

Lab 2 Introduction to Measurement and Uncertainty

Purpose: In this lab you will become familiar with some common types of measurement in the chemistry lab. You will also learn how to calculate percent error and develop an understanding of the accuracy and precision in the instruments and tools available as well as the importance of sample size.

Relevant text: Chapter 2

Materials: Calculators, balances, plastic wash bottle, 10 mL and 25 mL graduated cylinders.

Discussion

Uncertainty in measurements: Measurements will always have an uncertainty associated with them. This is partially due to the skill of the person using the measuring tools, and partially due to limitations on the precision of the measuring tool. This can best be appreciated by comparing measurements made using different methods and calculating the difference (% Error) between measurements. Sample size and the precision of the measuring device can also affect the outcome of an experiment. Today you will collect data and perform calculations to help understand the relationship between error, precision and sample size.

Accuracy and Precision The accuracy of an experiment is the difference between the *average of the measured values and the true known value*. The precision of an experiment is a *measure of the range of values found*. In a group, measurements are precise if they cover a very small range of values. An individual measurement is precise if it has a lot of significant figures. Generally precision in an experiment can be increased by using measuring devices that produce a large number of significant figures and/or by repeating experiments. Measurements can be accurate, precise, both, or neither. Of course, a scientist strives to have results that are both accurate and precise. The relationship between accuracy and precision can be understood in the following figure, where darts are thrown at a dart board. The bullseye represents the target/true value:

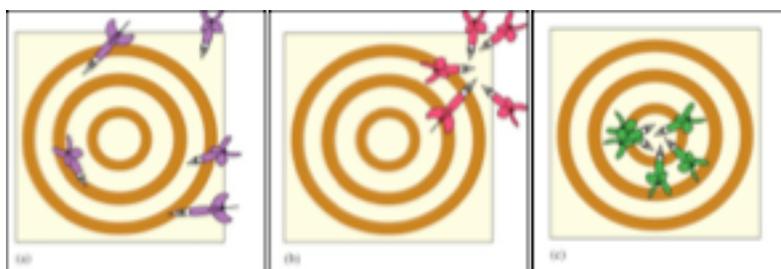


Figure 1. A) accurate but not precise-the average of the darts would result in the bullseye. B) precise, but not accurate-the darts are arranged very near to each other but off the bullseye. C) precise and accurate-the darts are both near each other and the bullseye.

Sample size is either the amount of substance being measured or repetitive measurements. This lab will focus on sample size, other labs will use repeated measurements to minimize error. When only a small sample is used, an uncertainty in reading a measuring tool like a graduated cylinder can translate into a large uncertainty in the final answer. Scientists strive to make the error as small as possible, by using precise equipment and repeating experiments (increasing sample size).

Significant figures are the numerical part of a measurement or calculation. When reporting direct measurements, remember that you are to estimate to one more decimal place (the uncertain last

digit). When using a measuring device with a digital read, all the digits will be recorded, the last digit is still uncertain. When performing calculations, report the significant figures according to the math performed, based on your input. For more discussion of significant figures, see your notes or text on Chapter 2.

Error: Because each measurement and subsequent calculation contains uncertainty, a method is needed for reporting error. In this course we will calculate percent error and use significant figures to report the error of both measurements and calculations. It is also common to see error expressed as the number \pm the amount of uncertainty. Carelessness, poor technique and mistakes can be referred to as “gross errors” and should be corrected when discovered. This may include repeating an experiment if time permits. If not, error analysis should admit the presence of such an error.

Percent Error: Every measurement we make in lab will have some degree of error. Generally the error in a measurement is calculated by subtracting the *true value* for a measurement from the *experimental value*, then dividing this by the true value-if a true value is known. This gives what we call *percent error*. A low percent error means a measured value is close to the true value, which is good. A high percent error should make you recheck your measurements and calculations. The calculations may result in a negative number; if that is the case, the absolute value is taken. Scientists do not always know the true value of something they measure. Instead, they repeat experiments and find the error between subsequent measurements using a different calculation that we will not discuss

$$\% \text{ error} = \frac{[\text{Experiment value} - \text{True value}]}{\text{True Value}} \times 100$$

here. In this experiment, we will use the following equation:

Density is a physical property of a substance that is the ratio of its mass to its volume. Density can be used in part to identify substances because a given substance will have same density at a given temperature. The units of density are often grams per milliliter (g/mL) but can be reported with any unit mass per any unit volume.

Making measurements with graduated cylinders:

Procedure:

1. Identify the interval on the measuring tool (cylinder) within which the quantity falls
2. Imagine 10 equal divisions of the interval
3. Use the imaginary increments to estimate the position of the quantity within the interval
4. Report the measured value by recording the number associated with the lower end of the interval plus the estimated incremental tenth of the interval.

Part 1 Practice making and recording volume measurements with graduated cylinders (in the hoods in the back of the classroom--be sure to indicate from which hood your samples came)

1. In Data Table A, record the volume that each major and minor division on each the graduated cylinders.
2. Observe and record 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 record the uncertainty for each graduated cylinder.

Part 2 Observe the effects of sample size and cylinder precision on % error.

- 2A 1. Obtain a clean, dry empty 25 mL graduated cylinder. Look at it carefully. Pay attention to the scale on the cylinder and think about the precision of this cylinder, the same way you did in Part 1 with the others.
2. Obtain the mass of the empty cylinder. Record this on line 1 of the data table for the 25 mL section-use the same cylinder for parts A-C.
3. Fill the cylinder to approximately 10.0 mL using a plastic wash bottle. (make sure you have at least 10.0 mL, a little more if ok.) Record this volume to the nearest 0.1 mL on the data sheet on line 4.
4. Obtain the mass of the graduated cylinder with the liquid. Record on line 2. Subtract the mass of the empty container to obtain the mass of the sample, record on line 3.
5. Calculate the mass per unit volume (density) of the liquid by dividing the mass of the liquid by the volume of the liquid; record on line 5.

ERROR ANALYSIS

6. Now **assume** that there is an uncertainty of **0.5 mL** in your volume measurement and that instead of the volume you record on line 4, subtract 0.5 mL and write that as your volume on line 6 as your new volume
7. Recalculate the density of the liquid and enter it on line 7 of the chart, using the “new” volume.
8. Find the % error between this density and the first density you calculated. Assume the first calculation was the true value, record on line 8.

Part 2B:

1. Add more water to the same 25 mL graduated cylinder until the volume is approximately 17.0 mL. Record this volume to the nearest 0.1 mL on the data sheet on line 4.
2. Repeat steps 4-8 from part 2A

Part 2C:

1. Add more water to the same 25 mL graduated cylinder until the volume is approximately 25 mL. Record this volume to the nearest 0.1 mL on the data sheet on line 4.
2. Repeat steps 4-8 from part 2A

Part 2D:

1. Obtain a clean, dry empty 10 mL graduated cylinder. Look at it carefully. Pay attention to the scale on the cylinder and think about the precision of this cylinder, remember, you saw a 10 mL cylinder in Part 1.
2. Obtain the mass of the empty cylinder. Record this on line 1 of the data table for the 10 mL section Part 2D
3. Fill the cylinder to approximately 10.00 mL using a plastic wash bottle. Record this volume to the nearest 0.01 mL on the data sheet on line 4.
4. Obtain the mass of the graduated cylinder with the liquid. Record on line 2. Subtract the mass of the empty container to obtain the mass of the sample, record on line 3.
5. Calculate the mass per unit volume (density) of the liquid by dividing the mass of the liquid by the volume of the liquid; record on line 5.

ERROR ANALYSIS

6. Now **assume** that there is an uncertainty of **0.05 mL** in your volume measurement and that instead of the volume you record on step 3, subtract 0.05 mL and write that as your volume on line 6 as your new volume

7. Repeat steps 7-8 from Part 2A.

Data Table 1 Volume measurements

Hood:

graduated cylinder	volume given by major scale (numbered scale)	volume given by minor scale (non-numbered scale)	Uncertainty (\pm how many mL)	observed volume
10 mL				
25 mL				

1. Do small scale divisions on a graduated cylinder result in more or less uncertainty than larger divisions?

2. Which size graduated cylinder gave you the most precise volume measurement? Why?

Data Table 2

Record all volumes precisely; record all masses according to the precision of the balance. Include *units* and *significant figures* for all your data and calculations. *Show your work for density and percent error calculations either on this sheet or a separate piece of paper.*

	Part 2A	Part 2B	Part 2C	Part 2D
1. Mass of cylinder				
2. Mass of cylinder + water				
3. Mass of water (line 2-line 1)				
4. volume of liquid (be PRECISE!)				
5. Density of liquid (line 3/line 4)				
6. "new" volume (subtract from line 4)				
7. New calculation of density (line 3/line 6)				
8. % error (see page 2)				

For questions 3-5 please refer to the measurements made in the 25 *mL cylinder*.

3. In which case did the 0.5 mL uncertainty in reading the graduated cylinder have the greatest percent error?

4. In which case did the uncertainty have the least effect on percent error?

5. What does this tell you about the relationship between sample sizes and error using the 50 mL graduated cylinder?

6. In comparing the results for Part A and Part D, where you measured the density of 10 mL of the same liquid, which had the greater error in the density determination?

7. If you needed to measure 10 mL of liquid, which cylinder (50 mL or 10 mL) would you feel would give you the most accurate measurement? Explain.

8. Does percent error measure accuracy or precision?