Lab Session 2, Experiment 1: Introductory Exercises

These experiments are meant to provide your first experience in the laboratory. If you have prior laboratory experience, these exercises constitute good review. Conduct the experiments in whatever order seems convenient. Keep all results to show to your instructor before you leave, or if requested, to turn in on the separate Report Form.

Weighing

You must learn how to use laboratory balances. As always, the *limit* of readable precision of the scale should be recorded.

When approaching the balance you will need the following:
1. The substance to be weighed;
2. Any container or holder for the sample while on the balance;
3. Any sample handling device such as a spatula; and
4. Your notebook and a pencil or pen to record your measurement.

Balances in this laboratory have a semi-automatic tare (an allowance for mass of the container or holder). On an electronic balance, "tare equals zero" is set by depressing the bar, which is also the on/off switch: up for off, down for on, down again to tare. These balances have an automatic range selector that will change the readout precision automatically to ± 0.01 g when the gross mass on the pan is over 35 g. The measurement precision for small masses is best if very light containers are used, such as the glassine weighing paper for dry solid samples. The precision for samples less than 30 g gross mass is ± 0.001 g.

1A Experiment: Mass

1. Select five pennies from your resources. Include a new shiny one if possible. Dates are useful for keeping them in order.
2. Without taring, place a sheet of paper on the pan. Read and record its mass in the table on this page. When possible, use the cover to protect the pan from air drafts to obtain higher precision.
3. *Add* the pennies to the pan one at a time, reading the mass after each addition. Enter each in the table below in the column entitled "Cumulative Mass." Keep the pennies in order. Calculate the mass of each penny by subtracting; record the differences in the column entitled "Mass by Difference."
4. Remove all the coins and weigh each individually, taring to zero. Record the mass of each coin in the table in the column entitled "Direct Weighing."
5. Calculate the mean or average mass ($\overline{m}$) of the pennies: $\overline{m} = \left(\sum m\right)/n$.
6. Calculate the absolute deviation ($d = |\mathrm{m} - \overline{\mathrm{m}}|$) from the mean of each mass (direct weighing) and then determine the Average Deviation: $\overline{d} = \left(\sum d\right)/n$.

Source	Cumulative Mass	Mass by Difference	Direct Weighing	Deviation from Mean
Weighing Paper	g			
1st penny	g	g	g	g
2nd penny	g	g	g	g
3rd penny	g	g	g	g
4th penny	g	g	g	g
5th penny	g	g	g	g
		Average:	g	g

Consider two hypotheses:

1. All Lincoln-head pennies are manufactured with equal mass (within ± 0.001 g), but their various histories result in different masses when measured.
2. New Lincoln-head pennies are lighter than older ones.

Observation is complicated by the various histories of the pennies. Some typical problems in chemistry are illustrated here. Most obviously, the state of corrosion of the pennies represents an uncontrolled experimental variable which can be important. Had we used non-circulated coins, we would have expected better precision. On the other hand, pennies may not be very uniform even when new. Another question arises: How much experimental difference is sufficient and how consistently must it be observed for us to consider two data sets, or groups of data sets as distinctly different? This is an important question for which statistical methods provide answers. Which hypothesis do you choose, and why?

Density

Density is defined as the ratio of the mass of a sample to its volume. Mass and volume are extensive properties of matter -- properties that depend on the quantities of substances. Such properties are not of themselves useful in characterizing substances.

Intensive properties, on the other hand, are useful in characterizing substances. Intensive properties are often determined by ratioing two extensive properties measured at constant temperature (T) and pressure (P). Density is an example of this kind of intensive property. When measured under known conditions of T and P, density can be used to characterize substances. Of course, two or more substances may have the same density, but for a given substance there is only one density (at constant T and P). If you determine that a colorless liquid has a density of 1.00 g/mL at 4º C and 1 atm, this does not prove the liquid is water. This fact is simply one piece of evidence that the substance may be water.

1B Experiment: The Density of Water at Room Temperature

1. Collect a small beaker of deionized water and measure its temperature.

   T = ________________ ºC

2. Place a clean dry 10 mL graduated cylinder on the balance and tare it to zero. Carefully transfer nearly 10 mL (but less) of water into the cylinder, taking care not to splash water up on the sides (read the mass to ± 0.001 g).

   "Weight" = Mass of H_2O = _________________ g

3. Carefully read the volume occupied by the water at the bottom of the meniscus holding the cylinder at eye level. The volume should be read to ± 0.1 mL.

   Volume of H_2O = __________________ mL

4. Calculate the density of water at the current temperature, noting the number of significant figures.

   D = Mass of H_2O/volume of H_2O = _________________g/mL

5. Consult the Table of Water Densities (below) and calculate the percent error in your determination according to the following formula.

   %Error = $[|D_{TAB}-D_{EXP}|\div D_{TAB}]\times 100$ = _________________ %Error

Table of Water Density at Various Temperatures

T, ºC	D, g/mL	T, ºC	D, g/mL	T, ºC	D, g/mL
15	0.9991	20	0.9982	25	0.9970
16	0.9989	21	0.9980	26	0.9967
17	0.9987	22	0.9978	27	0.9965
18	0.9986	23	0.9975	28	0.9962
19	0.9984	24	0.9973	29	0.9960

1C Experiment: The Density of a Metal

Different metals are furnished for this determination, either as cylindrical rods or as pellets or shot. In this experiment, you will determine the mass of a metal sample and its volume, then calculate its density.

1. Start with a 10 mL graduated cylinder about half filled with H_2O. Read the volume of water in the cylinder. Volume of H_2O = ________________ mL
2. Put a cylindrical metal rod or a sample of metal pellets or shot into the water so that the entire sample is submerged. Read the volume occupied by the water and the metal. Obtain the greatest change in the water level consistent with having all the metal sample submerged with no bubbles adhered to the surface of the sample. You may have to thump or jostle the cylinder to get rid of bubbles.

   Volume of H_2O + Volume of metal = ________________ mL
3. The difference in the two volumes is the volume of the metal sample.

   Volume of H_2O + Volume of metal = ________________ mL
   – Volume of H_2O = ________________ mL
   = Volume of metal = ________________ mL
4. Thoroughly dry the metal pieces and weigh them. Use brown paper towels to absorb most of the water, then a hair dryer if available.

   "Weight" = Mass of metal = ________________ g
5. Calculate the density of the metal and pick the metal from the Table of Metal Densities (below). D = Mass of metal ÷ Volume of metal = ________________ g/mL

   Metal name ______________ Metal symbol ______

Table of Metal Densities (g/mL)

Metal	D, g/mL	Metal	D, g/mL	Metal	D, g/mL
Aluminum	2.70	Iron	7.87	Tin	7.29
Antimony	6.62	Lead	11.34	Titanium	4.51
Bismuth	9.80	Magnesium	1.74	Tungsten	19.30
Copper	8.94	Molybdenum	10.22	Zinc	7.13

1D Experiment: Length

1. While you are thinking about the precision of reading a balance, select a wooden splint and measure its length on the inch scale and the centimeter scale.

   Length = ________________ inches. Length = ________________ cm
2. Convert the length in inches to length in centimeters using the factor 2.54 cm/in. Pay attention to the significant figures in your results.

   Length in inches converted to length in centimeters = ________________ cm

Adjusting a Bunsen Burner

When selecting a burner, check to see that the gas needle valve on the bottom will close completely. Also check to see that the barrel of the burner will screw in and out so that the air supply to the flame can be controlled.

With the burner gas valve off and the hose connected to the burner and the bench gas cock (see Figure 2.1), turn the bench gas cock fully on and check for leaks around the burner with a match. With the air vents closed, open the burner gas valve and light the flame. The flame should be yellow and luminous.

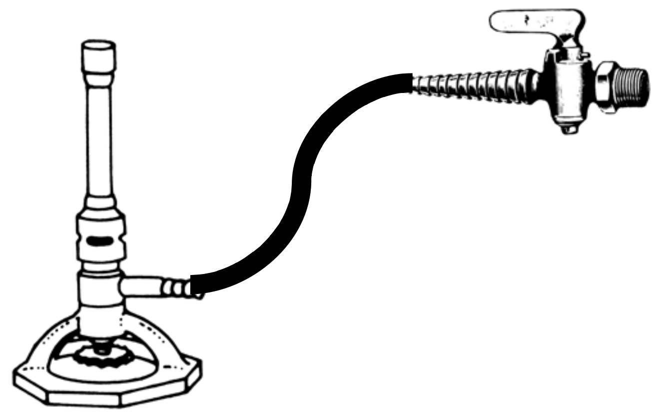

Figure 2.1

Stick a test tube into the flame briefly. You should observe a deposit of carbon black on the tube. When hydrocarbons such as methane [CH_4 (natural gas)] burns in too little air (oxygen), the reaction is:

$$CH_{4\,(gas)} + O_{2\,(gas)} \rightarrow C_{(sol)} + 2\,H_2O_{(liq)}$$

With a bit more air, the flame becomes hotter and blue, but carbon monoxide is formed:

$$2\,CH_{4\,(gas)} + 3\,O_{2\,(gas)} \rightarrow 2\,CO_{(gas)} + 4\,H_2O_{(liq)}$$

Now adjust the air supply -- you may also have to adjust the gas with the burner valve -- until the flame resembles Figure 2.2. This is the hottest flame and is characterized by a blue inverted cone shape within the flame that is the so-called reducing flame. A little above the apex of the cone is the hottest area in the flame, reaching temperatures around 1500ºC.

Figure 2.2

Towards the top of the flame, conditions are oxidizing (high temperatures, excess O_2). The well-adjusted flame completely converts methane and oxygen to carbon dioxide and water:

$$CH_{4\,(gas)} + 2\,O_{2\,(gas)} \rightarrow CO_{2\,(gas)} + 2\,H_2O_{(liq)}$$

1E Exercise: Understanding Flames

Take a wooden splint and hold it with its edge resting on the top of the burner. Notice how the splint is burned only on the edges of the flame. The flame under the cone is relatively cool (about 350 ^{o}C). Higher in the flame, the splint ignites uniformly. Show the splint to your instructor along with the rest of today's results.

To turn off the Bunsen burner, execute the lighting procedure in reverse. Shut the gas valve at the base of the burner, then close the close the bench gas cock.

Reactions and Separations

A very common and useful type of reaction is the double displacement reaction (also called a metathesis or exchange reaction). This occurs readily among ionic compounds in solution when two ions that form an "insoluble" salt are mixed. When the clear (not necessarily colorless) solutions are mixed, a solid forms that "falls out" of solution or precipitates. The solid that is formed, called the precipitate, may be separated from the remaining solution, which still contains the counter-ions of the two salts that formed the precipitate. Upon evaporation, the other more soluble product is recovered.

1F Experiment: Reactions and Separations I

Equal volumes of Na_2CO_3 and $CaCl_2$ solutions will be mixed. The concentrations of these solutions are such that equal volumes contain exact reacting quantities. The reaction is:

$$CaCl_{2\ (aq)} + Na_2CO_{3\ (aq)} \rightarrow CaCO_{3\ (sol)} + 2\ NaCl_{\ (aq)}$$

After mixing 5mL of each solution, note the formation of a white solid. Set up a filter as shown in Figure 2.3. Catch the filtrate (the solution which passes through the filter paper), which should be clear. Keep the precipitate that has been caught on the filter paper to show to your instructor. What is the formula of the precipitate caught by the filter paper?

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Set up an evaporating dish on a steam bath as shown in Figure 2.4 and evaporate a portion of the filtrate. Keep the residue in the evaporating dish to show to your instructor. Be sure you know what these compounds are.

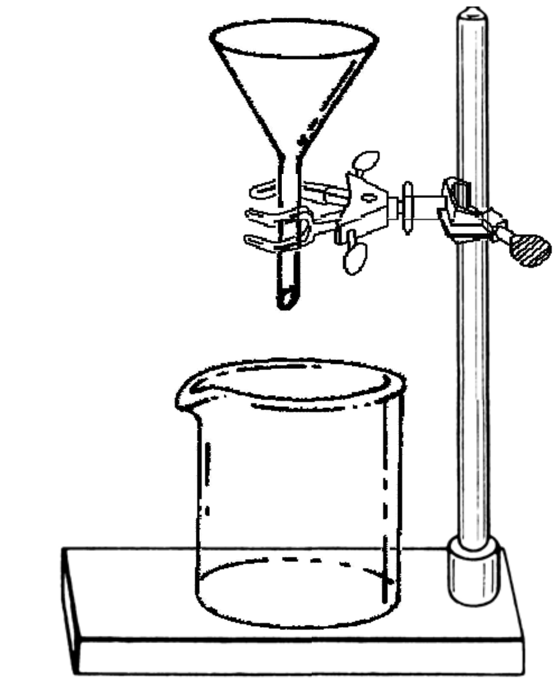

Figure 2.3

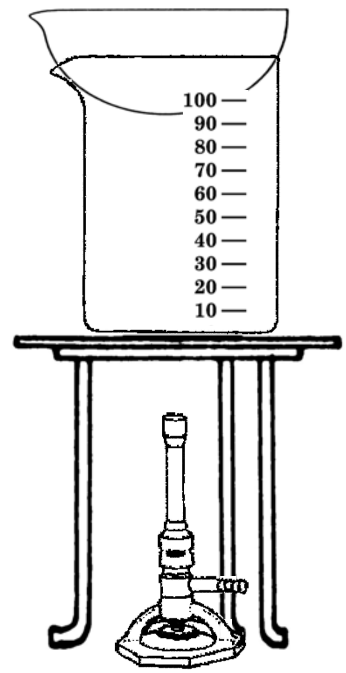

Figure 2.4

1G Exercise: Reactions and Separations II

Barium sulfate, $BaSO_4$ is very insoluble. Suppose solutions of $Ba(OH)_2$ and $H_2SO_{4\,(aq)}$ are mixed. Complete the equation below:

$$\_\_\_\_\_\_\ Ba(OH)_{2\ (aq)} + \_\_\_\_\_\_\ H_2SO_{4\,(aq)} \rightarrow \_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_$$

Report Form 1: Introductory Exercises

Name___________________________

Partner_____________Section #_____

Source	Cumulative Mass	Mass By Difference	Direct Weighing	Deviation From Mean
Weighing Paper	g			
1st penny	g	g	g	g
2nd penny	g	g	g	g
3rd penny	g	g	g	g
4th penny	g	g	g	g
5th penny	g	g	g	g
		Average:	g	g

1B Experiment: The Density of Water at Room Temperature

1. T=_______ ºC
2. "Weight" = Mass of H_2O = ______ g
3. Volume of H_2O = ______ mL
4. D = Mass of H_2O/volume of H_2O = ______g/mL
5. %Error = $[|D_{TAB}–D_{EXP}|÷D_{TAB}]×100$ = ______ %Error

1C Experiment: The Density of a Metal

6. Volume of H_2O = ______ mL
7. Volume of H_2O + Volume of metal = ______ mL
8. Volume of metal = ______ mL
9. "Weight" = Mass of metal = ______ g
10. D = Mass of metal ÷ Volume of metal = ______ g/mL

Metal name ______________

Metal symbol ____

1D Experiment: Length

11. Length = ______ inches Length = ______ cm
12. Length in inches converted to length in centimeters = ______ cm

1E Exercise: Understanding Flames

Show the splint to your instructor along with the rest of today's results.

1F Experiment: Reactions and Separations I

Keep the precipitate that has been caught on the filter paper to show to your instructor.
What is the formula of the precipitate caught by the filter paper? _________________________
Keep the residue in the evaporating dish to show to your instructor.

1G Exercise: Reactions and Separations II

______ $Ba(OH)_{2\ (aq)}$ + ______ $H_2SO_{4\ (aq)}$ → ______________ + ______________