The Tools of the Trade

Equipment

You will need a digital thermometer, a liquid thermometer, a 50 mL graduated cylinder, a 10 mL volumetric pipet, a 25 mL burette, a 250 mL beaker, a 150 mL beaker, a glass stirring rod, a scoopula or spoon (next to the NaCl), a cork ring and a ball bearing (next to a balance).

Chemicals

1 scoop of sodium chloride, crushed ice, water.

Introduction

Chemistry is an experimental science. One of the basic things we do during an experiment is to measure things. The results of these measurements allow us to find the answers to the questions we are trying to answer by doing the experiment.

In this laboratory experiment you will learn to use some of the tools that a chemist uses to make these measurements. The properties we commonly measure are mass, volume, and temperature.

Because there is always some error in any measurement we make, we always try to measure a value at least three times. By making at least three measurements we can estimate how accurate our measurements are (if we know what the true value of the property we are trying to measure is) and how precise our measurements.

Accuracy

Accuracy means how close the average of our measurements is to the true value. We calculate this using what is called **percent error**.

Suppose we measure the length of a table three times and get the following values ("m" stands for meters).

Measurement 1	Measurement 2	Measurement 3
1.743 m	1.738 m	1.746 m

If the actual length of the table is 1.745 m we calculate the percent error this way:

$$\text{Percent Error} = \frac{|\text{True Value} - \text{Average Value}|}{\text{True Value}} \times 100 \quad \text{(Equation 1)}$$

Note the absolute value bars!

The average value we got is:

$$\text{Average Value} = \frac{1.743\,\text{m} + 1.738\,\text{m} + 1.746\,\text{m}}{3} = 1.742_3\,\text{m} \quad \text{(Equation 2)}$$

and the percent error is:

$$\frac{|1.745\,\text{m} - 1.742_3\,\text{m}|}{1.745\,\text{m}} \times 100 = 0.2\% \quad \text{(Equation 3)}$$

Precision

Precision tells us how close together the measurements we made are to each other. Note that a set of measurements could be very precise (they are very close to each other) but not very accurate (their average is far from the true value).

The tool we use to measure precision in this class is called the **average deviation.** Each measurement has a deviation, and that is the absolute value of how far it is away from the average value.

$$\text{Deviation} = |\text{Value}_1 - \text{Average}| \quad \text{(Equation 4)}$$

For the measurements we made of the table earlier, the deviations are:

Deviation of measurement 1=$|1.743\text{ m} - 1.742_3\text{ m}| = 0.000_6\text{ m}$
Deviation of measurement 2=$|1.738\text{ m} - 1.742_3\text{ m}| = 0.004_3\text{ m}$ (Equation 4)
Deviation of measurement 3=$|1.746\text{ m} - 1.742_3\text{ m}| = 0.003_6\text{ m}$

The average deviation is just the average of these three deviations:

$$\text{Average Deviation} = \frac{\text{Deviation}_1 + \text{Deviation}_2 + \text{Deviation}_3}{3} = \frac{0.000_6\,\text{m} + 0.004_3\,\text{m} + 0.003_6\,\text{m}}{3} = 0.002_8\,\text{m} \quad \text{(Equation 5)}$$

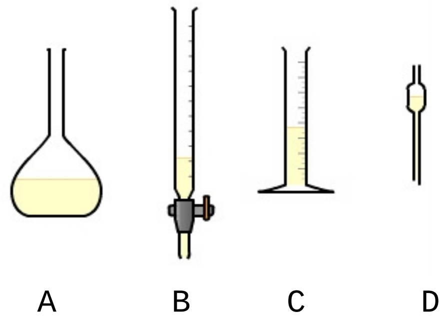
The smaller the average deviation is, the more precise that set of measurements is.

Mass

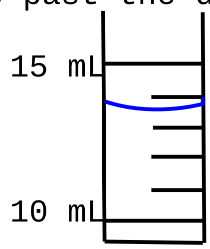
To measure mass we use a balance. Every balance in your laboratory measures mass in grams to 3 places past the decimal. **You must always write down three places past the decimal for any mass measurement you make in the laboratory.**

Volume

We have several devices we use to measure volume. These include a volumetric flask (A), a burette (B), graduated cylinder (C), and a volumetric pipette (D).



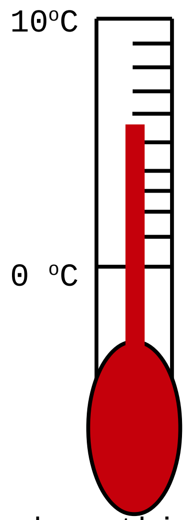
When reading the volume in containers B, & C, always write down one more place to the right of the decimal than the closest marks represent. For example, if the closest marks on a graduated cylinder are 1 mL apart, write down the volume in that graduated cylinder to the tenths place (1 place past the decimal).



Whenever you read the volume of a liquid in a column there will be a meniscus (the top of the liquid is curved). Always read the bottom of the meniscus. What volume is represented by the above drawing?

Temperature

We will use two types of thermometers, liquid and digital, in this course. When using a digital thermometer just record what the readout says (1 place past the decimal). When reading a liquid thermometer read it like a graduated cylinder, **write down one more place past the decimal than the closest marks are.**



What temperature do you read on this thermometer?

Procedure

Part A (Temperature): Fill your 250 mL beaker about half full with tap water. Measure the temperature using the glass thermometer in your locker and a digital thermometer. Record each temperature to the the correct place, including units. Record these in the Data section, page 8, **(A1) and (A2).**

Now add enough ice so that the beaker is almost, but not quite, full. Stir the mixture and record the temperature with both thermometers to the correct place, including units. Record these in the Data section, page 8,**(A3) and (A4).**

Next, using a scoopula add one medium sized scoop of salt (NaCl) to the ice water. Stir with your glass stirring rod and record the temperature with both thermometers to the correct place, including units. Record these in the Data section, page 8,**(A5) and (A6).**

Finally, measure the temperature of the boiling water in one of the hoods using both thermometers to the correct place, including units. Record these in the Data section, page 8, **(A7) and (A8).**

Part B (Mass): In your hand, hold separately a cork ring and a ball bearing. Which feels heaviest? Record this in the Data section, page 10, **(B1).** Which feels lightest? **(B2).**

Now, using one of the balances measure the mass of the same objects (cork ring and ball bearing). Record their masses to the correct place, including units. Record these in the Data section, page 10, **(B3) and (B4).**

Part C (Volume): Place your 150 mL beaker on a balance, close all of the doors, and tare the balance.

Remove the beaker from the balance, making sure not to touch any of the buttons on the balance, and add 10 mL of D.I. water to the beaker using your **graduated cylinder** to measure the volume of water.

Place the beaker back on the balance, close all of the doors, and record the mass of the 10 mL of water to three places past the decimal, including units. Record these in the Data section, page 11, **(C1).**

With the beaker and water still on the balance tare the balance.

Remove the beaker and add 10 mL more of water to it, using your

graduated cylinder to measure the volume.

Place the beaker back on the balance, close all of the doors, and record the mass of the 10 mL of water to three places past the decimal, including units. Record these in the Data section, page 11, **(C2).**

With the beaker and water still on the balance tare the balance.

Remove the beaker and add 10 mL more of water to it, using your **graduated cylinder** to measure the volume.

Place the beaker back on the balance, close all of the doors, and record the mass of the 10 mL of water to three places past the decimal, including units. Record these in the Data section, page 11, **(C3).**

With the beaker and water still on the balance tare the balance.

Remove the beaker and add 10 mL more of water to it, using your **volumetric pipet** to measure the volume.

Place the beaker back on the balance, close all of the doors, and record the mass of the 10 mL of water to three places past the decimal, including units. Record these in the Data section, page 11, **(C4).**

With the beaker and water still on the balance tare the balance.

Remove the beaker and add 10 mL more of water to it, using your **volumetric pipet** to measure the volume.

Place the beaker back on the balance, close all of the doors, and record the mass of the 10 mL of water to three places past the decimal, including units. Record these in the Data section, page 11, **(C5).** With the beaker and water still on the balance tare the balance.

Remove the beaker and add 10 mL more of water to it, using your **volumetric pipet** to measure the volume.

Place the beaker back on the balance, close all of the doors, and record the mass of the 10 mL of water to three places past the decimal, including units. Record these in the Data section, page 11, **(C6).**

With the beaker and water still on the balance tare the balance.

Remove the beaker and add 10 mL more of water to it, using your **burette** to measure the volume.

Place the beaker back on the balance, close all of the doors, and record the mass of the 10 mL of water to three places past the decimal, including units. Record these in the Data section, page 11, **(C7).**

With the beaker and water still on the balance tare the balance.

Remove the beaker and add 10 mL more of water to it, using your **burette** to measure the volume.

Place the beaker back on the balance, close all of the doors, and record the mass of the 10 mL of water to three places past the decimal, including units. Record these in the Data section, page 11, **(C8).**

With the beaker and water still on the balance tare the balance.

Remove the beaker and add 10 mL more of water to it, using your **burette** to measure the volume.

Place the beaker back on the balance, close all of the doors, and record the mass of the 10 mL of water to three places past the decimal, including units. Record these in the Data section, page 11, **(C9).**

Using a digital thermometer measure the temperature of the water in the beaker. Record these in the Data section, page 11, **(C10).**

Using the table on the next page, find the density of water at the temperature of your water. In the table the densities are in **g/mL** and the temperatures are in **^{o}C**.

To use the table, find the temperature to the ones place in the left column. Move across that row until you get to the column that corresponds to the number in the tenths place of your temperature. The number in that cell is your density. Record the density of your water in the data section. **(C11)**

For example, if your temperature is 14.7 ^{o}C, your density is shown by the intersection of the green cells (0.999144 g/mL).

Density of Water (g/mL) as a Function of Temperature (^oC)

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.999841	0.999847	0.999854	0.999860	0.999866	0.999872	0.999878	0.999884	0.999889	0.999895
1	0.999900	0.999905	0.999909	0.999914	0.999918	0.999923	0.999927	0.999930	0.999934	0.999938
2	0.999941	0.999944	0.999947	0.999950	0.999953	0.999955	0.999958	0.999960	0.999962	0.999964
3	0.999965	0.999967	0.999968	0.999969	0.999970	0.999971	0.999972	0.999972	0.999973	0.999973
4	0.999973	0.999973	0.999973	0.999972	0.999972	0.999972	0.999970	0.999969	0.999968	0.999966
5	0.999965	0.999963	0.999961	0.999959	0.999957	0.999955	0.999952	0.999950	0.999947	0.999944
6	0.999941	0.999938	0.999935	0.999931	0.999927	0.999924	0.999920	0.999916	0.999911	0.999907
7	0.999902	0.999898	0.999893	0.999888	0.999883	0.999877	0.999872	0.999866	0.999861	0.999855
8	0.999849	0.999843	0.999837	0.999830	0.999824	0.999817	0.999810	0.999803	0.999796	0.999789
9	0.999781	0.999774	0.999766	0.999758	0.999751	0.999742	0.999734	0.999726	0.999717	0.999709
10	0.999700	0.999691	0.999682	0.999673	0.999664	0.999654	0.999645	0.999635	0.999625	0.999615
11	0.999605	0.999595	0.999585	0.999574	0.999564	0.999553	0.999542	0.999531	0.999520	0.999509
12	0.999498	0.999486	0.999475	0.999463	0.999451	0.999439	0.999427	0.999415	0.999402	0.999390
13	0.999377	0.999364	0.999352	0.999339	0.999326	0.999312	0.999299	0.999285	0.999272	0.999258
14	0.999244	0.999230	0.999216	0.999202	0.999188	0.999173	0.999159	0.999144	0.999129	0.999114
15	0.999099	0.999084	0.999069	0.999054	0.999038	0.999023	0.999007	0.998991	0.998975	0.998959
16	0.998943	0.998926	0.998910	0.998893	0.998877	0.998860	0.998843	0.998826	0.998809	0.998792
17	0.998774	0.998757	0.998739	0.998722	0.998704	0.998686	0.998668	0.998650	0.998632	0.998613
18	0.998595	0.998576	0.998558	0.998539	0.998520	0.998501	0.998482	0.998463	0.998444	0.998424
19	0.998405	0.998385	0.998365	0.998345	0.998325	0.998305	0.998285	0.998265	0.998244	0.998224
20	0.998203	0.998183	0.998162	0.998141	0.998120	0.998099	0.998078	0.998056	0.998035	0.998013
21	0.997992	0.997970	0.997948	0.997926	0.997904	0.997882	0.997860	0.997837	0.997815	0.997792
22	0.997770	0.997747	0.997724	0.997701	0.997678	0.997655	0.997632	0.997608	0.997585	0.997561
23	0.997538	0.997514	0.997490	0.997466	0.997442	0.997418	0.997394	0.997369	0.997345	0.997320
24	0.997296	0.997271	0.997246	0.997221	0.997196	0.997171	0.997146	0.997120	0.997095	0.997069
25	0.997044	0.997018	0.996992	0.996967	0.996941	0.996914	0.996888	0.996862	0.996836	0.996809
26	0.996783	0.996756	0.996729	0.996703	0.996676	0.996649	0.996621	0.996594	0.996567	0.996540
27	0.996512	0.996485	0.996457	0.996429	0.996401	0.996373	0.996345	0.996317	0.996289	0.996261
28	0.996232	0.996204	0.996175	0.996147	0.996118	0.996089	0.996060	0.996031	0.996002	0.995973
29	0.995944	0.995914	0.995885	0.995855	0.995826	0.995796	0.995766	0.995736	0.995706	0.995676
30	0.995646	0.995616	0.995586	0.995555	0.995525	0.995494	0.995464	0.995433	0.995402	0.995371
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9

Data and Analysis

Part A Data:

Temperature of tap water with glass thermometer:_________________(A1)

Temperature of tap water with digital thermometer:_______________(A2)

Temperature of ice water with glass thermometer:_________________(A3)

Temperature of ice water with digital thermometer:_______________(A4)

Temperature of ice/salt water with glass thermometer:____________(A5)

Temperature of ice/salt water with digital thermometer:__________(A6)

Temperature of boiling water with glass thermometer:_____________(A7)

Temperature of boiling water with digital thermometer:___________(A8)

Part B Data:

Feels heaviest:____(B1)

Feels lightest:____(B2)

Mass of cork ring:__________________________(B3)

Mass of ball bearing:_______________________(B4)

Part C Data:

Mass of 1st 10 mL of water:_______________________(C1)

Mass of 2nd 10 mL of water:_______________________(C2)

Mass of 3rd 10 mL of water:_______________________(C3)

Mass of 4th 10 mL of water:_______________________(C4)

Mass of 5th 10 mL of water:_______________________(C5)

Mass of 6th 10 mL of water:________________________(C6)

Mass of 7th 10 mL of water:________________________(C7)

Mass of 8th 10 mL of water:________________________(C8)

Mass of 9th 10 mL of water:________________________(C9)

Temperature of the water:_________________________(C10)

Density of your water:____________________________(C11)

Part A Analysis:

1.) Calculate the absolute value of the difference between (A3) and the true value,(0.0 °C). Show your work in the space below. Make sure to include units and write your answer to the correct place.

$$|(\mathbf{A3})-\mathbf{0.0}=(\mathbf{A3})|$$

Difference:______________

2.) Calculate absolute value of the difference between (A4) and the true value,(0.0 °C). Show your work in the space below. Make sure to include units and write your answer to the correct place.

$$|(\mathbf{A4})-\mathbf{0.0}=(\mathbf{A4})|$$

Difference:______________

3.) Calculate the absolute value of the difference between (A7) and the true value,(100.0 °C). Show your work in the space below. Make sure to include units and write your answer to the correct place.

$$|(\mathbf{A7})-\mathbf{100.0}|$$

Difference:______________

4.) Calculate the absolute value of the difference between (A8) and the true value,(100.0 °C). Show your work in the space below. Make sure to include units and write your answer to the correct place.

$$|(\mathbf{A8})-\mathbf{100.0}|$$

Difference:______________

NAME:____________________________ **SECTION:________**

5.) Accuracy means how close a measurement is to the true value. That is, the smaller the difference between the experimental value and the true value, the more accurate that measurement is. Which thermometer was more accurate for the ice water? Which was more accurate for the boiling water?

Most Accurate:____________________

Part C Analysis:

6.) To find the true value for the mass of 10 mL of water in grams at your temperature, multiply the density in (C11) by 10 mL (exact). For example, if your value for (C11) were to be 0.999144 g/mL, the mass of 10 mL of water at your temperature would be 9.99144 g. Do this now. This is the “True Value” in **Equation 1 on page 1**.

Mass of 10 mL of water at your temperature:___________________

7.) Calculate the average of the values you got for **(C1), (C2)**, and **(C3)**. See **(Equation 2) page 1**.

Average:____________________

8.) Calculate the average of the values you got for **(C4), (C5)**, and **(C6)**.

Average:____________________

9.) Calculate the average of the values you got for **(C7), (C8)**, and **(C9)**.

Average:____________________

NAME:_________________________________ **SECTION:**________

10.) Calculate your percent error for the graduated cylinder using Equation 1. Here your answer to 6.) is the “True Value” and the answer to 7.) is the “Average Value”. See (Equation 3) page 2.

Percent Error:________________

11.) Calculate your percent error for the volumetric pipette using Equation 1. Here your answer to 6.) is the “True Value” and the answer to 8.) is the “Average Value”.

Percent Error:________________

12.) Calculate your percent error for the burette using Equation 1. Here your answer to 6.) is the “True Value” and the answer to 9.) is the “Average Value”.

Percent Error:________________

13.) Calculate the average deviation for the measurements made with the graduated cylinder, **your answer to question 7**, using (Equation 4) and (Equation 5) on page 2.

Average Deviation:________________

NAME:________________________________ **SECTION:**________

14.) Calculate the average deviation for the measurements made with the volumetric pipette, **your answer to question 8**, using (Equation 4) and (Equation 5) on page 2.

Average Deviation:_______________

15.) Calculate the average deviation for the measurements made with the burette, **your answer to question 9**, using (Equation 4) and (Equation 5) on page 2.

Average Deviation:_______________

16.) Which tool (the graduated cylinder, volumetric pipette, or burette) was more accurate for you? (Remember, smaller percent error means more accurate)

17.) Which tool (the graduated cylinder, volumetric pipette, or burette) was more precise for you? (Remember, smaller average deviation means more precise)

TURN IN PAGES 8-12 ONLY!

NAME:____________________________ **SECTION:________**