount of sample.

Density is a quantity that can be used to describe a sample, or even identify one from a limited set of possibilities. This property can be used for both pure materials and mixtures. The density of a sample is defined as the ratio of its mass divided by its volume. Based on this definition, is density properly classified as a 'physical' or 'chemical' property? In this experiment, we will also explore whether density is an 'extensive' or 'intensive' property.

Error Analysis. Appendix J ("Kinds of Measurements and their Reliability") introduces measurement techniques most often encountered in the chemistry laboratory, along with discussion of methods for assessing the reliability of measurements. *Accuracy* and *precision* are two different terms that are used to refer to the numbers that result from measurements. *Accuracy* refers to the agreement between a measured value and the true (or accepted) value. An accurate value is one that is very close to the true or accepted value. *Precision* refers to the degree of agreement among several measurements of the same quantity. Precision reflects the reproducibility of a given measurement. Precise values are very close to other values of the same measurement. For a set of data, the average may not be very accurate (far from its true value) but the data may be very precise (very similar values, reproducible). The goal of any experiment is to be both accurate and precise.

When reporting results, two useful quantities are the average (or mean) value and standard deviation of a set of data, which are defined as follows:

$$Average = mean = \bar{x} = \frac{\sum_{i=1}^{n}(x_i)}{n}$$

$$Standard\ deviation = s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

where the variable "n" represents the number of measurements in a data set. The numerical value of the standard deviation represents the "spread" of values in the data

A common way to compare a result to a true value (x_t) is determine the percent error:

$$\%\ Error = \left(\frac{x_i - x_t}{x_t}\right) x100$$

where x_i is an experimental value, either an individual measurement or the average of a set of data. The % error can be a positive or negative value depending on whether x_i is larger or smaller than the true value (x_t).

PRE-LAB: Before lab, complete the pre-lab exercises. Also read the safety agreement and sign it. Bring the safety sheet, your pre-lab, your safety goggles, your laptop and this handout with you to lab.

PROCEDURE:

Safety: Safety for you and your classmates is the highest priority in the laboratory. Your instructor will discuss laboratory safety, give a brief tour of the laboratory, and collect signed safety sheets from every student. You will be working with a lab partner, but each partner should record observations/data individually in the tables provided.

Part A: Making Observations in the Laboratory

1. Brass is an alloy, composed of approximately 30% zinc metal and 70% copper metal. You will observe reactions of the constituent metals with strong acids.
2. Your instructor will perform these demonstrations in the hood but you must also wear your goggles. Observe the reactions of copper with 7 M nitric acid (HNO_3) and copper with 7 M hydrochloric acid (HCl); then zinc with 7 M nitric acid (HNO_3), and zinc with 7 M hydrochloric acid (HCl).
3. Record your observations on page 1G-5. Answer the in-lab questions in the space provided.
4. Your instructor will perform these additional demonstrations in the hood. Observe the reaction of brass with 7 M nitric acid (HNO_3) and brass with 7 M hydrochloric acid (HCl). Record your observations.

Part B: Determination of the Density of a Sample Solution

Note – it is important to use the same balance for all mass measurements!

Group A: Using a Graduated Cylinder

1. With a clean 100 mL beaker, obtain about 40 mL of the prepared sample solution from the labeled container in the room.
2. Using a top-loading balance, determine the mass of a small bottle with its cap (don't forget to tare the balance first). It is not necessary that the bottle is completely dry on the inside as long as it is capped. The bottle must be dry on the outside.
3. Using the 10 mL graduated cylinder, measure about 5.0 mL of the solution and transfer it to the bottle. Record your actual volume with the correct number of significant figures on page 1G-6.
4. Weigh the capped bottle on a top-loading balance and record the mass.
5. Repeat steps 3-4 for four additional 5.0 mL volumes. **DO NOT** empty the bottle between each addition. It's only important that you know the volume of solution added from the graduated cylinder and its corresponding mass.
6. When done, clean glassware & plastic bottle by rinsing with deionized water.

Group B: Using a Pipet

1. With a clean 100 mL beaker, obtain about 40 mL of the prepared sample solution from the labeled container in the room.
2. Using a top-loading balance, determine the mass of a small bottle with its cap (don't forget to tare the balance first). It is not necessary that the bottle is completely dry on the inside as long as it is capped. The bottle must be dry on the outside.
3. Using the 5.00 mL pipet, transfer a 5.00 mL sample of the solution to the bottle.
4. Weigh the capped bottle on a top-loading balance and record the mass.
5. Repeat steps 3-4 for four more 5.00 mL volumes. **DO NOT** empty the bottle between each addition. It's only important that you know the volume of solution added from the pipet and its corresponding mass.
6. When done, clean glassware & plastic bottle by rinsing with deionized water.

Group C: Using a Buret

1. With a clean 100 mL beaker, obtain about 40 mL of the prepared sample solution from the labeled container in the room.
2. Using a top-loading balance, determine the mass of a small bottle with its cap (don't forget to tare the balance first). It is not necessary that the bottle is completely dry on the inside as long as it is capped. The bottle must be dry on the outside.
3. Pour the measured solution into the buret and make sure there are no air bubbles in the buret tip.
4. Record the initial buret reading with units and the correct number of significant figures. Buret volumes should be read to the hundredths place in volume (for example, 1.26 mL).

5. From the buret, add the first sample of the solution to the bottle. The actual volume of sample added is NOT critical, but should be around 5 mL.
6. Record the final buret reading.
7. Weigh the capped bottle on a top-loading balance and record the mass.
8. Repeat steps 5-7 for four more volumes of about 5 mL each. **DO NOT** empty the bottle between each addition. The volume of each sample added is not critical, but should not exceed 5 mL due to limited capacity of the bottle. It is simply necessary to make accurate buret readings before and after addition of each sample so that the sample volume can be calculated, and record the total mass after each addition, as above.
9. When done, clean glassware & plastic bottle by rinsing with deionized water.

Part C: Determination of the Density of a Metal

Density of Zinc or Copper

1. Using the equipment available in your hood and the dry metal pieces, design an experiment for measuring the density of your assigned metal.
2. Have your instructor initial your proposed procedure and assign your group a metal. Carry out your described measurements three times. Record your data with appropriate units and to the appropriate number of significant figures in the Data Section.

Clean-up:

Rinse all glassware with deionized water and return them to your lab bench area (hood). Organize your lab bench area. Clean up any spills. At the end of any lab experiment, wash your hands to remove traces of chemicals.

Name ____ Section ______________________

Partner ______________________________________

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DATA SHEET: Report numeric values with units <u>and</u> the proper number of significant figures.

Part A: Making Observations in the Laboratory

	Observations – describe what happened	Did a chemical reaction occur?
1. $Cu + HNO_3$		
2. Cu + HCl		
3. $Zn + HNO_3$		
4. Zn + HCl		

In-lab Question 1. Are zinc and copper elements, compounds or mixtures?

In-lab Question 2. Make a simple sketch of the particles present at the atomic level in pure zinc metal and pure copper metal.

Zinc: Copper:

In-lab Question 3. Brass is an *alloy* of zinc and copper. Is brass an element, a compound or a mixture?

In-lab Question 4. Make a simple sketch of the particles present at the atomic level in the alloy, brass.

Brass:

In-lab Question 5. Based on your observations for pure Cu and Zn, predict what will happen when the alloy brass is treated with 7M HNO_3 and when it is treated with 7M HCl:

HNO_3 prediction	HCl prediction

Record your observations below:

	Observations – describe what happened	Did a chemical reaction occur?
1. Brass + HNO_3		
2. Brass + HCl		

Part B: Determination of the Density of a Solution

Group A: Using a Graduated Cylinder

Solution sample	Volume of Solution added to bottle (mL)	Total mass of bottle + solution sample(s) added (g)
Empty Bottle	**-------------------------**	
1		
2		
3		
4		
5		

Group B: Using a Pipet

Solution sample	Volume of Solution added to bottle (mL)	Total mass of bottle + solution sample(s) added (g)
Empty Bottle	**---------------------**	
1		
2		
3		
4		
5		

Group C: Using a Buret

Solution sample	Initial Buret Reading (mL)	Final Buret Reading (mL)	Total mass of bottle + solution sample(s) added (g)
Empty Bottle	----------------	----------------------	
1			
2			
3			
4			
5			

Part C: Determining the Density of a Metal

1. Design an experiment for measuring the density of a metal. Write enough detail so that someone else could follow your procedure.

Assigned Metal ____________________ Instructor's Initials______________________

2. Carry out your experiment three times and record the data below:

DATA ANALYSIS AND QUESTIONS

Part B: Determination of the Density of a Solution

1. Using your data, complete the following tables and determine the density of the solution. Show one sample density calculation here:

Graduated Cylinder

Solution sample	Volume of solution added to vial (mL)	Total Volume of solution in bottle (mL)	Mass of bottle + solution (g)	Mass of solution (g)	Density (g/mL)
Empty bottle	--------------------	----------------------		0	--------------
1					
2					
3					
4					
5					

Pipet

Solution sample	Volume of solution added to vial (mL)	Total Volume of solution in vial (mL)	Mass of bottle + solution (g)	Mass of solution (g)	Density (g/mL)
Empty Bottle	--------------------	----------------------		0	--------------
1					
2					
3					
4					
5					

Buret

Solution sample	Initial Reading (mL)	Final Reading (mL)	Volume of solution added to vial (mL)	Total Volume of solution in bottle (mL)	Mass of vial and solution (g)	Mass of solution (g)	Density (g/mL)
Bottle	----------	---------	--------------	**0**		**0**	------------
1							
2							
3							
4							
5							

2. Determine the average density of the sample solution for each of the three methods. Show your work here.

Graduated cylinder: ____________

Pipet: ________________________

Buret: ________________________

3. **Using Excel to determine the density.**
    a. Enter your experimental data into Excel. Each data table should have columns corresponding to those shown above. **Use formulas** to calculate values. For help, see the Excel tutorial on the Plebe Chemistry website.
    https://www.usna.edu/ChemDept/_files/documents/excel-tutor/Excel%202016%20Tutorial.pdf
    b. For each set of data, **use formulas** to calculate the average density value, and the standard deviation for the data. Format numeric values to display the appropriate number of **significant figures**.
    c. For each set of data, create a graph (aka "chart") of **total mass vs. total volume added**. Unless directed otherwise, graphs for this course are Scatter charts and the independent variable is shown on the x-axis. For this experiment, total volume added is the independent variable.
    d. Add a **linear trendline** to each graph. Select the boxes to display the **trendline equation** and **R^2 value** on your plot.
    e. The equation is in the form of the equation of a line: y = mx + b, where m = slope and b = y-intercept.
        i. Slope is defined as "rise over run" ($\Delta y/\Delta x$). Since the numbers on your graph have units, slope will also have units.
        What are the **units** for your slope? ___________________
        ii. What physical property does the slope represent? __________________________
    f. The R^2 value reflects how close your data points are to the trendline, with a perfect line having an R^2 value of 1.00000. The closer the R^2 value is to 1.0000, the better the precision of measurement.

Part C: Determining the Density of a Metal

1. Calculate the density of your assigned metal from your experimental values. Show your work here.

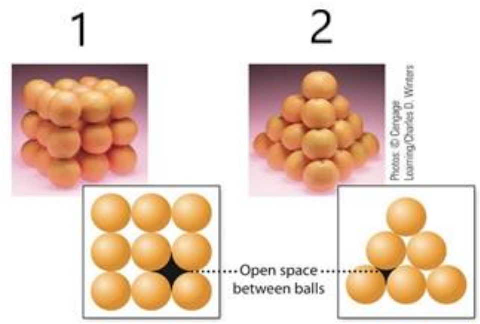
2. The accepted value for the density of copper is 8.960 g/cm^3 at 293K and the accepted value for the density of zinc is 7.133 g/cm^3 at 293K. Determine the % error in comparison to your experimentally determined value. Show your work.

Estimating the Volume and Radius of a Single Copper or Zinc atom.

SHOW WORK for all calculations in space provided.

1. Using the accepted value for the density of your metal (Cu or Zn) given above, together with the average atomic mass of your metal from the periodic table, calculate the **number of atoms** of your metal in a 1.00 cm^3 sample.

2. Assuming that atoms are spherical, we can imagine them packing in different possible arrangements within the solid. Two possible atomic packing arrangements are shown at right. Examining these two possibilities, which one is more efficient at filling space, that is, for which packing arrangement is there less empty space between the spheres?



3. The atomic packing arrangement in pure zinc and copper metals is similar to the arrangement (2) shown above. For this arrangement, it is known that 74% of the available space is taken up by atoms and 26% is empty space between the atoms. Using this knowledge, calculate the volume of space (in cm^3) that is actually occupied by atoms in a 1.00 cm^3 sample of your metal.

4. Using your values from 1 & 3 above, calculate the approximate volume occupied by a single atom in cm^3.

5. Using your result from 4 above, calculate the approximate radius (in cm) for an atom of your metal, and convert this value into picometers (1 pm = 10^{-12} m)

6. The accepted values for atomic radius are 127.8 pm for copper and 133.2 pm for zinc. Calculate the percent error for your metal.

Name ____   Section ______________________

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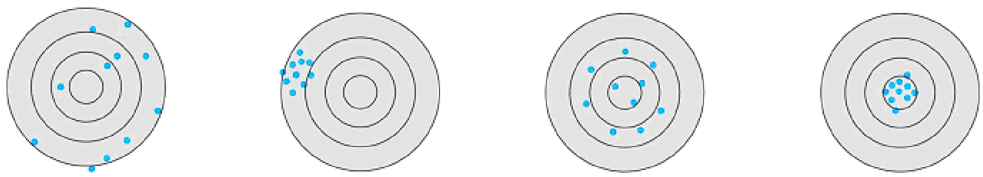
PRE-LAB EXERCISES

Complete this page prior to attending lab.

1. Based on the targets, which would be considered *inaccurate* but *precise*? Circle your choice.



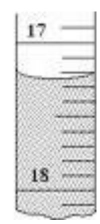
2. Given the following 3 values: 2.5 3.3 4.2

   a. Determine the average (or mean). Average = ______________

   b. Determine the standard deviation. Standard Deviation = ____________

3. Read the buret pictured and report value with the correct number of significant figures. →

   Buret reading = ______________________ mL



4. What is Archimedes' Principle? Search the web.

5. To the right is a picture of a volumetric flask. →

   Is it a TC (to contain) or TD (to deliver) piece of glassware? TC TD

6. Review the concept of significant figures in your textbook.

   a. How many significant figures do the following numbers contain?

      0.0129 has _________ significant figures. 2.0100 has _________ significant figures.

   b. Report these numbers to 3 significant figures.

      2.996 → ________________ 8000 → __________________________

   c. Perform this operation and report the answer with the proper number of significant figures.

      1.05 ÷ 12.00 = _____________________

7. Circle the chemical property. Mass Flammability Color

CHEMISTRY LABORATORY SAFETY AGREEMENT

Before working in the chemistry laboratory, read carefully the safety precautions and techniques for handling chemicals described in http://www.usna.edu/ChemDept/_files/documents/manual/SAFETY.pdf. **Give this agreement, signed and dated, to your laboratory instructor on the first day of lab.**

When you are in the laboratory, THINK about what you are doing at all times.

1. Always wear approved chemical splash goggles and lab aprons in the laboratory.
2. Do not attempt any unauthorized experiments. Follow directions carefully.
3. Know the location and operation of safety equipment.
4. Bring only necessary materials into lab. Book bags, jackets, covers, etc., are to be left in the hallway.
5. Never work alone in the laboratory.
6. Never eat or drink in the laboratory. Do not bring water bottles into the laboratory.
7. Use the fume hood for experiments. Keep lab stools at the tables, NOT by the hoods.
8. Keep your work area uncluttered. Clean up your area before leaving lab. Lower the hood sashes.
9. Use only equipment that is in good condition.
10. Dispose of waste and excess materials according to your laboratory instructor's directions.
11. No horseplay in the laboratory.
12. Do not sit or lean on laboratory work surfaces.
13. Handle chemicals with caution.
    (a) Read labels carefully.
    (b) Use only the amount required.
    (c) Leave reagent containers in their proper places.
    (d) Clean up all spills immediately.
    (e) Label all chemical containers.
14. Thoroughly wash your hands any time you leave the laboratory.
15. Immediately report all accidents and physical/chemical injuries, no matter how minor, to your laboratory instructor. Be ready to take immediate action as needed to assist any injured classmate.
16. Do not leave the laboratory without your instructor's approval.

I have carefully read all the safety precautions on the pages at the website above and recognize that it is my responsibility to observe them throughout my chemistry course.

Name ____________________________ Signature __________________________

Course ___________________________ Section ____________________________

Instructor ________________________ Date ______________________________