

Experiment 1

Determination of Density

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PURPOSE

Learn the relative precision of liquid measurements using beakers, graduated cylinders, and volumetric pipets. Learn how to accurately measure the density of a liquid.

MEASUREMENTS

The quality of a measurement is evaluated by two criteria, accuracy and precision. The **accuracy** of a measurement is determined by how well it agrees with the "true" or "accepted" value. Accuracy is measured in terms of **error**. Error is the difference between the measured value of a quantity and the true/accepted value.

The **precision** of a measurement indicates how reproducible it is. Precision can only be determined by making repetitive measurements of the same quantity using the same technique.

In making measurements it is important to try to identify and eliminate or reduce the sources of error. Experimental error may be classified as either **systematic** or **random** error. Systematic error is always attributable to a definite cause, such as a malfunction in an instrument, erroneous technique, miscalculation, etc.

Random errors are inherent in the device and technique being used for the particular measurement and tend to fluctuate in a random fashion about the "true" value of the quantity being measured. The smaller the random errors, the more precise the measurement is.

Good precision indicates that the random errors are small; however, there still may be systematic errors leading to poor accuracy. If the precision is poor then many repetitive measurements be taken and averaged.

DENSITY

A property that is often used to characterize or identify a substance is the density, mass per unit volume, commonly reported in g/cm³ or g/mL.

$$\text{Density} = \text{Mass} / \text{Volume}$$

Table I. *Density of water at various temperatures*

T(°C)	density (g/mL)	T(°C)	density (g/mL)
15	0.999103	23	0.997542
16	0.998946	24	0.997300
17	0.998778	25	0.997048
18	0.998599	26	0.996787
19	0.998408	27	0.996516
20	0.998207	28	0.996236
21	0.997996	29	0.995948
22	0.997774	30	0.995650

IN THIS EXPERIMENT

You will use various pieces of glassware to measure 10 mL of water to see which glassware is most precise. Assuming no equipment malfunctions and the procedure is followed correctly, all of the errors in this experiment should be random errors, not systematic errors. Hence, the most precise technique should also be the most accurate one. Using the best technique (glassware), you will measure the density of an unknown solution.

PRE-LABORATORY PREPARATION

1. Read the techniques, procedure and data analysis sections of the experiment.
 2. The computer-generated PRELAB assignment for this experiment will be done in lab. The prelab questions for this experiment exactly replicate the questions in the data analysis section.
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EXPERIMENTAL SECTION

WASTE DISPOSAL

All of the chemicals used in this experiment may be safely disposed of by washing down the sink.

TECHNIQUES

USING ELECTRONIC BALANCES

The chemical being weighed is always in a container and not on the balance pan. To obtain the mass of only the chemical, the mass of the container must be subtracted from the total mass. Balances do this for us:

1. Place the empty container or weighing paper in the center of the balance pan. Press the zero (or tare) button and wait until the reading is zero (± 0.001). This is called **taring** the balance.
2. Add the chemical to the container.
3. Wait until the reading stabilizes and record all digits displayed (to the nearest 0.001 g). If the last digit is randomly fluctuating, record its average value.

Good practices when using a balance:

- If there is a danger of spilling on the balance, remove the container before adding the chemical. The balance will remember the mass of the container until it is tared again.
- Do not weigh hot or warm objects; objects should be at room temperature.
- Avoid moving or causing any air currents that would cause the reading to fluctuate.

USING VOLUMETRIC PIPETS

Always use a suction bulb with a pipet. NEVER PUT A PIPET INTO YOUR MOUTH!

Use of a pipet:

1. Each time you use a pipet with a different solution, you should first rinse* the pipet with the new solution.
2. Draw liquid into the pipet** until the meniscus is at least an inch above the circular calibration line (partway up the top stem of the pipet). Slowly let up your finger on the end of the pipet to allow the liquid to slowly drain. Stop when the bottom of the meniscus rests on the calibration mark. Touch the tip of the pipet to the side of the container to remove any clinging drops.
3. Gently place the tip of the pipet inside of the receiving container and allow the liquid to drain. The liquid that remains in the tip is supposed to remain there and should not be blown out. Remove any clinging drops from the outside of the pipet's tip.

*Rinsing a pipet:

1. Draw liquid into the pipet**, until the liquid is about one-fourth the way up the wide bulge in the middle of the pipet.
2. Tip the pipet onto its side and then release your finger on the top of the pipet allowing the liquid to flow. Tilt and rotate the pipet so that the liquid rinses the complete inner surface of the pipet.
3. Place your finger over the end of pipet and then turn the pipet upright. Place the tip of

the pipet over a sink (or waste container) and release your finger allowing the liquid to drain out of the pipet.

- If drops are sticking to the inside of the pipet it is not clean and not delivering its claimed volume. If necessary, consult the instructor on how to clean it.

****To draw liquid into a pipet:**

- Be sure that the outside of the pipet is clean and will not contaminate your solution. Immerse the tip of the pipet in the solution, but not on the bottom of the container since this can block the opening. Hold the pipet with one hand placed close to its top.
- With your free hand, squeeze the suction bulb and then place it on top on the pipet. Do not insert the pipet into the suction bulb!
- Slowly release the pressure on the suction bulb, drawing liquid up into the pipet. Always draw excess liquid into the pipet since you will lose some performing the next step. *Do not draw liquid into the suction bulb; the liquid may damage the bulb and carry debris down into the pipet making it very difficult to clean and contaminating your experiment.*
- Quickly remove the suction bulb with one hand while simultaneously sliding a finger, from the hand holding the pipet, over the top of the pipet to prevent the liquid from escaping. It is recommended that you use the forefinger for this.

PROCEDURE

You will do the first half of this experiment with a partner. You will do the last half individually.

PREPARATION

- Remove a 250-mL beaker from the drawer at your station and fill it with distilled water until it is about half full.**

The only distilled water tap is the single tap located on the far left at the front sink. A carboy with distilled water may also be available at the back sink.

- Measure the temperature of the water, record it on your data sheet, and complete question 1 of the Data Analysis section.**

Look up the density at the measured temperature (see Table I on the first page). Calculate the mass of 10.00 mL of water at this temperature (as you did in the prelab).

You need to do this before continuing with the experiment. This value will tell you if you are getting accurate results.

- Clean both a 50-mL beaker and a 50-mL graduated cylinder.**

Rinse them with tap water and scrub with a test tube brush, if they look dirty. Do a final rinse with distilled water.

MEASURING THE MASS OF 10-mL OF H₂O

- Pour distilled water from your 250-mL beaker into the 50-mL beaker until it reaches the 10-mL calibration line.**

- Pour distilled water from your 250-mL beaker into the 50-mL graduated cylinder until it reaches the 10-mL calibration line.**

- Bring the 50-mL beaker, the 50-mL graduated cylinder, and an empty 100-mL beaker to a balance.**

- Place the 100-mL beaker on the balance and then tare (zero) the balance.**

The balance should read 0.000 (\pm 0.003) g.

- Remove the beaker from the balance pan and pour the 10-mL aliquot (sample) of distilled water from the 50-mL beaker into the 100-mL beaker. Return the 100-mL beaker to the balance.**

- Record the mass on your data sheet (aliquot 1 for the 50-mL beaker).**

The mass should be around 10 (\pm 3) grams. Be sure to record at least 3 digits after the decimal place (to the nearest 0.001 g), which may require estimating the last digit if it is fluctuating.

10. Tare the balance, remove the 100-mL beaker, and then add the distilled water from the 50-mL graduated cylinder to the 100-mL beaker. Return the beaker to the balance.

Since the balance is tared between samples, we do not need to empty the beaker in between.

11. Record the mass on your data sheet (aliquot 1 for the 50-mL graduated cylinder).

Again, the mass should be around 10 (\pm 3) grams. If your mass is close to 20 grams, you forgot to tare the balance in between samples.

12. Dump the water from the 100-mL beaker down the drain, return everything to your station.

13. Repeat steps 4-12. (This time, record the masses in the spaces for aliquot 2).

It is not necessary to dry the glassware since we are adding more of the same liquid (distilled water).

USING A PIPET TO MEASURE 10-mL OF H₂O

Everyone will need to know how to use a pipet, so this part must be done individually.

14. At your station, practice using a suction bulb and 10-mL pipet until you can smoothly deliver 10 mL of water into a 50-mL Erlenmeyer flask.

Your instructor should have explained how to use a pipet at the beginning of the experiment. If you need review or were not paying attention, read the techniques section on using a pipet.

15. Take your pipet, bulb, beaker of distilled water, and 50-mL Erlenmeyer flask to a balance. Place the flask on the balance and tare it.

16. Remove the flask from the pan and use the pipet to deliver an aliquot of distilled water into the flask.

17. Return the flask to the pan and record the mass (to the nearest 0.001 g) on your data sheet.

18. Tare the balance again (while the flask containing the liquid is still on it), remove the flask from the pan, and use the pipet to deliver a 2nd 10-mL aliquot to the flask.

19. Return the flask to the balance pan and record the mass of your 2nd aliquot.

DENSITY MEASUREMENT OF AN UNKNOWN

20. Complete the data table by calculating the error for each aliquot. Determine the best (most accurate & precise) technique to use.

The most accurate technique will be the one with the smallest errors (whether the error is positive or negative is irrelevant).

In order to have confidence in your technique, you should have an error smaller than 0.1 g for that method. If none of your techniques have errors this small, you should take more measurements (practice) or discuss with an instructor what might be going wrong.

21. Obtain 30-40 mL of an unknown liquid sample from the laboratory assistant.

You will need to bring the assistant a clean, dry 50 or 100 mL beaker for the unknown. Immediately record the unknown number on your data sheet.

22. Determine the mass of each of three 10-mL aliquots of your unknown using only the best (most accurate and precise) technique.

Follow the procedure used in the previous section for that technique. Record the mass for each trial on your data sheet.

23. If you are satisfied with the precision of your measured masses then clean up and proceed with the data analysis section.

Otherwise, continue taking measurements until you have three good readings. It is not necessary to get additional solution, as you may reuse your solution (unless it was contaminated).

RINSE YOUR GLASSWARE WITH DISTILLED WATER, DRY IT, AND RETURN IT TO YOUR DRAWER.

Name

Station Used

Instructor/Day/Time

Partner's Name

Station Checked & Approved

DATA SHEET

Record all of your data with the appropriate number of digits and the correct units. You may add extra lines if you wish to take more than the minimum two or three readings.

Temperature of water: _____

Measured mass of 10.00 mL of water:

	50-mL beaker	50-mL graduated cylinder	10-mL volumetric pipet
Mass of aliquot 1			
Mass of aliquot 2			
Error in aliquot 1			
Error in aliquot 2			

The error for each measurement is calculated by subtracting the theoretical mass (calculated in Data Analysis question 1) from the measured mass.

Based upon the calculated errors, which piece of equipment can be used most reliably to measure 10 mL?

Measured mass of 10.00 mL of unknown solution:

These values will be used to determine the density of your unknown solution.

(Add extra lines, if you need to take more measurements.)

unknown number: _____

mass of aliquot 1 _____

mass of aliquot 2 _____

mass of aliquot 3 _____

DATA ANALYSIS

Show your work for each type of calculation. They should be clearly organized, legible and include the units for each quantity. Be sure to round each answer to the proper number of digits.

1. Use the tabulated density of water at the measured temperature to calculate the theoretical mass of exactly 10 mL of distilled water. Since most of our balances show 3 places after the decimal, round your mass to 3 places after the decimal. This will also give the correct number of significant figures.

mass of water _____

2. Calculate the density of each aliquot of your unknown solution. *Again, report each answer to 3 places after the decimal point (which should be the correct number of significant figures).* It is not necessary to show your work for all of your trials. Only show the calculation for the first aliquot in detail. (Extra lines for results are provided in case you measured more than three aliquots of unknown.)

density of aliquot 1 _____

density of aliquot 2 _____

density of aliquot 3 _____

(optional) density of aliquot 4 _____

(optional) density of aliquot 5 _____

3. Calculate the average density of your unknown solution. Only use the results for what you considered to be “good” trials. Show your calculation so it is clear which you consider to be “good” trials.

average density _____

unknown number _____