Mass, Volume and Density

# Introduction

Chemistry, like all the natural sciences, is an experimental science. The principles of chemistry are not true because they seem reasonable or because we want them to be true, but because observation and data demonstrate that they accurately describe the behavior of the universe around us. As such, one of the most important purposes of the chemistry laboratory is to allow students to verify for themselves that the concepts and methods presented in the course are supported by experiment.

Experimental results are the foundation of chemistry. However, the conclusions drawn from experiment are subject to the conditions of precision and accuracy. *Precision* is the ability to reproduce a measurement consistently; *accuracy* refers to how close a measurement comes to the true value that exists in nature. Both precision and accuracy are affected by measurement techniques and the apparatus itself.

For example, a student may take a quick glance at a solution in a graduated cylinder and record a value as opposed to holding the cylinder at eye level and closely examining the top surface of the liquid (the *meniscus*) and carefully noting its relationship with respect to the marks on the glass.

Often laboratory glassware - for instance, a graduated cylinder - is marked in tenths of a milliliter. In the theory of measurement, the user should record a volume to the closest *hundredth* of a milliliter by estimating ten subdivisions between two marks (1). The reason for this is twofold: first, to increase the accuracy of the measurement; and second, to increase the number of significant figures allowed in calculations based on the measurement. Also, in terms of an experiment – you can say with confidence that the measurement is more precise than just the graduations – you can tell if it “right on” a line (for instance 1.10 mL) vs about halfway between two lines (1.15 mL).

The choice of apparatus and measuring tools will influence both accuracy and precision. For example, if measuring the width of a wire, a meterstick may be a bad choice. Also, a meter stick marked in centimeters is clearly less precise than one marked in millimeters. Different types of chemistry glassware are designed with different accuracy and precision in mind (1), and the precision of analytical glassware is guaranteed by quality control and/or calibration procedures.

Experimental procedures and conditions can also have significant effects on an experiment’s outcomes: for example, the effect of temperature on water density in today’s experiment. The point is that there are many reasons why the results of an experiment may be less than perfect, and therefore it is unrealistic to expect any experiment to yield ‘perfect’ results. However, that does not mean that the principle under investigation is suspect.

As an introductory course in chemistry, and as a teaching laboratory as opposed to a research laboratory, the goal is to introduce you to some of the glassware, tools, and measurement techniques common to the chemistry laboratory. This experiment is an opportunity to reflect on the concepts of precision and accuracy, and to recognize that the limitations of our experiments do not imply that the chemical principles they are based on are incorrect, even if the data is less than perfect.

# Materials and Methods

* plastic pipette
* LabQuest2 with a temperature probe
* 50 mL beaker, 100-mL beaker
* 10 mL graduated cylinder, 100 mL graduated cylinder
* 10 mL graduated syringe
* saltwater sample

# Procedure

## Measuring glassware mass

1. Clean and dry a 100-mL beaker. Label this as the ‘Weighing Beaker’.
2. Weigh the beaker.
   1. For a typical electronic balance: Close all sliding doors on the balance.
   2. Press the 0/T button (zero / tare) to set the display to zero. Make sure the scale is reading to the closest 0.000 gram.
   3. Open one of the doors, place the beaker on the balance pan, close the door.
   4. Record the mass to the closest 0.000 g on paper. *Reminder*: Record all data while weighing it.
3. Close all sliding doors before leaving the balance area.

## Measuring volume

1. As precisely as possible, measure 10 mL of water in a 50-mL beaker.
   1. Graphical user interface

      Description automatically generated with medium confidenceHold the beaker at eye level; the bottom of the meniscus should be at the 10 mL level.
   2. Use a plastic pipet, as needed, to add or remove water to complete the task.
2. Pour the water into the weighing beaker.
3. Find the mass of the weighing beaker and water, using the techniques from the previous section.
4. Use the temperature probe to measure the temperature of the water in the weighing beaker and record the value on the report sheet.
5. Empty and dry the weighing beaker.
6. Repeat this task for:
   1. a 10 mL graduated cylinder
   2. a 100 mL graduated cylinder
   3. a 10 mL syringe

Note: it is only necessary to find the temperature of water for the first sample.

## Calculating true volume

1. Convert from the mass of water to the true volume of water using these steps:
   1. Calculate the mass of each water sample as

*mass of beaker and water – mass of beaker = mass of water.*

For example, if the mass of the weighing beaker was 18.321 g and the mass of the beaker plus water was 29.235 g, then the calculation *on the report sheet* should be:

29.235 – 18.321 = 10.914 g

Be sure to include the unit ‘grams’ in the answer.

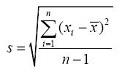
* 1. Determine the density of water using the measured temperature of water and following equation (The density of water is a function of temperature).
     1. For example, if I am working with water at 23.45 C:

Note that this is an “empirical fit equation” and should not be used for dimensional analysis or significant figure determination. Therefore, the final output is 0.9960 g/mL

* 1. Calculate the true volume of water. Each calculation should be set up as follows:
     1. For example:

Be sure to include units in the answer.

## Optional: statistics

1. Repeat the process outlined above for three more replicates (repeats) of each measurement and true volume calculation (see report sheet)
2. Calculate the average volume for each apparatus (beaker, 10mL cylinder, 100 mL cylinder, syringe)
   1. ; xi is each individual measurement and n is the number of measurements
3. Calculate the Standard Deviation for each apparatus using the following equation:
   1. ; xi is each individual measurement, is each individual measurement, n is the number of measurements, and s is the standard deviation
   2. Note: we will use standard deviation as our “+/-“ here, but in typical research and analytical work, a further calculation is involved to determine the confidence interval for a given level of confidence.

## The density of sea water

1. Obtain a 10-mL sample of sea water with the syringe.
2. Transfer the sample to the weighing beaker and find the mass of the beaker and sea water sample.
3. Find the mass of sea water.
4. Calculate the density of the saltwater sample on paper using the following equation:

For example, if 10.00 mL of solution had a mass of 11.325 g, then:

Be sure to include a unit with the answer.

## Clean up

The sea water used in this experiment is nonhazardous and therefore it may be disposed of in the sink. Follow your instructor’s directions for cleaning and storing the glassware used in this experiment.

## References

1. Harris, D. C. *Quantitative Chemical Analysis* 7ed; W.H. Freeman and Company: New York, 2007.