Experiment 1
Scientific Measurements: Precision and Accuracy

Purpose
The purpose of this activity is to get familiar with the approximate precision of the equipment in your laboratory. You will practice how to record measurements with an appropriate number of significant figures.

Background

Precision and accuracy are terms that are often used interchangeably, but they have very different meanings. *Accuracy is a measure of the correctness of a measurement.* For example, you might calculate the density of a piece of zinc to be 7.27 g/ml, but in actuality zinc has a density of 7.14 g/ml. Another student in the class may calculate the density of zinc to be 6.56 g/ml. Since your answer is closer to the agreed upon value, your measurement is more accurate. Often there is no "true" value to compare to in an experiment as we had above and therefore you cannot comment on a measurement's accuracy. On the other hand, you can comment on precision every time you take a series of measurements.

Precision is a measure of the reproducibility of a measurement. Imagine you repeated the zinc density experiment a second time and this time measured a value of 7.26 g/ml. Your value is very close to your first experiment. You could say that your precision is quite good.

Precision also deals with the closeness or fineness with which a measurement may be made. What does that mean? Think about measuring your weight. If you measure your weight at home on your bathroom scale, you may get a reading of 135.5 lbs. At a doctor's office that day the nurse measures your weight to be 135.39 lbs. The scale at the doctor's office has a higher precision than the one you have at home. The limited precision creates uncertainty which restricts the conclusions that can be made from the measurement. Scientists represent this precision in the equipment by putting writing "± error" after the measurement. For example, the first scale's measurement would be written as 135.5 ± 0.1 lb. This shows that there is an uncertainty in the last digit of the measurement. The doctor's scale measurement would be written as 135.39 ± 0.01 lb. Keeping track of the uncertainty of each piece of equipment could be painful. Scientists use significant figures (sig figs) to indicate the precision without having to keep track of which pieces of equipment were used to make all the measurements.

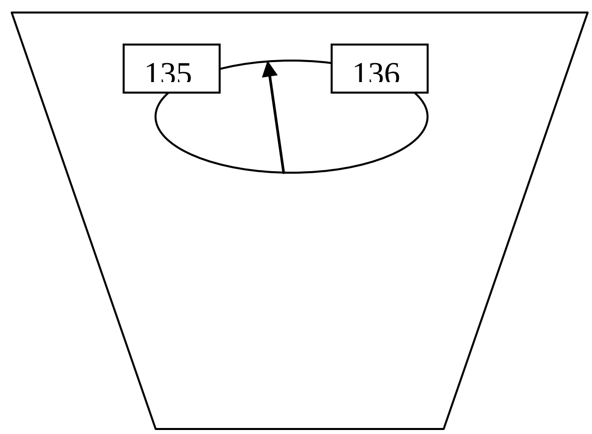


Figure 1 – Scale showing a mass between 135 and 136 lb. Note the lack of markings between 135 and 136.

Significant figures include all the known values of a measurement plus one guess. Let's go back to the scale example. When you stand on the bathroom scale, the needle might point between 135 lb and 136 lb (as in figure 1 below). You know that you weigh more than 135 lb but less than 136 lb. The correct way to report this value is to report the known values (135) plus a guess (135.*4* ← the 4 is the guess).

In general,

> Estimate the value to **one decimal place** more than the level of graduation.

In the example above, the graduation is every 1 lb. Therefore, the measurement is reported to the 0.1 lb (135.4 lb, which has one decimal place).

Every measurement you take must include the proper number of significant figures!! You can determine this by looking at the graduations on your device. Don't be afraid to guess at the last value. The last digit is uncertain. Many students ask if significant figures are important. Read the following fable and then draw your own conclusions:

Are Significant Figures Important?
A Fable

A student once needed a cube of metal which had to have a mass of 83 grams. He knew the density of this metal was 8.67 g/mL, which told him the cube's volume. Believing significant figures were invented just to make life difficult for chemistry students and had no practical use in the real world, he calculated the volume of the cube as 9.573 mL. He thus determined that the edge of the cube had to be 2.097 cm. He took his plans to the machine shop where his friend had the same type of work done the previous year. The shop foreman said, "Yes, we can make this according to your specifications - but it will be expensive."

"That's OK," replied the student. "It's important." He knew his friend has paid $35, and he had been given $50 out of the school's research budget to get the job done.

He returned the next day, expecting the job to be done. "Sorry," said the foreman. "We're still working on it. Try next week." Finally the day came, and our friend got his cube. It looked very, very smooth and shiny and beautiful in its velvet case. Seeing it, our hero had a premonition of disaster and became a bit nervous. But he summoned up enough courage to ask for the bill. "$500, and cheap at the price. We had a terrific job getting it right -- had to make three before we got one right."

"But--but--my friend paid only $35 for the same thing!"

"No. He wanted a cube 2.1 cm on an edge, and your specifications called for 2.097. We had yours roughed out to 2.1 that very afternoon, but it was the precision grinding and lapping to get it down to 2.097 which took so long and cost the big money. The first one we made was 2.089 on one edge when we got finshed, so we had to scrap it. The second was closer, but still not what you specified. That's why the three tries."

"Oh!"[1]

So, what do you think? Are sig figs important for communicating information about precision?

[1] http://dbhs.wvusd.k12.ca.us/webdocs/SigFigs/SigFigsFable.html

 Name__________________________ Section_______

Experiment 1 Turn-in Sheets

Scientific Measurements: Precision and Accuracy

You will be graded on the number of digits used, the presence of units on your measurements, and explanations.

Use a pen to record all measurements!!!

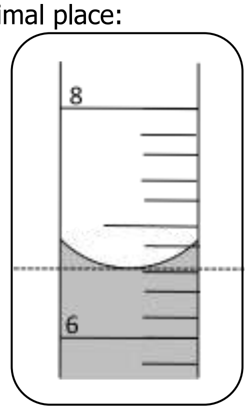
1) Take out a 10-ml graduated cylinder.

Check to see whether your graduated cylinder is calibrated to every 0.1 mL or every 0.2 mL.

My 10-mL cylinder is calibrated

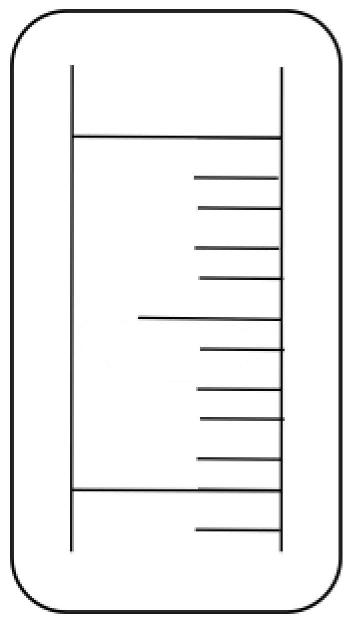
to every ______ mL.

Since the graduations are every tenth (or two tenths) you should try to report your volume to two decimal places. If your graduated cylinder has 0.2 mL graduations, use the following example to estimate the second decimal place:



With certainty, you can see the liquid is slightly above 6.6 mL. The bottom of the meniscus sits just above 6.6 mL.
Let's approximate that the liquid is 1/10 (0.1) of the distance between the graduations 6.6 and 6.8 mL.
Since each graduation is 0.2 mL, 0.1 x 0.2 mL = 0.02 mL.
Add this to your certain digits:
6.6 mL + 0.02 mL = 6.62 mL.
6.62 mL should be recorded.[2]

Place about 5-6 ml of water into your 10-mL cylinder and make a sketch of it below, with **at least two labeled graduations** (as in the previous drawing). Be as accurate in your drawing as possible.



Report your measurement with the correct number of significant figures here (Don't forget units!):

____

[2] http://jchemed.chem.wisc.edu/JCESoft/Programs/VideoCD/CPL/Sample/Modules/gradcyl/grad10mL.htm

2) Now find a small plastic ruler and measure your pencil.
Always use the smallest graduations on your instrument when taking a measurement

Length (cm) = ______________________

Length (mm) = ______________________

Make sure the number of significant figures are the same whether you measure in cm or mm.

Obtain a meter stick and record the length in meters.

Length (m) = ______________________

Does your measurement have a different precision when you use a meter stick? **Explain**.

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3) Obtain a penny. Use the balance to measure the mass of the weight. With a digital balance, always record every digit the balance displays. Record units.

Mass _________________

Now measure several other pennies and note their masses. Based on your observations, how many decimal places does this balance report?

____

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4) If you measured the mass of an object on the balance from question 3 and got a reading of 120.1 g would this be correct? **No**, your balance measures more sig figs than that. The balance just doesn't show trailing zeros like it should. Always report the correct sig figs despite the fact that the balance doesn't always show the zeros at then end. Always include units.

Correctly reported mass should be = __________ g instead of 120.1 g

Is there a difference in reporting 120.1 g versus 120.10 g? Explain how the meaning of the measurement changes.

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5) Take out a 50-ml beaker and examine its graduations. Complete the following statements:

The 50-ml beaker is graduated every _____ mL.

Since we estimate one decimal place more than the level of graduation, the

measurement should be recorded to every ______ mL.

Add approximately 15 ml of water to your beaker, using the graduations on the beaker.

Measure the volume of this water using the beaker and record it below.

_______________ mL (using a 50-mL beaker)

How many significant figures can you report based on the graduations? ________ sig figs

Which digit contains the uncertain value? Circle the digit above that was estimated.

6) Now take the contents of your beaker (the 15 mL of water) and pour it into a 100-mL graduated cylinder. Thinking about what you learned earlier (looking at the graduations), record a measurement for the volume of water.

_______________ mL(using a 100-mL graduated cylinder)

7) Which do you think is more ***accurate***, the volume measurement using the beaker or the graduated cylinder? How could you test this?

8) Which is more ***precise***, the volume measurement using the beaker or the graduated cylinder? Explain.

9) Given a choice, which glassware would you use to measure volumes more precisely, a graduated cylinder or a beaker? Explain.

10) Suppose a 10-mL pipet has an uncertainty of about ± 0.01 mL. If it is filled with to the mark (10-mL), the volume should be reported as (include the necessary decimal places):

_______________ mL

11) Many times you'll come across a new piece of lab equipment and need to determine its precision. What would you look at to determine the precision of a piece of glassware?

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When finished, clean up. Make sure your glassware is put away. Help your instructor by checking and tidying up the common areas near the balance.

***Go back and check all of your measurements. Did you include units?

Mark any questions you had trouble with, and ask your classmates or your instructor about them before you leave.

Fill this out after you have cleaned your station and before you ask your instructor to sign:

BCC Chemistry 161 Name__________________________

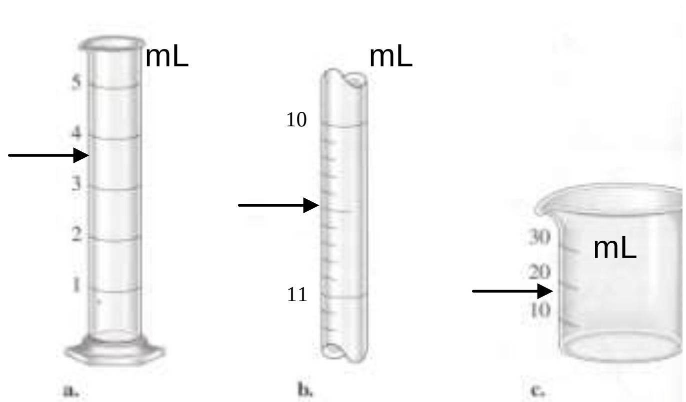
Section_______

Experiment 1 Scientific Measurements: Precision and Accuracy

Pre-Lab Assignment—To be completed BEFORE lab!

<u>To answer the following questions, make sure you have read the BACKGROUND section of this lab!!!</u> For more information and a review on measurements and significant figures, try reading the section on significant figures in the Appendix in your textbook.

1) Provide a measurement for each of the following pieces of glassware filled to the level indicated by the arrow. Use the correct number of significant figures in your answer. Always use units. **Remember to estimate one digit more than the level of graduation.**



________ ________ ________

Which gives the most precision, the graduated cylinder (a), the buret (b), or the beaker (c)? How can you tell by simply looking at the glassware?

2) On the back of this sheet, sketch two pieces of glassware: one that can ***report*** volume to the thousandths place and one that can ***report*** volume only to the ones place. ("Report" means to record the digits including your estimation.)

   HINT: A common *mistake* is to draw devices graduated to the thousandths or ones place—don't do this!

3) A student performed an analysis of a sample for its calcium content and got the following results.

   14.92 g 14.91 g 14.88 g 14.92 g

   (The actual amount of calcium in the sample is 20.90 g)

   How accurate are the student's results? How precise are the results? Explain briefly.