ALE 1. Uncertainty in Measurement

CHEM 161 – K. Marr

Name ______________________________

Team No. ________ **Section** _________

How can one determine the uncertainty in a measured value?

Welcome to CHEM 161! In this class, you will work in small groups in order to learn course content as well as develop the general skills of problem solving, communication (both written and verbal), time management, and how to work effectively with your peers.

I have more-or-less randomly determined who your teammates will be. You should begin by learning who your teammates are.

Exercise A: ♬ "Getting to know you . . ." ♬

Spend a couple of minutes introducing yourselves to each other. In addition to your name, tell your teammates: (1) what your major is (or just say whether you think you're interested in one of the sciences if your major is now "undeclared"); (2) what year you are in at GRCC ("freshman", "sophomore", *etc*.); and (3) what your initial impression of Chemistry is and why.

Exercise B: Role playing

To help your team work efficiently and smoothly each class session, you will have an assigned role. Each role within a team is vitally important to the team's success (*i.e.*, to learn chemistry), but not everyone within the team will have the same "job description". How are the team roles alike? You will all be active participants in the learning process. How are the team roles different? Let's find out!

Your instructor will explain how you can find out what each of your roles is for today's session. Next, read the below table.

Title	Duties
1. Manager	Actively participates in team discussions, keeps the team on task, distributes work and responsibilities, resolves disputes, assures that *all* team members participate and understand the activity the team is working on
2. Recorder	Actively participates in team discussions and keeps a written record of the team's work by completing in the "***Recorder's Report***" as the team formulates responses while working collaboratively on an activity in class.
3. Spokesperson	Actively participates in team discussions, communicates to the other teams orally or in writing (*e.g.*, on the classroom's whiteboard), represents the team when interacting with the instructor and other teams in the classroom. If *anyone* on the team has a question for the instructor, for another team, the class etc., the spokesperson asks it.
4. Strategy Analyst	Actively participates in team discussions, reflects on the team's performance by assessing whether they are using their time effectively or if they ought to adopt a different strategy; identifies what the team is doing well, what needs improvement, and insights and discoveries individual and team performance by completing the "***Strategy Analyst's Report***" and/or coordinates the completion of the "***Weekly Student Evaluation***" form.

To the best of your ability, in your own words (but you may refer back to this sheet if you need to) tell each other what you perceive is your job. Each of you should respond, adding to your teammates perceptions, clarifying, even disputing if need be.

It will take you a while to become comfortable with what each of these roles entails—perhaps even more time to get comfortable playing out each of these roles. But practice is the key, so let's get started! *Review the following* ***Model*** *and then answer the* ***Key Questions*** *and* ***Exercises*** *that follow the model.*

The Model: Uncertainty in Measuring Length

(Reference: Section 1.6 in *Silberberg 5th ed.*)

The number of digits, i.e. significant figures, reported for a numerical quantity conveys the quality of the measurement or analysis to the reader. In any business involving numerical values, the ***precision*** of these values, which is represented by the number of digits, is vital information. In this course and in others, you will have to use a meaningful number of digits in reporting your results. Laboratory measuring instruments have their limits, just as your senses have their limits. One of your tasks, in addition to learning how to use various measuring instruments properly, will be to correctly determine the precision of the measuring devices that you use in the lab.

Distances are normally measured with a meter stick or ruler. The limit of accuracy of a meter stick is indicated by how "precisely" you can read the length on the meter stick's scale—that is, how well you can estimate the fractions of degrees between the marks. On the portion of the meter stick shown in Figure1, the distance between the closest marks is 0.1 cm. The dotted line to the right of the meter stick is at a length of 6.65 cm. The last decimal place, the hundredth's place, in the measurement is estimated. Here is the key for determining the precision of most measuring devices:

You can usually estimate to only one decimal place beyond the closest marks on any measuring device!!

On the ruler in figure 1, the closest marks are 0.1 cm apart, so you can estimate to the hundredths place, 0.01 cm. However, when looking at a metric ruler in the real world, the smallest marks (i.e. millimeter marks, mm) are so close that it is all we can do just to determine that the dotted line is between two of them—about half way. Therefore, your best estimate of the position of the dotted line is 6.65 centimeters. We can say that the measuring instrument is readable to ±0.05 cm. The ±0.05 cm means that your measurement may be off by as much as 0.05 cm above or below its true value. This value is called the ***uncertainty or the precision*** of the instrument.

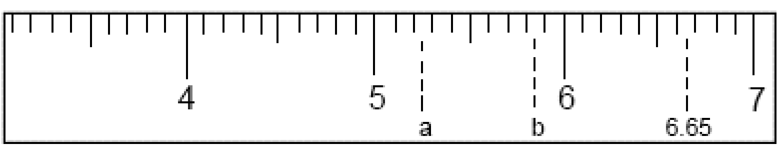

Figure 1. A *portion* of a metric ruler (the centimeter scale has been enlarged for ease in reading)

Key Questions

1. What is the smallest scale increment of the ruler shown in fig. 1, above?

2. What distance is represented by dotted line “a” in Figure 1? How much uncertainty is there in this measurement?

3. What distance is represented by dotted line “b” in Figure 1? How much uncertainty is there in this measurement?

Exercises (Use units and the correct number of “significant figures” for all numerical answers!)

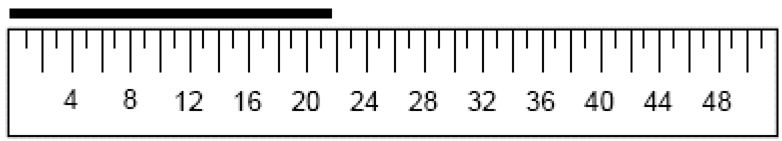

Figure 2. A centimeter ruler (the scale has been enlarged for ease in reading)

4. What is the smallest scale increment of the ruler shown in fig. 2, above?

5. What is the length of the line above the centimeter scale in Figure 2, above? How much uncertainty is there in this measurement?

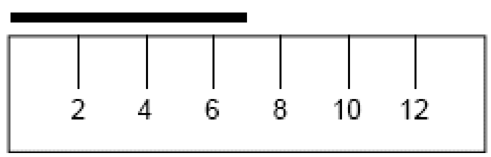

Figure 3. The "Slurp" Scale

6. What is the smallest scale increment of the ruler shown in fig. 3, above?

7. What is the length of the line above the "Slurp" scale in Figure 3, above? How much uncertainty is there in this measurement?

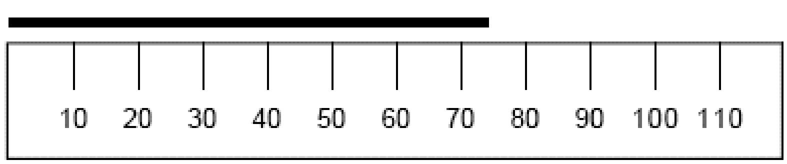

Figure 4. The "Klump" Scale

8. What is the smallest scale increment of the ruler shown in fig. 4, above?

9. What is the length of the line above the "Klump" scale in Figure 4, above? How much uncertainty is there in this measurement?

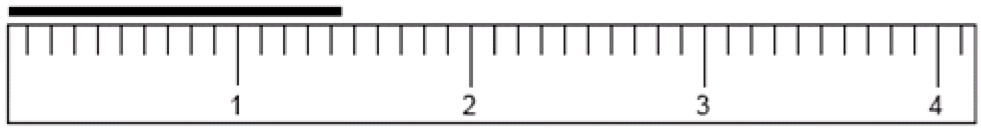

Figure 5. The "Glip" Scale

10. What is the smallest scale increment of the ruler shown in fig. 5, above?

11. What is the length of the line above the "Glip" scale in Figure 5, above? How much uncertainty is there in this measurement?

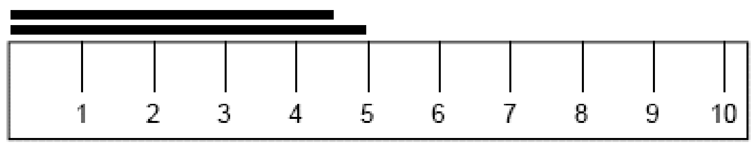

Figure 6. The "Zorch" Scale

12. What is the smallest scale increment of the ruler shown in fig. 6, above?

13. What is the length of the *short* line above the "zorch" scale in Figure 6? What is the uncertainty of this measurement?

14. What is the length of the *long* line above the "zorch" scale in Figure 6? What is the uncertainty of this measurement?

Using a Metric Ruler

15. Get a metric ruler or meter stick. What is the length (in cm) between the closest marks on your measuring device?

16. To what decimal place is your measuring device precise to?

17. What is the length of this page in cm?

18. What is the width of this page in cm?

19. How much uncertainty (in cm) is there in your measurements?

The Model: Uncertainty in Measuring the Volume of a Liquid

In the chemistry laboratory the volume of a liquid is normally measured in liters (L) or in milliliters (mL). Almost every lab activity you will be doing throughout this course involves measuring volumes. A graduated cylinder is often used to measure the volume of liquids in the lab.

Many liquids in a graduated cylinder have cohesive properties. This means the particles (i.e. molecules) of the liquid have a tendency to stick to each other. There is also an adhesive property of most liquids to glass, meaning unlike particles (liquid and glass) stick to each other. These two properties (adhesion and cohesion) combine to cause a liquid to "climb" the walls of a graduated cylinder and form a bend or dip on the surface of the liquid. This dip is called the ***meniscus***.

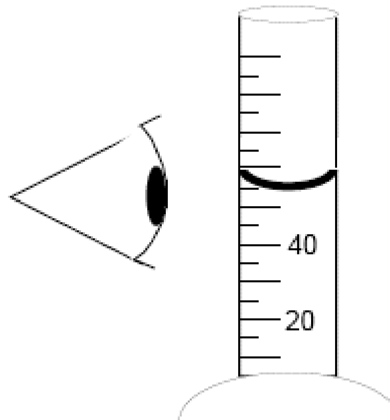

Figure 7. Reading a meniscus

To read a graduated cylinder, set the cylinder on a level surface and bring your eye even with the liquid level. Most liquids form a curve that goes down in the center of the cylinder. This curve is called the meniscus. Read the level of the liquid at the lowest point of the meniscus—i.e. Read the scale where the bottom of the meniscus rests.

Key Questions

20. What is the smallest scale increment of the graduated cylinder shown in fig. 7, above?

21. What is the volume of liquid in the graduated cylinder in fig. 7, above? How much uncertainty is there in this measurement?

Exercises

22. What is the scale increment for the 100 mL graduated cylinder in figure 8?

23. What is the volume of water in the graduated cylinder in fig. 8? How much uncertainty is there in this measurement?

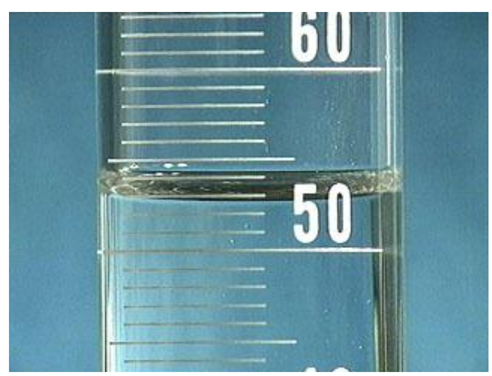

Figure 8. Water in a 100 mL graduated cylinder

24. What is the volume of water in the 100 mL graduated cylinder in fig. 9? Use table 1 on the next page to determine how much uncertainty this measurement has.

Figure 9. Water in a 100 mL graduated cylinder

25. What is the scale increment for the 10 mL graduated cylinder in figure 10?

26. What is the volume of 0.20 M HCl in the graduated cylinder in fig. 10? Use table 1 on the next page to determine how much uncertainty this measurement has.

Figure 10. 0.20 M HCl (hydrochloric acid) in a 10 mL graduated cylinder

27. What is the scale increment for the burette in figure 11?

28. If the initial volume of 0.10 M NaOH in the burette in figure 11 was zero mL, what volume of solution was delivered? Use table 1 on the next page to determine how much uncertainty this volume has.

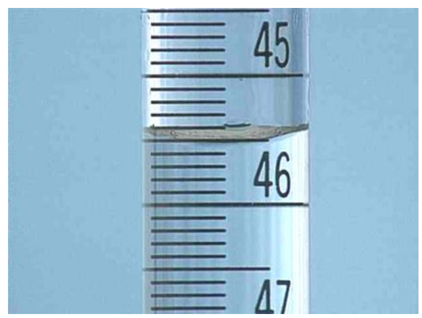

Figure 11. 0.10 M NaOH (Sodium hydroxide) in a 50 mL burette

29. Carefully examine table 1 and figure 12 on the following page. Which glassware would you use to measure out … (justify your response in each case)
   a.) 25 mL of an aqueous solution as precisely as possible.

   b.) About 35 mL of deionized water to wash a precipitate on filter paper inside a funnel.

   c.) 38 mL of an aqueous solution as precisely as possible.

   d.) About 7 mL of an aqueous solution.

Table 1. Typical uncertainties of volumetric glassware commonly used in the chemistry laboratory.

Glassware	Volume (mL)	± Uncertainty (mL)	Uncertainty as % of Volume
Volumetric Pipettes (deliver a fixed volume)	1.00 10.00 25.00	0.006 0.02 0.03	0.60 0.20 0.12
Volumetric Flasks (contain a fixed volume)	100.00 250.00 500.0	0.03 0.12 0.2	0.03 0.05 0.04
Burette	0.00 to 50.00	0.03	Varies
Erlenmeyer Flasks	100 250	5 10	5 4
Beaker	50 100	5 5	10 5
Graduated Cylinders	10.0 100.0	0.1 0.5	1 0.5

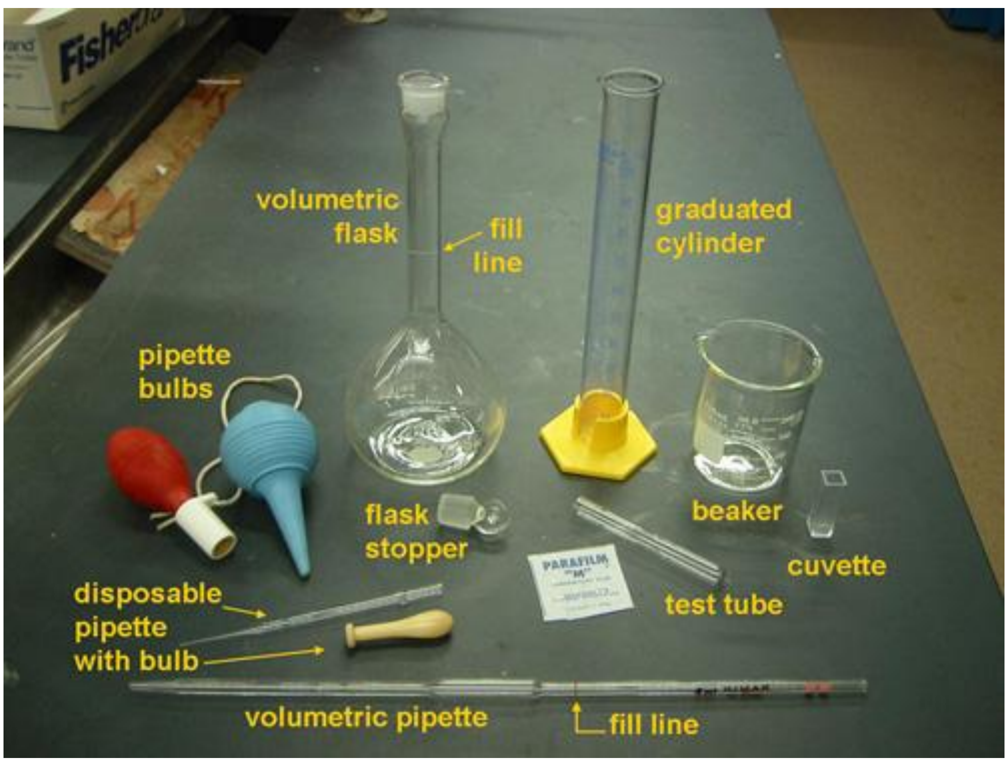

Figure 12. Common laboratory glassware used to measure, deliver and contain liquids.