

Name _____

Hour _____

Chemistry Lab: Introduction to Measurement

(adapted from Flinn ChemTopic Labs)

Introduction

Much of what we know about the physical world has been obtained from measurements made in the laboratory. Skill is required to design experiments so that careful measurements can be made. Skill is also needed to use lab equipment correctly so that errors can be minimized. At the same time, it is important to understand the limitations of scientific measurements.

Concepts

- Measurement
- Accuracy and precision
- Significant figures
- Experimental error

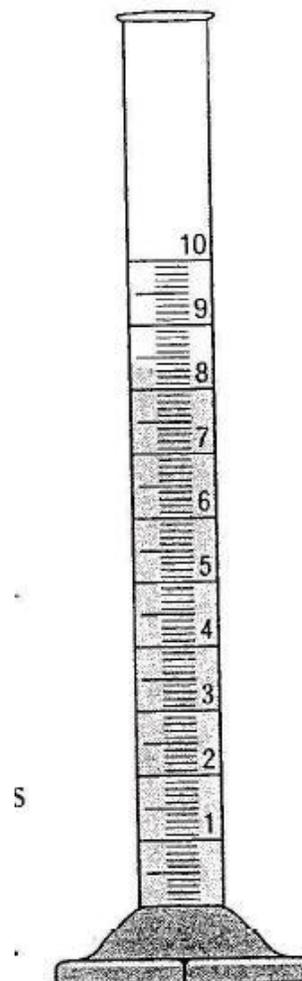
Background

Experimental observations often include measurements of mass, length, volume, temperature, and time. There are three parts to any *measurement*:

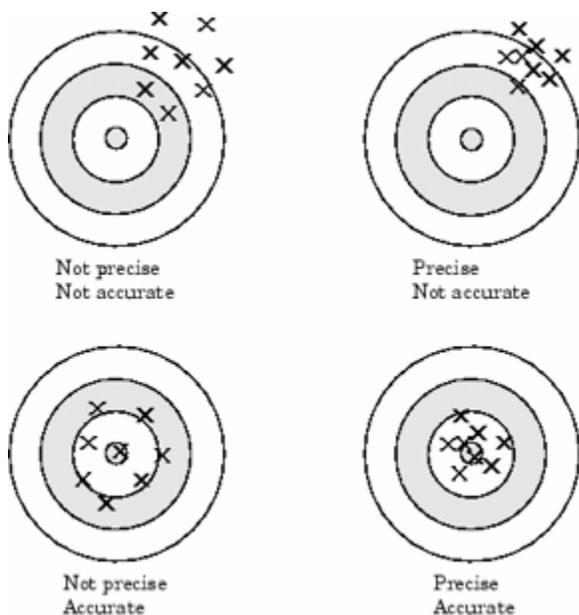
- its numerical value (magnitude)
- the unit of measurement that denotes the scale
- an estimate of the uncertainty of the measurement.

The numerical value of a laboratory measurement should always be recorded with the proper number of *significant figures*. The number of significant figures depends on the instrument or measuring device used and is equal to the digits definitely known from the scale divisions marked on the instrument plus one estimated or "doubtful" digit. The last, estimated, digit represents the uncertainty in the measurement and indicates the precision of the instrument.

Measurements made with rulers and graduated cylinders should always be estimated to one place beyond the smallest scale division that is marked. If the smallest scale division on a ruler is centimeters, measurements of length should be estimated to the nearest 0.1 cm. If a ruler is marked in millimeters, readings are usually estimated to the nearest 0.2 or 0.5 mm, depending on the observer. The same reasoning applies to volume measurements made using a graduated cylinder. A 10-mL graduated cylinder has major scale divisions every 1 mL and minor scale divisions every 0.1 mL. It is therefore possible to "read" the volume of a liquid in a 10-mL graduated cylinder to the nearest 0.02 or 0.05 mL. Three observers might estimate the volume of liquid in the 10-mL graduated cylinder shown at the right as 8.32, 8.30, or 8.33 mL. These are all valid readings. It would NOT be correct to record this volume of liquid as simply 8.3 mL. Likewise, a reading of 8.325 mL would be too precise.



Some instruments, such as electronic balances, give a direct reading-there are no obvious or marked scale divisions. This does NOT mean that there is no uncertainty in an electronic balance measurement; it means that the estimation has been carried out internally (by electronic means) and the result is being reported digitally. There is still uncertainty in the last digit. On an electronic centigram balance, for example, the mass of a rubber stopper might be measured as 5.67 g. If three observers measured the mass of the same rubber stopper, they might obtain readings of 5.65, 5.67, and 5.68 g. The uncertainty of an electronic balance measurement is usually one unit in the smallest scale division that is reported-on a centigram balance this would be ± 0.01 g.



These dartboard targets illustrate the difference between accuracy and precision.

Accuracy and precision are two different ways to describe the error associated with measurement. *Accuracy* describes how "correct" a measured or calculated value is, that is, how close the measured value is to an actual or accepted value. The only way to determine the accuracy of an experimental measurement is to compare it to a "true" value-if one is known! *Precision* describes the closeness with which several measurements of the same quantity agree. The precision of a measurement is limited by the uncertainty of the measuring device. Uncertainty is often represented by the symbol \pm ("plus or minus"), followed by an amount. Thus, if the measured length of an object is 24.72 cm and the estimated uncertainty is 0.05 cm, the length would be reported as 24.72 ± 0.05 cm.

Variations among measured results that do not result from carelessness, mistakes, or incorrect procedure are called *experimental errors*. Experimental error is unavoidable. The magnitude and sources of experimental error should always be considered when evaluating the results of an experiment.

Experiment Overview

The purpose of this activity is to make accurate volume measurements using common glassware, to learn the meaning of significant figures in the measurements, and to compare the accuracy and precision of laboratory measurements.

Pre-Lab Questions

1. Explain how the uncertainty associated with a measurement is conveyed through the proper use of significant figures.
2. A pipet is a type of glassware that is used to deliver a specified volume of liquid. A 5 mL pipet has major scale divisions marked for every milliliter and minor scale divisions marked for every 0.1 mL. What is the uncertainty (in mL) made using this pipet? Would it be proper to report that the pipet was used to deliver 3.2 mL of liquid? Explain why or why not.



Materials

Balance, centigram (0.01 g)

Beaker, Flask and Graduated Cylinder; all 50-mL

Graduated cylinders with colored water at different levels: 10-, 50-, 100- mL

50 mL beaker and Graduated cylinders 10-, 50- and 100- mL

Pipet, Beral-type

Water

Safety Precautions

The materials in this lab activity are considered nonhazardous. Always wear chemical splash goggles when working in the laboratory with glassware, heat, or chemicals.

Throughout the lab, you will need to make careful volume measurements. Use the technique illustrated below to make accurate, consistent readings.

When water (or an aqueous solution) is contained in a narrow glass container such as a graduated cylinder, the liquid surface is not flat, as might be expected. Rather, the liquid surface is *curved* (see Figure 2-3). This curved surface is called a **meniscus**, and is caused by an interaction between the water molecules and the molecules of the glass container wall. When reading the volume of a liquid that makes a meniscus, hold the graduated cylinder so that the meniscus is at eye level, and read the liquid level at the *bottom* of the curved surface.

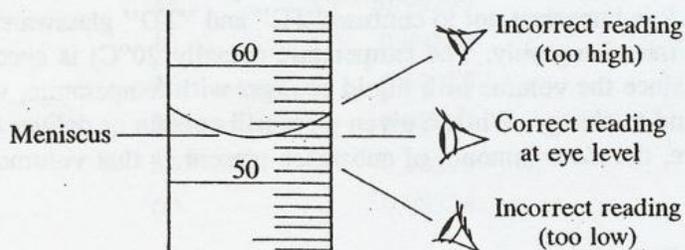


Figure 2-3. Reading a meniscus. Read the bottom of the meniscus while holding at eye level.

Procedure

Part A. Practice Making and Recording Volume Measurements with Graduated Cylinders

For this part, use the three graduated cylinders, each containing a specific quantity of liquid to which some food coloring has been added to make the volume easier to read.

1. In Data Table A, record the maximum capacity of each graduated cylinder and the volume that each major and minor scale division represents on each graduated cylinder.
2. Observe the volume of liquid in each cylinder and record the results in Data Table A. Remember to include the units and the correct number of significant figures.
3. In Data Table A, estimate the "uncertainty" involved in each volume measurement.

Data Table A. Volume Measurements

Graduated Cylinder	Maximum Capacity (mL)	Volume Given by Major Scale	Volume Given by Minor Scale	Observed Volume	Uncertainty (\pm how many mL)
A					
B					
C					

Part B. Comparing Volume Measurements Made with Three Different Sized Graduated Cylinders

4. Use tap water to fill a 50-mL beaker to the 20-mL mark. Use a disposable plastic pipet to adjust the water level until the bottom of the meniscus is lined up as precisely as possible with the 20-mL line.
5. Pour the water from the 50 mL beaker into a clean, 25-mL graduated cylinder. Read the volume of liquid in the 25 mL graduated cylinder and record the result in Data Table B. Remember to include the units and the correct number of significant figures based on the glassware's scale. **(Note: If the water level is not on the 20 mL mark, do NOT add or remove water. Record the level of water that you see.)**
6. Transfer the water from the 25-mL graduated cylinder to a clean, 50-mL graduated cylinder and again read its volume. Record the result with the correct number of significant figures in Data Table B.
7. Transfer the water from the 50-mL graduated cylinder to a clean, 100-mL graduated cylinder and again read its volume. Record the result with the correct number of significant figures in Data Table B. Discard the water into the sink.
8. Repeat steps 4-7 two more times for a total of three independent sets of volume measurements. Dry the beaker and graduated cylinders between trials. Record all results in Data Table B.
9. Calculate the average (mean) volume of water in the 25, 50 and 100-mL graduated cylinders for the three trials. Enter the results in Data Table B.

Data Table B. Comparing Volume Measurements

<i>Measured Volume of "20 mL" of Water</i>			
Trial	25 mL Graduated Cylinder	50 mL Graduated Cylinder	100 mL Graduated Cylinder
1			
2			
3			
Average			

Post-Lab Questions

1. What is the relationship between the scale divisions marked on the graduated cylinders in Part A and the estimated uncertainty in volume measurements?
2. In Part A, which graduated cylinder(s) gave the most precise volume measurement? Why?
3. It is common to get different volume readings for each container in Part B. What explanation can you offer for an apparent decrease or increase in volume?
4. Why does every human measurement have uncertainty associated with it? Why must we manage the uncertainty during calculations?