Lab 1. How Can the Density of a Substance be Determined Accurately and Precisely?

Prelab Assignment

Before coming to lab:

- Read carefully the handout, "Lab Notebook Policy"
- Read this lab handout and then devise specific procedures for Activities 1 - 3 of this lab exercise. Use a pen to record these *preliminary methods* in your lab notebook under the "Materials and Methods" section of your lab 1 report. These procedures will serve as a starting point. In class you and your lab partners will compare each other's methodologies, develop a common protocol for each of the three activities and then record your *finalized protocols in your lab notebook* (but only if different from your original protocol).
- Before coming to lab, *use a pen* to complete the following sections of your report for this lab exercise *in your lab notebook*:
    - Title and Date of Lab,
    - Introduction and Materials/Methods sections
    - Once your lab protocols are finalized at the start of lab, in consultation with your team, you will devise and record in your lab notebook an appropriate data table for each of the three activities
- Complete the Prelab questions on the last page of this lab handout *and hand in on the instructor's table when you arrive in lab*. Answer the prelab questions on the last page, *not* in your lab notebook.

Purpose

This lab exercise will provide a review of laboratory techniques for measuring the mass and volume of substance. The proper use of significant figures, metric units and the use of labels in all calculations will be emphasized. Your job is to come up with a method for measuring the density of various substances and to use proper techniques to experimentally determine the density of each substance as ***accurately*** and ***precisely*** as the lab equipment allows. The ultimate goals of this lab are to determine the densities of two unknown liquids (**Activity 1**), find the inner volume of a Beral pipette (**Activity 2**) and measure the density of and identify an unknown ionic salt (**Activity 3**).

Introduction

Pure substances may be characterized by their physical and chemical properties. These properties are useful in identifying unknown substances. In this lab you will determine the ***density*** different substances (two unknown liquids and an unknown solid) by measuring the mass and volume of each substance as precisely and accurately as possible.

$$\text{Density} = \frac{\text{mass (g)}}{\text{volume (cm}^3\text{)}}$$

For liquids and solids the mass is usually expressed in grams (g) and the volume in milliliters (mL). Note that ***1 mL = 1 cm^3.*** Thus, in order to calculate the ***density*** of an object you need to know both its ***mass*** and its ***volume***.

For this experiment, and all future experiments too, all of your experimental data must be recorded in your laboratory notebook according to the guidelines laid out in the "Lab Notebook Policy" handout. You will also be expected to use of significant digits correctly, to show all calculations, and to label all numbers with the correct units. ***Keep in mind that a part of your grades on lab reports will be based on the correct use of the lab notebook***.

Procedure

Before coming to lab devise a method for Activities 1 – 3, below. Before you begin any measurements in lab, your team must come to a consensus for each procedure, and record an outline of each *finalized procedure* directly into your lab notebook in *Materials and Method section* of your report. Record each procedure in sufficient depth that a competent Chem 161 student could replicate the experiment and get reasonably good results. The procedure should include the type and size of glassware used and the name and approximate amount of each substance to be measured out.

Activity #1. The use of density to distinguish between and identify two unknown liquids

Each group will be assigned two unknown liquids. The liquids may be either a pure compound or a solution. Your instructor will explain how to obtain each of the two unknown liquids. Use the property of density to determine if the two liquids are likely to be the same liquid. Describe the method you developed to solve this problem using the appropriate glassware in your lab drawer and a milligram electronic balance (a balance that measures to 0.001 gram). *Remember to record the number of each unknown in your lab notebook*. See page 4 for a picture of the equipment in your lab drawer that is available for you to work with.

Use a *ruler* to create a ***data table for activity 1***. Number the table as table1 and give it an informative title that includes the number of each unknown. *For each unknown liquid* neatly enter in the table: the unknown number, *all data measured during this part of the lab*, the liquid's mass and volume, the calculated density, the theoretical density (it will be provided at the end of lab) and the % error for the density of each liquid. Use *units of measure and correct significant figures* for *all* measured and calculated values.

Activity #2. What is the *total* inner volume of a Beral pipette?

Devise and carry out an experiment to determine as precisely as possible (i.e. to 3 decimal places) the total inner volume of a Beral pipette (figure 1). In addition to a Beral pipette, the only other things you are permitted to use are DI water, a beaker, a thermometer, an electronic balance and the table of the density of water at various temperatures (Table 1 on the next page). Describe the method you developed to solve this problem in enough detail so a competent Chem 161 student could repeat the experiment and get reasonable results.

Create a *ruled* ***data table for activity 2***. Number the table as table 2 and give it an informative title. Include the following in the table: *all measurements made in activity 2*, all calculated values (including the volume of the pipette!), the temperature and density of the DI H_2O used. Use units of measure and correct significant figures for *all* measured and calculated values.

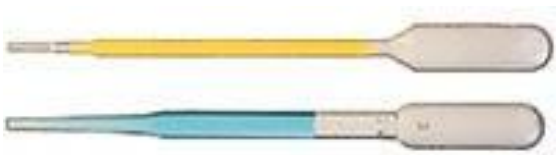


Figure 1. Beral pipettes (a.k.a. transfer pipette) come in a variety of sizes and are made of flexible plastic.
(Note that the label for figures belongs *below* the figure and figures are numbered consecutively!!)

Table 1. Density of Water (g/cm^3) at Temperatures from 15.0°C to 30.9°C by 0.1°C increments
(Note that the captions for tables belong *above* the table and that tables are numbered consecutively.)

	0.0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
15	0.999099	0.999084	0.999069	0.999054	0.999038	0.999023	0.999007	0.998991	0.998975	0.998959
16	0.998943	0.998926	0.998910	0.998893	0.998877	0.998860	0.998843	0.998826	0.998809	0.998792
17	0.998774	0.998757	0.998739	0.998722	0.998704	0.998686	0.998668	0.998650	0.998632	0.998613
18	0.998595	0.998576	0.998558	0.998539	0.998520	0.998501	0.998482	0.998463	0.998444	0.998424
19	0.998405	0.998385	0.998365	0.998345	0.998325	0.998305	0.998285	0.998265	0.998244	0.998224
20	0.998203	0.998183	0.998162	0.998141	0.998120	0.998099	0.998078	0.998056	0.998035	0.998013
21	0.997992	0.997970	0.997948	0.997926	0.997904	0.997882	0.997860	0.997837	0.997815	0.997792
22	0.997770	0.997747	0.997724	0.997701	0.997678	0.997655	0.997632	0.997608	0.997585	0.997561
23	0.997538	0.997514	0.997490	0.997466	0.997442	0.997418	0.997394	0.997369	0.997345	0.997320
24	0.997296	0.997271	0.997246	0.997221	0.997196	0.997171	0.997146	0.997120	0.997095	0.997069
25	0.997044	0.997018	0.996992	0.996967	0.996941	0.996914	0.996888	0.996862	0.996836	0.996809
26	0.996783	0.996756	0.996729	0.996703	0.996676	0.996649	0.996621	0.996594	0.996567	0.996540
27	0.996512	0.996485	0.996457	0.996429	0.996401	0.996373	0.996345	0.996317	0.996289	0.996261
28	0.996232	0.996204	0.996175	0.996147	0.996118	0.996089	0.996060	0.996031	0.996002	0.995973
29	0.995944	0.995914	0.995885	0.995855	0.995826	0.995796	0.995766	0.995736	0.995706	0.995676
30	0.995646	0.995616	0.995586	0.995555	0.995525	0.995494	0.995464	0.995433	0.995402	0.995371
	0.0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**

Activity #3. What are the density and the identity of an unknown salt?

Your team will be assigned a white unknown salt. Devise and carry out an experiment to determine the density of the salt and use table 3 to identify the salt. Describe the method you developed to solve this problem using the appropriate glassware in your lab drawer (page 4) and a milligram electronic balance to determine the density of the salt as precisely and accurately as your equipment allow. *Hints*: Your salt is one of the salts in Table 3 (all ionic compounds). Ionic compounds are relatively insoluble in organic solvents as illustrated by NaCl in Table 2, below.

Create a *ruled* data table for activity 3. Number the table as table 3 and give it an informative title that includes the number of the unknown salt. *Neatly* enter in the table: the unknown number, *all measured values*, all calculated values, the mass and volume of the salt, the calculated density, the theoretical density, % error, the name and formula of the unknown salt. Use *units of measure and correct significant figures* for *all* measured and calculated values.

Table 2. Solubility of NaCl in various solvents.

Formula of Solvent	Solvent Name	Solubility of NaCl (g/100 g solvent)
H_2O	water	35.92
CH_3OH	methanol	1.40
CH_3CH_2OH	ethanol	0.065
$CH_3(CH_2)_2OH$	1-propanol	0.012

Table 3. Possible salts for activity 3.

Salt	Name	Density (g/cm^3)
NH_4C1	Ammonium chloride	1.53
$(NH_4)_2SO_4$	Ammonium sulfate	1.77
KCl	Potassium chloride	1.99
LiCl	Lithium chloride	2.07
NaCl	Sodium chloride	2.16
$NaNO_3$	Sodium nitrate	2.26
Na_2SO_4	Sodium sulfate	2.68
$ZnCl_2$	Zinc chloride	2.91

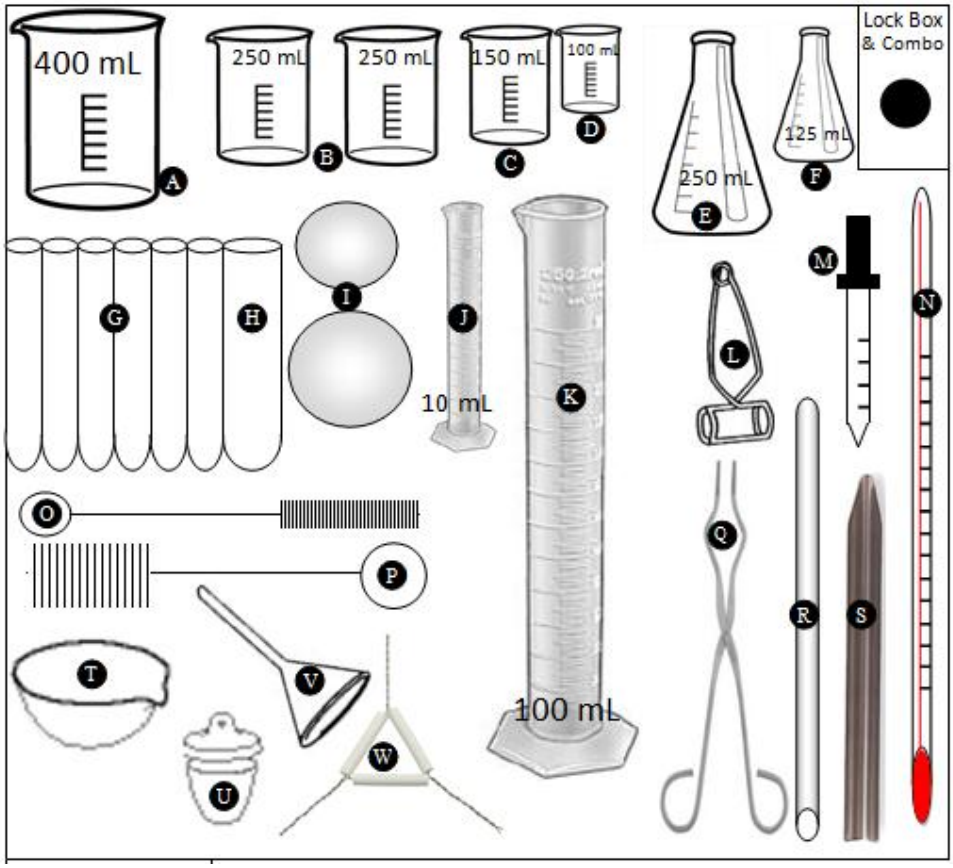
Clean-up! When you have finished the lab work for Activities 1 – 3…

- Empty all non-aqueous liquids (i.e. any of the alcohols from activity 3) into the appropriate waste container under the hood.
- Rinse out all glassware with tap water, followed by a rinse in DI water; shake off excess water
- Clean up and dry your work area before leaving lab.
- *Clean the balances and the table-top around your assigned balances*. ***Points will be deducted from the lab report of all team members if your assigned balances and the surrounding table top are not left spotlessly clean.***

The Lab 1 Report

Refer to the guidelines in the "Lab Notebook Policy" handout and the ***Lab 1 Guidelines and Report Checklist*** on the next page while completing your lab 1 report.

Chemistry Lab Drawer Equipment



Key	Equipment Name	Key	Equipment Name	Key	Equipment Name
A	400 mL beaker	**I**	watch glass (any size)	**Q**	crucible tongs
B	250 mL beaker	**J**	10 mL graduated cylinder	**R**	glass stir rod
C	150 mL beaker	**K**	100 mL graduated cylinder	**S**	lab scoop
D	100 mL beaker	**L**	test tube holder	**T**	evaporating dish
E	250 mL Erlenmeyer flask	**M**	medicine dropper	**U**	crucible with lid
F	125 mL Erlenmeyer flask	**N**	thermometer	**V**	funnel
G	16 x 150 mm test tube	**O**	test tube brush, small	**W**	clay triangle
H	25 x 150 mm test tube	**P**	test tube brush, large		

Lab 1 Report Guidelines

As indicated previously, be sure to include all the data collected in lab and calculations in your report, according to the guidelines in "*Lab Notebook Policy*" handout. Below is a checklist of what should appear in each of the 5 sections of your lab report.

General Considerations

- ***Write the entire report for lab 1 in your lab notebook in ink*** (No pencil!!) with errors neatly crossed out and *not* obliterated or obscured with "whiteout."
- Make sure your report is ***neat and easy to follow.*** Be concise and avoid being "wordy," but write in sufficient depth that would be expected of a college-level class.
- ***Write across the entire page for all sections of the repor***t.
- Use correct spelling and grammatically correct English—go the GRCC writing center for help if necessary and/or have other students ***proofread your report*** two or three days *before* it is due and make revisions as needed! *Suggestion*: *Use the GRCC writing center as a resource!!*
- *Clearly indicate at the top the report's 1st page*: The Title and Date of Experiment, Your first and last name, the first and last names of your lab partner(s), Course, Section and group number.

Lab 1 Report Checklist

Introduction

- State clearly *in your own words* the overall goals of lab 1 and the specific goals for activities 1 – 3.
- Summarize in your own words the background information about the lab and density on the first page of this lab handout.

Materials and Methods

- Outline the procedures for Activities 1 -3 in enough detail so a competent student could replicate the experiment and get reasonably good results.
- Include the name and size of the glassware used and the approximate amounts of chemical reagents to measure out.
- Both the preliminary protocols and the finalized protocols (if different) should be clearly labeled.

Results

- Use a *ruler* to construct all data tables
- Give each data table an informative title (caption) and number the tables consecutively (Table 1, Table 2, etc.). Table captions belong *above* each table.
- Each table should be neat and easy to follow.
- Include data for all measurements made during the experiment.
- Use correct significant figures and units of measure for all measured and calculated values.
- Clearly indicate the unknown numbers for activities 1 and 3.
- Each table should include entries that summarizes the results of major calculations (e.g. Density of the substance for activities 1 and 3; The volume of Beral pipette for activity 2; Accepted density and % Error for activities 1 & 3)

Continued on the next page!!

Lab 1 Report Checklist (cont.)

Analysis of Results

Precede all calculations with an easy to find heading (label) that clearly indicates what you are about to calculate. Clearly show work for all calculations, but only show *one sample calculation* for calculations that involve the same method (e.g. Show only one of the two calculations for the two unknown liquids in activity 1.)

Activity 1 – Determination of the Density of two unknown Liquids

- Calculate the density of each liquid.
- Are the liquids the same or different? Support your response by citing *specific numerical data* from this experiment.
- Calculate the % Error for the calculated density of each liquid.
- ***Error Analysis***: Discuss the most likely source(s) of error responsible for the calculated density being too high or low. *Use specific numerical data and results* when discussing sources of error.

Activity 2 – Determination of the Inner Volume of a Beral Pipette

- Calculate the inner volume of the Beral pipette and compare your result with the class average. Calculate the % difference between your result and the class average.
- ***Error Analysis***: Discuss the most likely source(s) of error responsible for your volume determination being either higher or lower than the class average. Use *specific numerical data and results* when discussing sources of error.

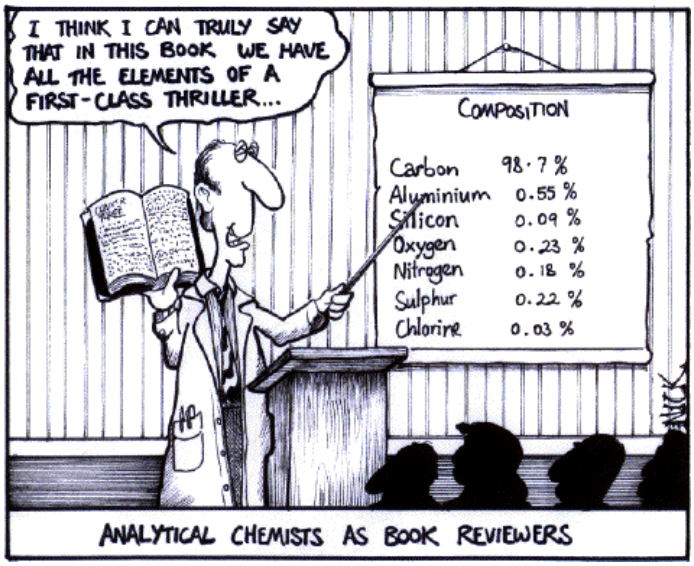
Activity 3 – Determination of the Density and the Identification of an Unknown Ionic Compound

- Calculate the density of your unknown salt.
- Identify the salt from the list provided on page 3. Support your response by citing specific numerical data collected in this experiment and compare it with the densities in table 3 on page 4 (Include this table as table 4 in your report!!).
- Calculate the % Error for the density determination of your unknown salt.
- ***Error Analysis***: Discuss the most likely source(s) of error responsible for the density being too high or low. Use *specific numerical data and results* when discussing sources of error.

Conclusion

Use "bullets" to summarize the major conclusions for each of the three activities:

- For each liquid in Activity 1: The Density, % Error and the major source(s) of error
- The volume of the Beral pipette in Activity 2, the class average, the % difference and the major source(s) of error
- The density and identification of the unknown salt in activity 3, the % Error and the major source(s) of error



Lab 1 Prelab Questions ***Name*_____**
Density and Measurement ***Team* _____*Date* _____*Section* _____**

Instructions: Complete the following three questions in the spaces provided below and hand in this page on the instructor's table at the start of your lab period. Show your work with units and correct significant figures for all questions that involve a calculation. ***Circle your numerical answers***.

1. A plastic container has a mass of 25.620 g when clean, dry, and empty. When the container is filled with distilled water, the total mass is 32.567 g at a temperature of 20.0 ^{o}C. The density of water at this temperature is 0.9982 g/mL. What is the precise volume capacity of the plastic container? *Circle your answer*.

2. The plastic container in question 1, above, is filled with an unknown liquid and then weighed. The total mass is 28.606 g. What is the density of the unknown liquid? *Circle your answer*.

3. Suppose you have a small cube of *ligna vitae*, a very dense tropical wood. If it measures 1.5 cm on a side and has a mass of 4.00 g, could it float in the unknown liquid from in question 2, above? *Explain and support your response with a calculation*.