CHM 130

Measurements, Significant Figures, Derived Quantities,

**and Unit Conversions**

Objectives

1. Use measuring tools correctly

2. Read and record measurements correctly (significant digits and unit)

3. Associate metric units with the quantities being measured

4. Determine the density of a solid

Introduction

Chemistry is an experimental science. It depends on careful observation and the use of good laboratory techniques. In this experiment you will become familiar with some basic operations that will help you throughout the course. Your success in future experiments will depend upon your mastering these fundamental operations. Because every measurement made in the laboratory is really an approximation, it is important that the numbers you record reflect the uncertainty of the device you are using to make the measurement. The assumption is made in this course that an uncertainty of at least one unit exists in the last digit.

10.01 mL could actually be 10.00 mL or 10.02 mL

## Significant Figures and Metric Conversions

Significant figures are important in describing the accuracy and reliability of a measurement. The following rules, which you should have covered in lecture, will help you determine the number of significant figures in a measurement.

1. All nonzero digits are significant. 3.467 cm has 4 sig figs

1. Zeros between nonzero digits are significant. 2.07 mL has 3 sig figs
2. Zeros preceding the first nonzero digit in a number are not significant. 0.0341 g has 3 sig figs
3. Zeros beyond the decimal point at the end of a number are significant. 6.00 mL has 3 sig figs
4. Zeros at the end of a number with no decimal point shown are ambiguous. 2300 has 2, 3, or 4 sig figs
5. The number of sig figs is the number of digits shown when the number is written in scientific notation.

500 g written expressing 3 sig figs would = 5.00 x 102 g

500 g written expressing 2 sig figs would = 5.0 x 102 g

500 g written expressing 1 sig fig would = 5 x 102 g

**Units**

In science the metric system is used almost exclusively. The basic unit of length is the meter (m); of mass, the gram (g); of volume, the liter (l). The meter, the gram, and the liter are related to larger and smaller units by multiples of 10. Prefixes are used for the unit of measure expressing these multiples of 10.

## Exact Numbers and Conversion Factors

Some numbers by their very nature are exact numbers. When you say you are holding five beakers in your hand, you mean exactly five beakers, not six or four. Thus, if this figure 5 is used in a calculation, you may regard it as having as many significant figures as desired: 5.0000… (an unlimited number). Another example of an exact number is a number used to relate quantities (conversion factors) within the same system of units: 1.0000… m = 100.0000… cm. These are defined values and possess an unlimited number of significant figures.

**Calculations with Measured Values**

Often a measured value must be converted into a different unit, or combined with other measured values to calculate a final answer. It is important to understand the rules for dealing with significant figures in a calculation.

**Addition and Subtraction**

The answer to an addition or subtraction problem must be rounded to the correct place value or decimal place, based on the least accurate value used in the calculation.

*For Example:*

$$79.95 + 78.151 – 56.19 = 101.911 =101.91$$

 *79.95 has 2 decimal places (hundredths place)*

 *78.151 has 3 decimal places (thousandths place)*

*56.19 has 2 decimal places (hundredths place)*

*The final answer must be rounded to 2 decimal places (hundredths place)*

# Multiplication and Division

The answer to a multiplication or division problem must be rounded to the correct number of total significant digits, based on the number with the fewest total significant digits used in the calculation.

*For Example:*

$$\frac{621\*6.773}{12.1}=347.606=348$$

 *621 has 3 significant digits*

* 1. *has 4 significant digits*

*12.1 has 3 significant digits*

*The final answer must be rounded to 3 significant digits*

# Combined Calculations

Often a calculation requires using both rules above in the same problem. The calculation must be completed in steps, with the correct decimal place or total digits determined before moving on to the next step of the calculation. It is important that the answers are not rounded at each step, only at the very end, to avoid rounding errors.

*For Example:*

$$\frac{(62.18 + 9.713)}{24.4}= \frac{\overline{71.89}3}{24.4}=2.94643=2.95$$

 *62.18 has 2 decimal places (hundredths place)*

 *9.713 has 3 decimal places (thousandths place)*

 *The answer to step 1 of the calculation 71.893, is only accurate to 2 decimal places (hundredths place).*

 *71.893 really has 4 significant digits, the underline is used to indicate the significant digits*

 *24.4 has 3 significant digits*

 *The answer to step 2 of the calculation, must be rounded to 3 significant digits*

**Some Exceptions**

When the numbers in a calculation come from a measured quantity, the final answer to the calculation cannot show more accuracy than the original measurements. This is often encountered when computing an average.

*For Example:*

$$\frac{(6.563+6.545+6.542)}{3}= \frac{19.650}{3}=6.550$$

 *6.563, 6.545 and 6.542 are all accurate to 3 decimal places (thousandths place)*

*Even though the answer to step 1 of the calculation has 5 significant digits, the final answer must be rounded to reflect the accuracy of the original measured values, 3 decimal places (thousandths place)*

# Mass

The directions in this experiment are written for use with a digital pan balance. Our balances at SCC are very accurate, giving a mass measurement to the thousandth place (0.001 g or 1 mg). This is considered the precision of the balance. Even though this is a digital instrument, the balance is making an estimate at the thousandths place. All measurements recorded in your data sheet should reflect this degree of precision. When using the analytical balance please be gentle with these sensitive instruments and use the following procedures:

1. Before placing your item to be massed on the balance check the display to make sure it is reading zero. If not press the tare bar once to zero out the balance.
2. Carefully place the item on the pan and close all of the doors on the balance.
3. Allow sufficient time for the mass to be measured.
4. Record the mass, remove the item.
5. Never place chemicals directly on the balance pan; first place them on a weighing boat or in a container and then place the boat or container on the balance pan.
6. Clean up any materials you spill on or around the balance.
7. Never make any adjustments to the balance. If it seems out of order tell your instructor.

## Length – metric ruler

The standard unit of length is the meter (m), which is approximately 39.37 inches in length. The metric rulers you will be using in lab are 30.48 cm in length, which is 12 inches. Since you can estimate the measurement to the hundredths place with these rulers, all measurements recorded in your data sheet should reflect this degree of precision (0.01cm).

**Volume**

The graduated cylinder is the device you will be using in lab to measure liquid volumes. Graduated cylinders are tall, cylindrical vessels with graduations scribed along the side of the cylinder. Since volumes are measured in these cylinders by measuring the height of liquid, it is crucial that the cylinder have a uniform diameter along its entire height, which is the case with the glass cylinders you are using in lab. The precision for a graduated cylinder can be determined by taking the distance between markings on the cylinder and dividing by 10.

Beakers and flasks are marked to indicate only approximate volumes and should not be used to measure volumes during experiments.



When measuring a volume in a graduated cylinder, read the point on the graduated scale that coincides with the bottom of the curved surface, called the meniscus, of the liquid. Volumes measured in the graduated cylinder should be estimated and recorded to the correct number of significant figures. For the cylinder shown at right, the correct volume is 56.0mL



The volume of a solid object can also be measured using the graduated cylinder by water displacement. Fill a graduated cylinder with enough water that it will completely cover the solid object when it is placed into the cylinder. The difference between the measured volume of water before and after adding the solid object is the volume of that object.

Volume initial = 4.80mL

Volume final (w object) = 5.60mL

Volume of object = Vfinal – Vinitial = 5.60mL – 4.80mL = 0.80mL

**Procedure:**

Record all data on the Report sheet. The report sheet corresponds to the procedure in letter and number. You will be graded based on accuracy of the values recorded, accuracy expressed in the correct number of significant figures in your measurement and neatness in presentation of the lab report.

Traditionally a pen is used to record data in the laboratory. If you make an error in recording your data simply draw a single line through your mistake and rewrite it correctly.

1. **Mass**

\*\*\* **Note**: you should always use the same balance throughout an experiment \*\*\*

1. Describe the precision of the top loading pan balance.
2. Weigh 5 pennies separately and record the mass of each on your Report sheet. To weigh the pennies, use a small beaker as a container on the balance. When you initially place the beaker on the balance pan, tare (i.e. re-zero) the balance – the display should go back to 0.000 g. By taring the beaker on the balance pan, you have essentially made the beaker a part of the balance pan. The reason we are using the beaker as a container is that pennies are difficult to remove directly from the balance pan, and you could damage the balance if you put too much pressure on the pan. A beaker is easier to lift off the balance pan than a penny is. To weigh a penny, lift the tared beaker off the pan, add the penny, then carefully place the beaker back on the pan.
3. On your Report sheet, add the 5 masses and record the total mass.
4. Weigh all 5 pennies together and record the mass. Compare this value to the total from Step 3.
5. Based on your measurements, calculate the average mass of a penny.
6. **Volume and Density**
7. Describe the precision of your 50-mL graduated cylinder.
8. Fill the 50-mL cylinder with about 20 mL of water. Read and record the initial volume on your Report sheet. Be sure to read the cylinder to the correct number of decimal places (i.e. to the correct precision).
9. Carefully add your 5 pennies to the water in the cylinder. Read and record the final volume on your Report sheet.
10. Calculate the total volume occupied by your 5 pennies.
11. Calculate the density of the pennies.
12. **Length and Area**

Using a metric ruler, make the following measurements in centimeters.

1. Describe the precision of the metric ruler.

1. Compute the area of the triangle shown on the Report sheet using each of the 3 sides as the base.

**Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Section \_\_\_\_\_\_ Lab Partner \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

Report– Measurements

Read the appropriate section of the lab introduction or procedure before starting each section.

1. Mass

Before you get started, what is the precision of our top loading pan balances? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ g

|  |  |  |
| --- | --- | --- |
| Trial | Mass of penny (in g) | Total mass of 5 pennies measured together: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ gAverage mass in grams of 1 penny (show calculation): |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |
| Sum |  |

Questions:

A1) The sum of the masses of each penny is probably slightly different than the mass of the 5 pennies measured together. Why do you think this is?

1. Volume and Density

Before you get started, what is the precision of your 50-mL graduated cylinder? \_\_\_\_\_\_\_\_\_\_\_ mL

1. Initial volume of water in the cylinder \_\_\_\_\_\_\_\_\_\_ mL

2. Volume of water in the cylinder after addition of 5 pennies \_\_\_\_\_\_\_\_\_\_ mL

3. Volume of 5 pennies \_\_\_\_\_\_\_\_\_\_ mL

 Questions

B1) Using your mass data from Part A (all 5 pennies together) and your volume value for 5 pennies, compute the density of the alloy used to make pennies, in units of g/cm3. Note that 1 mL = 1 cm3 exactly, so these units may always be interchanged.

1. Length and Area

1. What is the precision of the metric ruler? \_\_\_\_\_\_\_\_\_\_\_ cm

2. Compute the area (Area = ½ base \* height) of the triangle shown below using each of the 3 sides as the base. To find the height, you must draw a line that is perpendicular (90˚ angle) to the base and intersects the corner opposite the base (see diagrams below). If you have drawn all three height lines correctly, they should intersect at a single point.

 C

 A B

|  |  |  |  |
| --- | --- | --- | --- |
|  | Base AB | Base AC | Base BC |
| Length of base (cm) |  |  |  |
| Height from base (cm) |  |  |  |
| Area (cm2)(full calculator readout) |  |  |  |
| Area (cm2)(rounded) |  |  |  |

 Show your calculations for at least one of your area determinations. Watch units and significant figures.

 Questions

 C1) If all of your measurements for the triangle had been perfect, what should have been true about all the area values you calculated? Which of your area calculations – the full readouts or the values corrected for sig figs – do you think are more reliable, and why? Why do we use significant figures when reporting a derived quantity, such as area or density?

 Extra Questions:

1) Solve each of the following problems. Report the final answer to the correct significant figures. Show your work.

|  |  |  |
| --- | --- | --- |
| $$\frac{923.0 g}{20312 cm^{3}}= $$ | $$1.23x10^{4} m\*8.9x10^{-2} m=$$ | $$7.987 cm-0.54 cm=$$ |
| $$34.530 g+12.1 g+1222.34 g=$$ | $$\frac{23.5-21.3}{1.58x10^{-5}}=$$ | $$\frac{4.83}{2.4+9.8}=$$ |
| The mass of a watch glass was measured four times. The masses were 99.997 g, 100.008 g, 100.011 g, and 100.005 g. What is the average mass of the watch glass? | If the beaker containing a sample of alcohol weighs 49.876 g and the empty beaker weighs 49.214 g, what is the weight of the alcohol? |

2) Report how many significant figures each of the following numbers has and then write the number in standard scientific notation.

|  |  |  |
| --- | --- | --- |
|  Number | Number of Significant Figures | Standard Scientific Notation |
| 0.0000620 |  |  |
| 0.05600 |  |  |
| 70820.0 |  |  |
| 309100 |  |  |

Conversion Factors: 1000 g = 1 kg 453.6 g = 1 lb 12 in = 1 ft 2.54 cm = 1 in

2) Convert 52.30 grams to kilograms. Show your work

3) Convert 52.30 cm to in. Show your work.

4) Compute the average area of the triangle in Part C. Show your work.

5) Convert the average area of the triangle in Part C to units of m2. Show your work, organized with units.

6) Convert the average area of the triangle in Part C to units of ft2. Show your work, organized with units.

7) Convert your density of penny metal from Part B to units of lb/ft3. Show your work, organized with units.