Name: _____ Section: _____

Data and Calculations

Part 1

Diameter: _____ cm Radius: _____ cm Height (cylinder part): _____ cm

Volume (cylinder part): _____ cm^3
SHOW CALCULATION:

Volume (half-sphere part): _____ cm^3
SHOW CALCULATION:

Total Volume (sum): _____ cm^3

Volume (graduated cylinder): _____ mL

Average Volume: _____ mL
SHOW CALCULATION:

Percent Difference: _____ %
SHOW CALCULATION:

Part 2

Mass of Metal Cylinder _____

Diameter _____ Length _____ Volume $_{calipers}$ _____

Volume$_{water}$ _____ Volume$_{metal + water}$ _____ Volume $_{water\ displacement}$_____

Density of the Cylinder: calipers: _____ water displacement: _____

Handbook Density _____

Identity of Metal _____

% Error: calipers: _____ water displacement: _____

SHOW CALCULATIONS:

Name: _____ Section: _____

Part 3 Unknown Number _____

Mass of Flask with stopper _____ Initial Buret reading _____

Sample	**Mass** Flask+Stopper+Liquid **(g)**	**Mass** Liquid Only **(g)**	**Final Buret Reading (mL)**	**Net Volume (mL)**	**Density (x_m) (g / mL)** 4 sig. figs.	**d ($x_m - \bar{x}$)**	**d^2**
1							
2							
3							
4							
5							
6							
				sum of x_m:		sum of d^2:	

Show your calculation of the standard deviation, s, from d^2 below:

Mean value ($\bar{x}$): _____ Standard Deviation (s): _____

Range: _____ % NaCl from Table: _____

Name: _____ Section: _____

Post-lab Questions

1. Calculate the density of a pure gold sphere with a diameter of 2.120 cm and a mass of 94.19 g.

2. The density of aluminum is 2.70 g/cm^3. Calculate the thickness of a rectangular sheet of aluminum foil with a width of 11.5 cm, a length of 14.0 cm, and a mass of 2.04 g.

3. Examine your results from your data table in Part 3. Do you have any values for the density of the salt solution that lie OUTSIDE the range ($\bar{x} \pm 2s$)? If so, list them here:

   Recalculate $\bar{x}$ by omitting values that lie OUTSIDE the range. This is the density value you should use to determine your experimental % NaCl.

Name: _____ Section: _____

Pre-lab Questions

Upon reading the procedure in preparation for this experiment, you should also answer the following questions:

1. Consider Example One in the laboratory discussion. Since measurement 8 lies outside the range, it may be omitted in the calculation of the reported value. Omit measurement 8 and recalculate the mean ($\bar{x}$). Fill in the d and d^2 columns in the table, then calculate the standard deviation (s) and the range.

   Recalculated mean ($\bar{x}$), without measurement 8: _____

Balance Number	**Mass (g) = x_m**	**d = $x_m - \bar{x}$**	**d^2**
1	24.29		
2	24.26		
3	24.17		
4	24.31		
5	24.28		
6	24.19		
7	24.33		
8 – OMITTED	~~24.50~~		
9	24.30		
10	24.23		
sum of x_m:		sum of d^2:	

   Recalculated standard deviatiation (s): _____ and range: _____

   SHOW CALCULATIONS:

2. Now consider Example Two in the laboratory discussion. The student doing the titration repeated the experiment twice more. The following five values were obtained: 0.555 M, 0.565 M, 0.564 M, 0.567 M, and 0.563 M.

   A. Use the *Q Test* to demonstrate that the first value should be rejected.

   B. Recalculate the values for $\bar{x}$, omitting the value 0.555 M. Compare with the original value of $\bar{x}$.

Name: _____ Section: _____

Data and Calculations

Liquid Unknown # _____

Measurement #	Volume (mL)	Mass (g) of beaker + cover + liquid
1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____
5	_____	_____
6	_____	_____

Post-lab Questions

1. Using your hand-written graph, determine the density of your unknown (recall that slope = $\Delta y / \Delta x$). When graphing, use all the data points, then draw the best fit straight line. Start at zero for the x axis, and about 10 to 20 grams less than you smallest mass for the y axis. The line may not exactly touch each point. Determine the slope using two points on the best fit line spread apart from each other. Do not use just two data points measured in the experiment as they may not be on the best fit line.

2. Using your hand-written graph, estimate:

   A. the mass (in grams) of 27.0 mL of your liquid. _____

   B. what volume (in mL) would 17.0 g of your liquid occupy. _____

3. Using your Excel® plot and constructed trendline, write the slope-intercept equation for your liquid unknown. What is the density of your unknown? Make sure to include the appropriate units. How does this density value compare to your result from question #1 above?

Name: _____ Section: _____

4. Using your slope-intercept equation, determine:

   A. the mass (in grams) of 27.0 mL of your liquid.

   B. what volume (in mL) would 17.0 g of your liquid occupy.

5. The data for temperature and pressure of a certain sample of gas is found to be:

Temperature (°C)	Pressure (mmHg)
–196	215
–78.5	542
–17.8	711
0.1	761
22.7	824
99.3	1037
189	1287

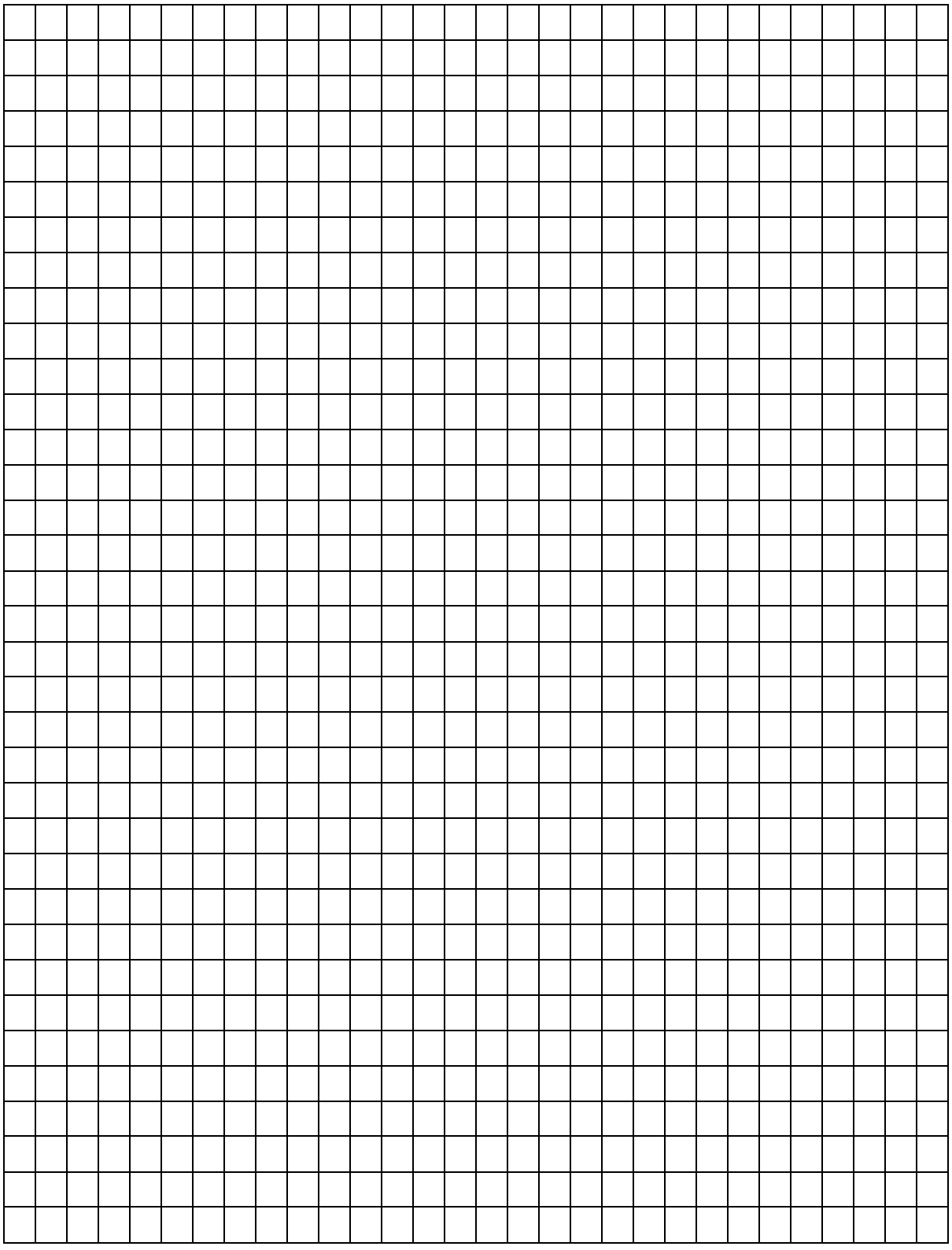
   The researcher seals the gas inside of a container, adjusts the temperature of the container, and then measures the pressure of the gas inside. Therefore, temperature is the independent variable and pressure is the dependent variable.

   A. Construct an Excel® graph of this data with a linear trendline. Make sure to print out a copy of this graph with the slope-intercept equation of the trendline displayed for inclusion with this report. Rewrite the equation, below, using T and P instead of x and y to show the relationship between temperature (T) and pressure (P):

   B. Use the equation of the line to calculate the expected pressure of the gas at a temperature of 42.3 °C.

   C. Use the equation of the line to predict the temperature of the gas when its pressure is 437 mmHg.

Name: _____ Section: _____



Name: _____ Section: _____

Data and Calculations

Mass of empty test tube: _____

Mass of the test tube + copper oxide before heating _____

Mass of the test tube + solid after 20 minutes of heating _____

Mass of the test tube + solid after 30 minutes of heating: _____

Mass of the test tube + solid after 40 minutes of heating:* _____
*if necessary; add more lines if needed

Mass of the copper oxide *before* you heated: _____

Final mass of the copper metal powder: _____

Mass that disappeared during the heating: _____

What element or compound disappeared
from the copper oxide during heating? _____

Moles of copper in the pellet: _____

SHOW CALCULATION:

Moles of oxide that escaped: _____

SHOW CALCULATION:

Empirical formula of the initial copper oxide: _____

SHOW CALCULATION:

Mass percentage of copper in copper oxide: _____

SHOW CALCULATION:

Name: _____ Section: _____

Post-lab Questions

1. Write the balanced chemical equation for the reaction of your oxide using the experimentally determined empirical formula.

2. Imagine you had just discovered copper. Which of the following formulas would be *possible* guesses (however unlikely) for the empirical formula of copper oxide? Which would be *good* guesses if you used the periodic table as a guide to understanding copper's probable charge? Briefly explain your choices below.

   $Cu_{10}O$ Cu_5O Cu_3O_2 Cu_2O

   CuO Cu_2O_3 CuO_2 CuO_{11}

3. A sample of an iron oxide weighing 1.996 g yields 1.396 g of iron on reaction with methane gas. Determine the percent composition and the empirical formula of the iron oxide from this data. SHOW ALL CALCULATIONS! Random guessing will NOT earn you any credit.

Name: _____ Section: _____

Option Fe: Pre-lab Calculations for the Iron Based Experiment:

1. Calculate the molar mass of the starting hydrated salt material, $FeSO_4 \cdot 7H_2O$.

2. Your oxalate synthesis product will be $FeC_2O_4 \cdot 2H_2O$. Calculate the molar mass of $FeC_2O_4 \cdot 2H_2O$.

3. Write a balanced molecular equation that shows your $FeSO_4 \cdot 7H_2O$, reacting with oxalic acid ($H_2C_2O_4$) to form $FeC_2O_4 \cdot 2H_2O$. What will be the other product(s) of the double displacement reaction? Water will need to be added somewhere to balance correctly.

4. Pyrolysis of $FeC_2O_4 \cdot 2H_2O$ will follow one of the following molecular equations. Balance each molecular equation. *(It's OK to keep a fraction when balancing the O_2 molecule in* A *or* B*)*

   A. $FeC_2O_4 \cdot 2H_2O(s) + O_2(g) \rightarrow FeO(s) + H_2O(g) + CO_2(g)$

   B. $FeC_2O_4 \cdot 2H_2O(s) + O_2(g) \rightarrow Fe_2O_3(s) + H_2O(g) + CO_2(g)$

   C. $FeC_2O_4 \cdot 2H_2O(s) \rightarrow FeCO_3(s) + H_2O(g) + CO(g)$

Name: _____ Section: _____

5. For each of the possible reactions, calculate the theoretical yield (in grams) of the solid product, assuming that you use 1.0 g $FeC_2O_4 \cdot 2H_2O$ and that oxygen is the excess reactant. You will need to write in coefficients from question 4 to balance the molecular equations.

   A. $FeC_2O_4 \cdot 2H_2O(s) + O_2(g) \rightarrow FeO(s) + H_2O(g) + CO_2(g)$

   B. $FeC_2O_4 \cdot 2H_2O(s) + O_2(g) \rightarrow Fe_2O_3(s) + H_2O(g) + CO_2(g)$

   C. $FeC_2O_4 \cdot 2H_2O(s) \rightarrow FeCO_3(s) + H_2O(g) + CO(g)$

Name: _____ Section: _____

Option Mn: Pre-lab calculations for the Manganese based experiment:

1. Calculate the molar mass of the starting hydrated salt material, $MnSO_4 \cdot H_2O$.

2. Your oxalate synthesis product will be $MnC_2O_4 \cdot 3H_2O$. Calculate the molar mass of $MnC_2O_4 \cdot 3H_2O$

3. Write a balanced molecular equation that shows $MnSO_4 \cdot H_2O$, reacting with oxalic acid ($H_2C_2O_4$) to form $MnC_2O_4 \cdot 3H_2O$. What will be the other product(s) of the double displacement reaction? Water will need to be added somewhere to balance correctly.

4. Pyrolysis of $MnC_2O_4 \cdot 3H_2O$ will follow one of the following molecular equations. Balance each molecular equation. *(It's OK to keep a fraction when balancing the O_2 molecule in* A *or* B.*)*

   A. $MnC_2O_4 \cdot 3H_2O(s) + O_2(g) \rightarrow MnO(s) + H_2O(g) + CO_2(g)$

   B. $MnC_2O_4 \cdot 3H_2O(s) + O_2(g) \rightarrow Mn_3O_4(s) + H_2O(g) + CO_2(g)$

   C. $MnC_2O_4 \cdot 3H_2O(s) \rightarrow MnCO_3(s) + H_2O(g) + CO(g)$

Name: _____ Section: _____

5. For each of the possible reactions, calculate the theoretical yield (in grams) of the solid product, assuming that you use 1.0 g $MnC_2O_4 \cdot 3H_2O$ and that oxygen is the excess reactant. You will need to write in coefficients from question 4 to balance the molecular equations.

   A. $MnC_2O_4 \cdot 3H_2O(s) + O_2(g) \rightarrow MnO(s) + H_2O(g) + CO_2(g)$

   B. $MnC_2O_4 \cdot 3H_2O(s) + O_2(g) \rightarrow Mn_3O_4(s) + H_2O(g) + CO_2(g)$

   C. $MnC_2O_4 \cdot 3H_2O(s) \rightarrow MnCO_3(s) + H_2O(g) + CO(g)$

Name: _____ Section: _____

Data and Calculations

Part 1: Synthesis of Metal Oxalate

Determine the identity of the limiting reactant, theoretical yield of the hydrated metal oxalate, and the percent yield of the hydrated metal oxalate product. Complete Table 1.

Table 1. Synthesis of Metal Oxalate

a) complete chemical formula of your starting material: (formula found on question 1)	
b) mass of hydrated metal salt used (g) *tare your 100 ml beaker and add 1.9-2.1g sample*	
c) moles of hydrated metal salt used convert grams from (b) using molar mass in question 1	
d) volume of 0.888M oxalic acid solution used *should be close to 25.0mL*	
e) moles of oxalic acid used *calculate from volume and molarity*	
f) mass of filter paper	
g) experimental yield: total mass of hydrated metal oxalate precipitate (grams) after drying by vacuum filtration. filter paper + salt mass: _____ *subtract the filter paper*	
h) identify the limiting reactant: either your starting formula in part (a) or oxalic acid *Refer to the balanced chemical equation in pre-lab quest. #3 and your moles of each reactant calculated in c and e*	
i) theoretical yield of hydrated metal oxalate product (g)	
j) percent yield of hydrated metal oxalate product	

Calculations: Show your calculations. Watch your units and report all answers with the correct number of significant figures.

Name: _____ Section: _____

Data and Calculations

Part 2: Decomposition (Pyrolysis) of Metal Oxalate

Complete Table 2. The pyrolysis reaction occurs with near 100% yield, so the actual yield of the pyrolysis reaction should be very close to the theoretical yield you calculated for the correct reaction equation (as calculated in Question #5 of the prelab).

Table 2. Pyrolysis of Metal Oxalate

a) Weigh the empty Aluminum dish before adding the filtered product.	
b) Before pyrolysis: mass of hydrated metal oxalate (grams) *Ideally between 0.99 to 1.01 gram* Al + oxalate salt mass: _____ *subtract the Al dish*	
c) After pyrolysis: final mass of pyrolysis product (grams) Al + pyrolyzed salt mass: _____ *subtract the Al dish*	
d) theoretical mass of product in reaction **A** From prelab (quest. #5A):	
e) theoretical mass of product in reaction **B** From prelab (quest. #5B):	
f) theoretical mass of product in reaction **C** From prelab (quest. #5C):	
g) Using the above information, which pyrolysis reactions actually occurred, **A**, **B** or **C**?	
h) What is the expected chemical formula of the pyrolyzed metal salt formed?	

Calculations: Refer to your work from prelab Question #5 from your option. Watch your units and report all answers with the correct number of significant figures.

Name: _____ Section: _____

Procedure

1. Set up the apparatus as indicated in the picture.

2. Clean the solid Cu strip with steel wool; wash BOTH Cu strips with dilute NaOH, followed by dilute HNO_3, and finally rinse with DI H_2O. At this point, make certain to handle both Cu strips with forceps.

3. Rinse strips with acetone and when dry, weigh and record the mass of the Cu strips.

4. Place the strips in a 250 mL beaker containing about 200 mL of 1M $CuSO_4$. DO NOT ALLOW THE STRIPS TO TOUCH.

5. Adjust the current to approximately 0.175 Amp (175 mA) and run the system for 30 minutes. If you cannot maintain a constant amp reading, take readings at 5 minute intervals and average the current.

6. Carefully rinse both Cu strips under a slow stream of DI water, then rinse with acetone, and allow to dry. Weigh and record the mass of each dry Cu strip.

Data and Calculations

1. Current _____ amps

2. Time _____ seconds

3. Initial Mass of Copper A (solid) _____

4. Final Mass of Copper A (solid) _____

5. Change in mass of Copper A (solid) _____

6. Initial Mass of Copper B (screen) _____

7. Final Mass of Copper B (screen) _____

8. Change in mass of Copper B (screen) _____

9. Average change in mass of the Copper Strips _____

Name: _____ Section: _____

Post-lab Questions

1. Was the change in mass by the screen the same as the solid mass? Briefly explain your results.

2. Calculate the value of Avogadro's number starting with the amount of current you used. SHOW ALL YOUR WORK.

3. Calculate the percent error in your experimental value of Avogadro's number.

6. Part D: Transfer the filter paper and solid back to the original beaker. Dissolve the solid copper oxide by adding approximately 10 mL of 3 M H_2SO_4(aq) to the filter paper containing the residue from the previous step. Once the solid has dissolved, remove the filter paper and rinse it with 10 – 20 mL of deionized water. Add the washings to the acid solution, and save the solution for the next step. Note any color change. Also note the reaction that is occurring.

7. Part E: WORK IN THE HOOD! Add about 0.40 g of zinc metal to the acidic copper solution. If any blue color remains after the zinc has dissolved, a bit more zinc may need to be added (record in your report!). Note the reaction that is occurring. Dissolve any excess zinc with a small amount (approximately 5 mL) of 3 M H_2SO_4(aq).

8. Filter the supernatant liquid from the solid and wash the solid 3 times with 20 mL portions of deionized water.

9. Transfer the solid copper onto a large watch glass and place it in the laboratory oven (PS 103 or PS 107) for 15 to 20 minutes at around 100 °C or until dry. Weigh to determine the mass of recovered copper.

Data Analysis and Calculations

Initial color and form of the copper _____

Mass of Cu(s) at the beginning of the experiment _____

Mass Recovered _____

% Recovery _____

Comment and discussion: Do your results support Lavoisier's law of conservation of mass? How does your percent recovery deviate from the expected 100%? Briefly explain.

Name: _____ Section: _____

Post-lab Questions

1. Write the symbol or formula for the form of copper that is present in the following parts of the experiment:

   A. after adding nitric acid _____

   B. after adding NaOH, litmus paper turns blue _____

   C. after boiling _____

   D. after adding sulfuric acid _____

   E. after adding zinc _____

2. Now give the color of the copper substances in each of the steps above:

   A. _____ D. _____

   B. _____ E. _____

   C. _____

3. A student reports 115% recovery. How could he/she possibly have more copper at the end of the experiment than he/she started with? Explain.

4. If a student used a penny as the source of copper in this experiment, would it matter if a pre-1982 penny (essentially pure copper) versus a post-1982 penny (copper exterior over a zinc core) was used? Would using a post-1982 penny pose any experimental complications? Briefly explain.

Name: _____ Section: _____

5. Part A in today's experiment is classified as a redox reaction in which electrons are transferred via oxidation of Cu and reduction of the N in HNO_3. The balanced molecular equation is:

$$Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$$

The net ionic equation for this reaction is:

$$Cu(s) + 4H^+(aq) + 2NO_3^-(aq) \rightarrow Cu^{+2}(aq) + 2NO_2(g) + 2H_2O(l)$$

Write balanced molecular, ionic, and net ionic equations for the other four reactions in this inorganic sequence. Classify the types of each reaction in as many possible ways (i.e. redox, synthesis, combustion, decomposition, single replacement, double displacement, precipitation, neutralization).

Part B:

Part C:

Part D:

Part E:

6. Referring to part E, write the reaction for the reduction of copper(II) ion into solid copper using zinc. Calculate the theoretical mass of zinc needed to carry out the reaction based on the initial mass of copper used. Compare this theoretical mass of zinc with the actual amount used in the laboratory. Justify any differences.

Name: _____ Section: _____

Pre-lab Questions

Upon reading the procedure in preparation for this experiment, you should also answer the following questions:

1. Use the outlined procedure to describe:

   a) a test for determining whether a solution is basic enough.

   b) a test to decide whether enough zinc has been added.

2. Write out and classify the molecular, ionic, and net ionic equations that take place when H_2SO_4 is added to the excess zinc in part E.

3. Does observing a color change always indicate that a chemical change has occurred? Explain why or why not.

4. What should the student do if the solution in step E is still blue?

those solutions, you can make mixtures with the other solutions in which one of the components is known. From the results obtained with those mixtures and the information in the matrix, you can identify other solutions. These can be used to identify still others, until the entire set of ten is finally identified.

Pre-lab Questions

1. Fill in the matrix below to show how various solutions react, as described in the procedure.

HCl	H_2SO_4	NaOH	NH_4OH	$Al(NO_3)_3$	$AgNO_3$	$Ca(NO_3)_2$	$Cu(NO_3)_2$	$Ni(NO_3)_2$	$SnCl_4$	
										HCl
										H_2SO_4
										NaOH
										NH_4OH
										$Al(NO_3)_3$
										$AgNO_3$
										$Ca(NO_3)_2$
										$Cu(NO_3)_2$
										$Ni(NO_3)_2$
										$SnCl_4$
										NOTES

Name: _____ Section: _____

2. Which solutions should you expect to identify by simple observations?

3. Outline the procedure you will follow in identifying the remaining solutions. Be specific about what to look for and what conclusions you expect to draw from your observations.

Name: _____ Section: _____

QUALITATIVE ANALYSIS Report Sheet

Final Identifications:

No. 1 _____ No. 6 _____

No. 2 _____ No. 7 _____

No. 3 _____ No. 8 _____

No. 4 _____ No. 9 _____

No. 5 _____ No. 10 _____

Use the next few pages to write balanced MOLECULAR, IONIC, and NET-IONIC equations for TEN of the reactions that occurred during this laboratory experiment. Make sure to include the physical states of all the products. These equations must be turned in along with this report sheet to receive full credit upon conclusion of the lab.

1. Molecular:

   Ionic:

   Net-ionic:

2. Molecular:

   Ionic:

   Net-ionic:

3. Molecular:

   Ionic:

   Net-ionic:

4. Molecular:

   Ionic:

   Net-ionic:

Name: _____ Section: _____

5. Molecular:

   Ionic:

   Net-ionic:

6. Molecular:

   Ionic:

   Net-ionic:

7. Molecular:

   Ionic:

   Net-ionic:

8. Molecular:

   Ionic:

   Net-ionic:

9. Molecular:

   Ionic:

   Net-ionic:

10. Molecular:

    Ionic:

    Net-ionic:

Name: _____ Section: _____

Data and Calculations

Mass of clean, dry calorimeter: _____ g

Mass of calorimeter with solution after conclusion of reaction: _____ g

Final mass of reaction solution: _____ g

Initial temperature of H_2SO_4 solution: _____ °C

Initial temperature of NaOH solution: _____ °C

Average initial temperature of starting solutions: _____ °C

Final temperature of mixture: _____ °C

Change in temperature of solution (ΔT): _____ °C

1. Write the balanced chemical equation for your acid/base neutralization reaction.

2. Determine the theoretical yield of water (in grams) of the reaction that you carried out.

3. What is the limiting reactant of your reaction?

4. Calculate the mass of each reactant that is theoretically left over at the end of your reaction.

_____ g of NaOH left over _____ g of H_2SO_4 left over

Name: _____ Section: _____

5. Assuming that the specific heat capacity of the solution that you used is equal to 3.70 J / g °C, calculate the heat ($q_{solution}$) in kJ that was absorbed by the contents of the coffee cup during the reaction.

6. Calculate ΔH of your reaction using the units specified:

_____ kJ / g H_2O formed _____ kJ / mol H_2O formed

7. Rewrite your balanced chemical equation and include the value of ΔH beside it:

_____ → _____ ΔH = _____ kJ

8. Use the $\Delta H_f°$ values given to calculate the theoretical value of ΔH for your reaction.

Substance	**$\Delta H_f°$ (kJ / mol)**
H_2SO_4 *(aq)*	–909.3
NaOH *(aq)*	–470.1
H_2O *(l)*	–285.8
Na_2SO_4 *(aq)*	–1387.1

9. Using your results from questions 7 & 8, calculate the percent error in your determination of ΔH.

Name: _____ Section: _____

Pre-lab Assignment

A student carries out the following reaction in lab by mixing 50.0 mL of a 1.00 M solution of hydrochloric acid with 50.0 mL of a 1.00 M solution of potassium hydroxide:

$$HCl\ (aq)\ +\ KOH\ (aq)\ \rightarrow\ KCl\ (aq)\ +\ H_2O\ (l)$$

The average initial temperature of the two solutions was 25.00 °C. After mixing, the final temperature of the solution was 31.43 °C. The mass of the resulting solution was 100.2 g.

1. Determine the theoretical yield of KCl (in moles) of the student's reaction.

2. Assuming that the specific heat capacity of the solutions that the student used are equal to the specific heat capacity of pure water, calculate the heat ($q_{solution}$) in kJ that was absorbed by the contents of the coffee cup from the reaction.

3. Calculate the value of ΔH_{rxn} in the units kJ / mol KCl.

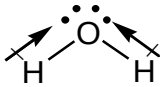
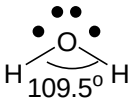
4. For this reaction, the theoretical value of ΔH_{rxn} is –55.8 kJ / mol KCl. What was the student's percent error when determining ΔH_{rxn}?

Name: _____ Section: _____

Source and Color of Line	a (cm)	b (cm)	d (cm)	Wavelength (cm)	Wavelength (nm)	Frequency (s^{-1})	Energy (J/photon)	Energy (kJ/mole)	Rydberg Eq calculation of λ (nm)
1. H (red) $n = 3 \rightarrow n = 2$									
2. H (blue) $n = 4 \rightarrow n = 2$									
3. H (violet) $n = 5 \rightarrow n = 2$									
4. He (yellow)									
5. Hg (green)									
6. H $n = 2 \rightarrow n = 1$	Show calculation to determine d here:								IR, Vis, UV
7. H $n = \infty \rightarrow n = 1$									IR, Vis, UV
8. H $n = 4 \rightarrow n = 3$									IR, Vis, UV
9. H $n = \infty \rightarrow n = 3$									IR, Vis, UV
10. H $n = \infty \rightarrow n = 2$									IR, Vis, UV

Name: _____ Section: _____

Complete the following table for the indicated species:

Substance	**H_2O**	**HF**	**O_2**	**CO**
a) Draw the best Lewis structure(s), resonances, and structural isomers if any b) In your structure above, indicate polar bonds with dipole arrows toward the more electronegative atom c) Include formal charges if they are not zero	 (does NOT need to be bent at this point!) formal charge $_O = 0$ formal charge $_H = 0$			
Name the electronic geometry around central atom(s)	Tetrahedral			
Give hybridization for central atom(s)	sp^3			
Name the shape around central atom(s)	Bent (or angular)			
Show 3-D sketch of the structure and label all bond angles				
How many sigma bonds? How many pi bonds?	2 σ and 0 π bonds			
Is the substance an ionic compound, a polar molecule, a nonpolar molecule, or a polyatomic ion?	polar molecule			

Name: _____ Section: _____

Complete the following table for the indicated species:

Substance	**NH_4^{+1}**	**Na_2S**	**SO_3**	**ClO_2^-**
a) Draw the best Lewis structure(s), resonances, and structural isomers if any b) In your structure above, indicate polar bonds with dipole arrows toward the more electronegative atom c) Include formal charges if they are not zero				
Name the electronic geometry around central atom(s)				
Give hybridization for central atom(s)				
Name the shape around central atom(s)				
Show 3-D sketch of the structure and label all bond angles				
How many sigma bonds? How many pi bonds?				
Is the substance an ionic compound, a polar molecule, a nonpolar molecule, or a polyatomic ion?				

Name: _____ Section: _____

Complete the following table for the indicated species:

Substance	**SO_3^{-2}**	**CH_2O**	**CO_2**	**SCN^-**
a) Draw the best Lewis structure(s), resonances, and structural isomers if any b) In your structure above, indicate polar bonds with dipole arrows toward the more electronegative atom c) Include formal charges if they are not zero				
Name the electronic geometry around central atom(s)				
Give hybridization for central atom(s)				
Name the shape around central atom(s)				
Show 3-D sketch of the structure and label all bond angles				
How many sigma bonds? How many pi bonds?				
Is the substance an ionic compound, a polar molecule, a nonpolar molecule, or a polyatomic ion?				

Name: _____ Section: _____

Complete the following table for the indicated species:

Substance	**$C_2H_2Br_2$**	**NF_3**	**CH_2Cl_2**	**CH_3OH**
a) Draw the best Lewis structure(s), resonances, and structural isomers if any b) In your structure above, indicate polar bonds with dipole arrows toward the more electronegative atom c) Include formal charges if they are not zero				
Name the electronic geometry around central atom(s)				
Give hybridization for central atom(s)				
Name the shape around central atom(s)				
Show 3-D sketch of the structure and label all bond angles				
How many sigma bonds? How many pi bonds?				
Is the substance an ionic compound, a polar molecule, a nonpolar molecule, or a polyatomic ion?				

Name: _____ Section: _____

Complete the following table for the indicated species:

Substance	**C_6H_6 (ring)**	**S_8**	**PO_4^{-3}**	**C_3H_8O**
a) Draw the best Lewis structure(s), resonances, and structural isomers if any b) In your structure above, indicate polar bonds with dipole arrows toward the more electronegative atom c) Include formal charges if they are not zero				
Name the electronic geometry around central atom(s)				
Give hybridization for central atom(s)				
Name the shape around central atom(s)				
Show 3-D sketch of the structure and label all bond angles				
How many sigma bonds? How many pi bonds?				
Is the substance an ionic compound, a polar molecule, a nonpolar molecule, or a polyatomic ion?				

Name: _____ Section: _____

Complete the following table for the indicated species:

Substance	**NO_3^-**	**NO_2**	**H_2O_2**	**C_2H_2**
a) Draw the best Lewis structure(s), resonances, and structural isomers if any b) In your structure above, indicate polar bonds with dipole arrows toward the more electronegative atom c) Include formal charges if they are not zero				
Name the electronic geometry around central atom(s)				
Give hybridization for central atom(s)				
Name the shape around central atom(s)				
Show 3-D sketch of the structure and label all bond angles				
How many sigma bonds? How many pi bonds?				
Is the substance an ionic compound, a polar molecule, a nonpolar molecule, or a polyatomic ion?				

Name: _____ Section: _____

Complete the following table for the indicated species:

Substance	**A: $C_2H_4O_2$**	**B: $C_2H_4O_2$**	**C_2H_6**	**BaO**
a) Draw the best Lewis structure(s), resonances, and structural isomers if any b) In your structure above, indicate polar bonds with dipole arrows toward the more electronegative atom c) Include formal charges if they are not zero	Draw one structural isomer with C–C bond that has one C connected to 3 H and the other to 2 O. This is acetic acid	Draw a new structural isomer keeping all formal charges = 0. More than 5 isomers are possible		
Name the electronic geometry around central atom(s)				
Give hybridization for central atom(s)				
Name the shape around central atom(s)				
Show 3-D sketch of the structure and label all bond angles				
How many sigma bonds? How many pi bonds?				
Is the substance an ionic compound, a polar molecule, a nonpolar molecule, or a polyatomic ion?				

Name: _____ Section: _____

Complete the following table (the central atom for each species has an expanded octet):

Substance	**I_3^-**	**ICl_5**	**SF_6**	**$XeOCl_2$**
a) Draw the best Lewis structure(s), resonances, and structural isomers if any b) In your structure above, indicate polar bonds with dipole arrows toward the more electronegative atom c) Include formal charges if they are not zero				
Name the electronic geometry around central atom(s)				
Give hybridization for central atom(s)				
Name the shape around central atom(s)				
Show 3-D sketch of the structure and label all bond angles				
How many sigma bonds? How many pi bonds?				
Is the substance an ionic compound, a polar molecule, a nonpolar molecule, or a polyatomic ion?				

Name: _____ Section: _____

Data and Calculations

Unknown Number _____

Atmospheric pressure _____ torr = _____ atm

	Trial 1		Trial 2
1. Mass of dry flask with stopper	_____	=	_____
2. Mass of flask, stopper, & condensed liquid	_____		_____
3. Mass of condensed liquid	_____		_____
4. Temperature of boiling water	_____		_____
5. Volume of flask (see flask)	_____	=	_____
6. Molecular weight of sample)	_____		_____

(These values must be within 5 % of each other. If not, a third trial must be run.)

7. Average Molecular Weight* _____

**Average only those values within the limit*

SHOW CALCULATIONS:

Name: _____ Section: _____

Questions (to be completed while in the laboratory)

1. Obtain the mass percent composition information of your unknown from your instructor. Solve for the empirical formula, and then using your determined molecular weight, solve for the molecular formula of your compound.

Empirical Formula _____

Molecular Formula _____

2. Determine your percent error using your experimental molecular weight and the theoretical molecular weight determined via your molecular formula.

3. Write the ideal gas law equation for molecular weight.

Name: _____ Section: _____

Post-lab Questions

4. It was found that 0.801 gram of vapor exerted a pressure of 744 torr at 100 ^{o}C when confined to a 260 mL flask. If this vapor came from a volatile liquid, what is the molecular weight of the liquid?

5. Based on this experiment:

   A. How do you experimentally determine the temperature of the unknown when it is a gas?

   B. How do you experimentally determine the pressure of the unknown when it is a gas?

6. What is the purpose of cooling the flask?

7. Why will air rush into the cooled flask when the stopper is removed?

Name: _____ Section: _____

8. How would each of the following procedural errors affect the calculated molecular weight in this experiment? Give your reasoning in each case.

   A. All of the liquid was not vaporized when the flask was removed from the water bath.

   B. The flask was not dried before the final weighing with the condensed vapor inside.

   C. The flask was left open to the atmosphere while it was being cooled, and the stopper was inserted just before the final weighing.

   D. The flask was removed from the bath after all of the liquid had vaporized but before the vapor had reached the temperature of the boiling water.

Name: _____ Section: _____

Data and Calculations

1. Unknown sample number _____
2. Mass of test tube: _____
3. Mass of test tube and sample *before* heating: _____
4. Mass of test tube and sample *after* heating: _____
5. Mass of sample in the tube *before* heating: _____
6. Mass of residue in test tube *after* heating: _____
7. Mass of oxygen gas released: _____
8. Volume of oxygen gas at room temperature: _____
9. Atmospheric pressure: _____
10. Vapor pressure of water: _____
11. Temperature of water: _____

Questions (to be completed while in the laboratory)

1. Calculate the pressure of the collected oxygen gas (i.e. correct for the vapor pressure of water).

2. How much volume would the gas in question #1 occupy at STP?

3. Determine the moles of oxygen gas collected from the experimental mass of the oxygen gas.

Name: _____ Section: _____

4. Use questions #2 and #3 to determine the molar volume (i.e. how many Liters/mole the gas would occupy at STP).

5. Determine the % error of your molar volume from that of an ideal gas.

6. Along with oxygen gas, potassium chloride is also formed from the potassium chlorate. Write a balanced equation for the reaction. Also describe the purpose of the MnO_2. Do you suspect that this "filler" is necessary for this particular reaction? Briefly explain why or why not.

7. Calculate the number of grams of potassium chlorate in your original sample.

8. Determine the mass percent of $KClO_3$ in your original sample. (Remember that the sample was not pure $KClO_3$ but has varying amounts of other compounds)

9. What would happen if you didn't remove the stopper from the hot test tube?

Name: _____ Section: _____

Post-lab Questions

1. A sample of an unknown metal chlorate weighing 1.725 g is heated until all of the oxygen is driven off. The residue remaining in the container weighs 0.859 g. Calculate the percentage of oxygen in this metal chlorate.

2. 340 mL of oxygen gas are collected by displacement of water at 33 ^{o}C and 742 torr, where the vapor pressure of water at this temperature is known to be 37.8 torr.

   A. What is the pressure of the oxygen gas?

   B. Determine the volume of the oxygen gas at STP.

Name: _____ Section: _____

Data and Results

Substance	Melting range (check one)	Soluble in xylene?	Soluble in ethanol?	Soluble in water?	Conducts electricity as a solid?	Conducts as an aqueous solution?	Classification: Metallic Ionic Molecular (P) Molecular (NP) Network-Cov.
Known A	□ <100 °C □ 100–300 °C □ 300–600 °C □ 600 °C						
Known B	□ <100 °C □ 100–300 °C □ 300–600 °C □ 600 °C						
Known C	□ <100 °C □ 100–300 °C □ 300–600 °C □ 600 °C						
Known D	□ <100 °C □ 100–300 °C □ 300–600 °C □ 600 °C						
Known E	□ <100 °C □ 100–300 °C □ 300–600 °C □ 600 °C						
Known F	□ <100 °C □ 100–300 °C □ 300–600 °C □ 600 °C						
Unknown A	□ <100 °C □ 100–300 °C □ 300–600 °C □ 600 °C						
Unknown B	□ <100 °C □ 100–300 °C □ 300–600 °C □ 600 °C						

Name: _____ Section: _____

2. Use the reagent pump to add 7.0 mL of 12 M (conc) HCl to the solution and cover with a small watch glass.

3. Place the beaker inside a 250 mL beaker which is about one-third full of DI water. Heat this water bath to a GENTLE boil for about 5 minutes or until a solid material forms in the smaller beaker. Keep the small watch glass on the inside beaker while boiling.

4. Cool the solution by placing the smaller beaker in a cold water bath.

5. Weigh and record the mass of a piece of filter paper. Pour your newly synthesized compound Y mixture through this filter paper so that the liquid drains into a 250 mL Erlenmeyer flask. Wash any remaining solid into the filter paper by rinsing the beaker with small amounts of cold DI water from a wash bottle. Allow the crystals to drain. Wash the precipitate 3 or 4 times with 5 mL portions of cold distilled water.

6. Transfer the crystals and filter paper to a previously weighed large watch glass. Dry the crystals by using one of the following methods: (1) place the watch glass over an appropriate sized beaker about one-third full of boiling water; or (2) place in a drying oven.

7. Once the sample is dry, weigh and record the mass of the watch glass, filter paper, and crystals. Label the crystals as compound Y and keep them in a stoppered test tube in your locker for further analysis. Do not leave the crystals in an open container in your locker, as this may damage the locking mechanism.

   Mass of Compound Y: _____

PART II

1. In the fume hood, take a piece of thick copper wire and heat it in a Bunsen burner flame until its glowing. Note the flame color. Let the wire cool for 20 seconds, and dip the wire into a container with Parlon. Cover the tip in the powder, place the compound in the flame and burn it. Observe the color. Parlon contains chlorine, which burns with a distinctive color in the presence of copper.

2. Follow the same procedure using another wire to test a sample of Chemical X. This should not have any unusual color, only burning with the orange color of a typical hydrocarbon fuelled fire.

3. Follow the same procedure using another wire to test a sample of Chemical Y. Does it contain chlorine?

   Parlon Flame Color: _____ Chemical X Flame Color: _____

   Chemical Y Flame Color: _____

Name: _____ Section: _____

PART III

Use the mel-temp apparatus for melting point determination. To determine the melting point, place a small amount of crystals into a thin-walled capillary tube (about 0.7–1.0 cm). Place the tube into the mel-temp apparatus, turn it on, and record the temperature range at which the sample melts. You can heat quickly to start, but when you get near the melting point (10 – 20 ^{o}C), lower the rate of heating so you can get a more accurate reading. If you don't know the melting point, you can do one fast run to get an approximate reading, then do a more careful and gradual second run. Please note that you cannot rerun a sample once it has melted.

The melting point of compound Y is close to 300 ^{o}C. Do NOT attempt to take its melting point as the electronic thermometers will fail at such a high temperature.

While you are testing compound X, also test 4-aminobenzoic acid and phenacetin to calibrate your results. The Mel-temp will run three samples at the same time. Perform two separate trials for each substance. These two values should be within 3^{o} of each other.

	Trial 1	Trial 2	CRC Handbook
4-Aminobenzoic Acid	_____	_____	_____
Phenacetin	_____	_____	_____
Compound X	_____	_____	_____
Compound Y	*(not experimentally measured)*		~300 °C

PART IV

Dissolve about 0.2 gram of compounds X and Y separately in a 100 mL beaker containing 40 mL DI water. Use these solutions for all tests in this section.

Compare the solubility of X and Y in water.

X: Y:

Use pH paper to determine the pH of both solutions: X: _____ and Y: _____

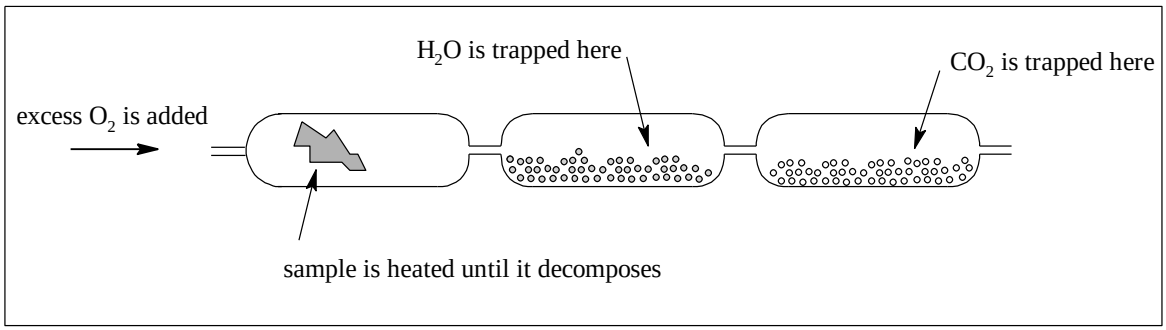
To each solution add a small quantity of Na_2CO_3. What happened? What class of compounds causes sodium carbonate to react this way?

X: Y:

Name: _____ Section: _____

PART V

The empirical formula of an organic compound can be determined via combustion analysis. A typical combustion apparatus is shown below:



A sample of the chemical is burned in oxygen in a tube packed with copper oxide to ensure complete combustion. The carbon in the compound is converted to CO_2, which is absorbed in a tube packed with ascarite. The hydrogen is converted to water vapor and is absorbed in a tube packed with drierite. The increase in weight of the absorber tubes corresponds to the CO_2 and H_2O produced during combustion. Compounds X and Y do NOT contain any nitrogen, sulfur, or halogen atoms; both compounds do contain oxygen.

A 1.0542 g sample of X was burned in a combustion apparatus. The results were:

Weight of ascarite tube before combustion	75.2382 g
Weight of ascarite tube after combustion	76.8377 g
Weight of drierite tube before combustion	81.4128 g
Weight of drierite tube after combustion	81.7418 g

Given this data, calculate the empirical formula of compound X: _____

A 1.4745 g sample of Y was burned in a combustion apparatus. The results were:

Weight of ascarite tube before combustion	80.7821 g
Weight of ascarite tube after combustion	83.0196 g
Weight of drierite tube before combustion	78.2988 g
Weight of drierite tube after combustion	78.7560 g

Given this data, calculate the empirical formula of compound Y: _____

Name: _____ Section: _____

PART VI

Before you can titrate your unknowns, you need to first determine the exact molarity of the NaOH solution you are going to use, a process known as standardization. Sodium hydroxide solutions often change concentration if they are exposed to air for long periods, and they are usually checked when first made and after a few days of use.

1. Pour about 150 mL of the approximate 0.2 M NaOH solution into a clean, dry 250 mL beaker which is labeled NaOH. Fill a clean buret with this solution.

2. Into a clean 125 mL Erlenmeyer, place about 0.5 g of KHP acid (KHP = Potassium Hydrogen Phthalate = $KHC_8H_4O_4$; MW of KHP = 204.2 g/mol). Record the exact amount of KHP in the flask.

3. Dissolve the KHP acid in your flask in about 30 mL of DI water. Add about 3 drops of phenolphthalein indicator to the flask.

4. Take the initial buret reading of the level of NaOH, and slowly add NaOH to the flask from the buret. Swirl flask continually. The solution will change from clear to light pink in exactly one drop, so watch closely. If the color disappears with swirling, then you have not reached the endpoint. A dark pink color indicates you have passed the endpoint. When you think you are close to the endpoint, begin to add the NaOH one drop at a time. Record the exact volume of NaOH solution added.

5. Repeat the titration until the molarity is consistent within 0.004 M.

<u>Data for Part VI Standardization:</u>

Recall that at the endpoint, moles OH^- = moles H^+. Because each mole of KHP contains one acid group, the moles of H^+ = moles KHP.

Mass KHP acid	_____	_____	_____
Moles KHP acid	_____	_____	_____
Volume of NaOH added	_____	_____	_____
Molarity NaOH	_____	_____	_____

Average Molarity (Use values within limit) _____

Name: _____ Section: _____

Now knowing that both compounds X and Y are acidic, you can titrate each using your previously standardized NaOH solution. Moreover, if you could determine the molecular weight using another technique (Part VII), you can ultimately determine how much mass of the compound is "attached" to each acidic proton. This is known as the "gram equivalent weight".

1. To an empty 250 mL Erlenmeyer flask, add about 0.20 grams of X to the flask (record its exact mass).

2. To the flask, add about 30 mL of DI water and 3 drops of phenolphthalein indicator. Titrate the sample with standardized NaOH solution. The endpoint will be a faint pink color that persists for more than 30 seconds.

3. Repeat the titration until you get two consistent results (within 2%), and compare the mass X / mole H^+ values.

Data for Part VI Titration of Compound X

Mass X	_____	_____	_____
Volume of NaOH added	_____	_____	_____
Moles OH^-	_____	_____	_____
Moles H^+	_____	_____	_____
Grams X per mole H^+	_____	_____	_____
Average grams X per mole H^+ (Use values within limit)		_____	
Mole H^+ per mole X (Must know molecular weight from Part VII)		_____	

Name: _____ Section: _____

Repeat the titration using compound Y. Compound Y titrates slowly, and it may take longer for the pink color to persist as Y will still be dissolving during the titration. You may wish to start the titration before Y has completely dissolved. It should dissolve before you are halfway through adding the NaOH solution.

Data for Part VI Titration of Compound Y

Mass Y	_____	_____	_____
Volume of NaOH added	_____	_____	_____
Moles OH^-	_____	_____	_____
Moles H^+	_____	_____	_____
Grams Y per mole H^+	_____	_____	_____

Average grams Y per mole H^+
(Use values within limit) _____

Mole H^+ per mole Y
(Must know molecular weight from Part VII) _____

Name: _____ Section: _____

Data for Part VII

Mass of compound X _____

Mass of H_2O _____

	Trial 1	Trial 2
Freezing temperature of pure water	_____ =	_____
Freezing temperature of solution	_____	_____
ΔT_f	_____	_____
Molecular weight of compound X	_____	_____

Average Molecular Weight (values must be within 10%): _____

PART VIII

Chemists generally turn to instrumentation first in most research and industrial settings. In this section, you are going to use two techniques to investigate your compounds.

Mass Spectrometry (MS) is a powerful technique that gives you the molecular weight of most compounds quickly and accurately. It is easy enough to employ that it is used for multiple purposes, for example, to scan luggage for explosive residues in airports. Analysis of the small fragments and exact patterns of the mass spectra is difficult, but finding the molecular weight of the compound is usually trivial. A mass spectrum features various mass-to-charge ratios of charged particles, where unknown compounds are identified by their fragmentation patterns. For this lab, you are looking for the *molecular* (or *parent*) *ion* which corresponds to the unknown compound's molecular mass. It is important to note (as you will see) that the molecular ion can be weak with a small height on the actual spectrum; don't assume that the largest peak present in your spectrum necessarily corresponds to the molecular ion peak. Consider the following: does your average molecular weight value from Part VII correlate with any peaks in your mass spectra in Part VIII?

Infrared Spectroscopy (IR), which is more difficult to interpret, gives you information about which type of functional groups are present in a molecule. By comparing peaks to known values, you can determine if your molecule has those types of functional groups.

On the next page are the MS and IR for both compounds. Your instructor will give you guidance about the level of interpretation that is expected. You can find databases of spectra from the SDBS (spectral data base system from Japan's AIST) online to compare these spectra to.