CH 111 Lab Schedule Fall 2022

Module 1: Density and Measurement

Week of August 30 (Week 1) Sink or Float: A study of bowling balls and eggs

Week of September 6 (Week 2) Coke vs. Diet Coke

Week of September 13 (Week 3) Determination of Sugar Content in Sodas using Density

Module 2: Synthesis and Empirical Formulas

Week of September 20 (Week 4) Synthesis of Model Compounds

Week of September 27 (Week 5) Synthesis of Amino Acid Complexes

Week of October 4 (Week 6) Titration and Spectroscopy of Model Compounds

****Module 1 Report due Sunday, October 9, by 11:59 pm****

Week of October 11 (Week 7) Titration and Spectroscopy of Amino Acid Complexes

Module 3: Calorimetry

Week of October 18 (Week 8) Introduction to Calorimetry

Week of October 25 (Week 9) The Acidity of Vinegar

Week of November 1 (Week 10) What Properties Make a Good Fuel?

****Module 2 Report due Sunday, November 6, by 11:59 pm****

Week of November 8 (Week 11) Molecular Modeling

Week of November 15 (Week 12) Group Work on Poster (Last lab period)

****Module 3 Poster due Sunday, November 20, by 11:59 pm****

Laboratory experiments may not be made up after your assigned lab period. If you have an excused absence (such as participation in a college sports event) you must make arrangements with your laboratory instructor in advance of the lab you will be missing. If you are ill and feel that you cannot attend lab, you must email your lab instructor before the beginning of the lab period and obtain a doctor's excuse before you will be able to make up the experiment. Any unexcused late lab reports will have significant points deducted.
Many experiments have a pre-lab assignment that will be checked at the beginning of the laboratory period. It is important that you have read the appropriate sections of your lab manual and prepared your lab notebook prior to coming to class.

Grading

Your lab grade constitutes 25% of your grade in General Chemistry. A neat, legible notebook is a critical aspect of laboratory work. Your work must be legible not only to yourself but to others who may depend on its contents. Each lab, students will turn in the yellow copy pages from your lab notebook for grading along with any graphs or tables you made on the computer. These are due at the beginning of the next week's lab period. Points can be deduced from your weekly lab report grade if you do not clean up your lab area. **Late papers and reports will lose 10% credit for every day late.** Below is an estimation of how your grade will be calculated.

Weekly Lab Reports and Prelab 9 (all equally weighted)	35%
Prelabs 1-8 and 10-12 (all equally weighted)	10%
3 Module projects (all equally weighted)	55%

Honor Code

Students are expected to abide by all aspects of the Honor Code in the laboratory work. Although you may seek assistance in your pre-lab or conclusion questions, the work you turn in must be your own. You cannot copy responses from others including classmates or former students. The data you present in your laboratory notebook, weekly reports or lab papers, must be the actual data collected by you or your lab group. If you have permission from your instructor to use data from another source, you need to cite that source in both your lab manual and any written reports. Students **should not** use laboratory reports or papers from previous classes as a guide for their work. If you are using sources for background material in your lab reports, it needs to be properly cited. If you need clarification about the assignment, contact your instructor.

BIRMINGHAM SOUTHERN COLLEGE
DEPARTMENT OF CHEMISTRY AND PHYSICS
LABORATORY SAFETY AGREEMENT
(Student's copy)

At all times, while working in or visiting the chemistry laboratory, I will practice the following safety precautions:

1. Know the exact location of all safety equipment.

2. Never work in the laboratory alone without the knowledge of a member of the chemistry faculty or a qualified TA. A member of the faculty must be present in the department whenever students are in the laboratory.

3. Do only the assigned experiments, following the designated procedure.

4. Wear departmentally approved eye protection at all times. Departmentally approved eye protection is stamped with the code "Z87.1-1987" and may be purchased from the bookstore or will be provided in the form of safety goggles. Eyeglasses do not qualify as departmentally approved safety glasses.

5. Wear sensible clothing as it may be subjected to spills that will stain or burn the clothing. Also, sandals, perforated, or open-toes do not provide adequate protection from spills. Confine long hair. Wear pants.

6. Keep the laboratory bench free of items not related to the experiment as they may be subject to damage, or may increase the likelihood of an accident.

7. There will be no eating or drinking whatsoever in the laboratory. Also, be aware that anything comes into contact with your mouth or eyes (such as fingers) may be contaminated with laboratory chemicals.

8. Dispose of waste materials as directed by your instructor. If unsure whether it is safe to dispose of something in the sink, ask.

9. Use the fume hood when the experiment involves noxious vapors.

10. Do not use mouth suction when pipetting or starting a siphon.

11. Be aware that any object you touch may be hot.

12. Read the label on the bottle or container to be certain that it contains the desired chemical.

13. Clean the work area before leaving the lab every day. Spills or traces of chemicals left on a bench top pose a risk to the next student that uses that work area.

14. No horseplay in the lab.

15. Report all accidents that result in injury, no matter how minor, to the instructor immediately.

16. Consult a physician if you are pregnant or have any other medical condition that might render you susceptible to exposure to the chemicals used in this laboratory.

I have read the safety precautions on the front of this page and understand their importance for the safety of others and myself in the laboratory.

Course and Lab Section _____

Signature _____ Date _____

_____ (Print)

BIRMINGHAM SOUTHERN COLLEGE
DEPARTMENT OF CHEMISTRY AND PHYSICS
LABORATORY SAFETY AGREEMENT
(Instructor's copy)

At all times, while working in or visiting the chemistry laboratory, I will practice the following safety precautions:

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Course and Lab Section _____

Signature _____ **Date** _____

_____ (Print)

CH 111 Guidelines for Laboratory Notebooks

For this class, you will need a carbonless duplicate copy laboratory notebook that can be purchased in the bookstore. You will need to bring this to lab each week and if you do not have it, your lab score will be lowered by 25% that week. It is not acceptable to do your work on paper and then transfer it to your lab notebook after class. All laboratory work must be recorded in your notebook. These lab notebooks make carbonless copies of your work. All students will be required to turn in the copy at the end of the lab period. Follow the guidelines listed below for your lab notebook:

- ➢ Be sure to use the cardboard cover under the page while you are writing in your notebook. If you forget, you will ruin the copy pages for future work.
- ➢ Never tear out a page in your laboratory notebook. The pages are numbered and if pages are missing you will lose points. If you make a mistake, you simply cross through your work and begin again.
- ➢ Do your work in pen (no lead pencil) so that you get a clean copy. The copy is what will be graded; so be sure it is clear and readable. If you make a mistake, simply cross it out neatly with **a single line** through the error.
- ➢ Each week update the table of contents in the front of the lab notebook.
- ➢ When you have tables or graphs that are made using a computer, be sure to save a copy to a portable digital memory device (ie, flash drive) with the folder location and document title written in your notebook. Make a hard copy to turn in with your carbon copies.

Each week your laboratory notebook will have the following format:

Heading: Title, Date, Name of lab partner(s).

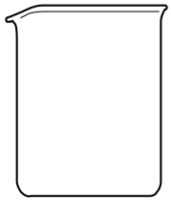
Procedure: Write out a detailed stepwise procedure for your measurements. Be sure to give enough details that someone reading it can repeat your procedure. If you prepare this section before doing the experiment, leave enough room to make modifications if needed.

Data: Typically this section will consist of tables of experimental data you collect. Be sure all data is labeled with correct and complete units and recorded with proper significant figures.

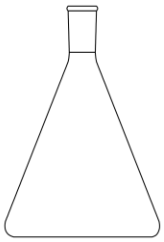
Calculations and Results: Show your calculations. Be sure to give any formulas you used, clearly define the variables, and show at least one example of each type of calculation using number substitutions. All calculations should include proper units. Calculate the standard deviation of all repeated measurements. All final results should be circled and have the proper units. You should include the results of your work and any accumulated results of the class. These will often be in the form of a spreadsheet, graph, or table.

Conclusions: Most weeks you will have questions to answer for this section. Answer in complete sentences so that someone could understand the answer without reading the question.

General Chemistry Equipment List

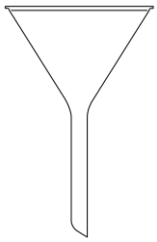


Beaker

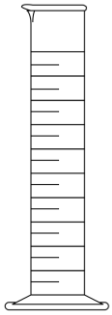


Erlenmeyer Flask

Wash Bottle

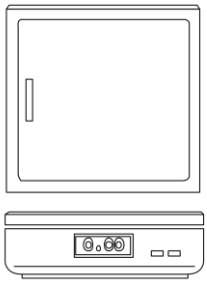


Funnel

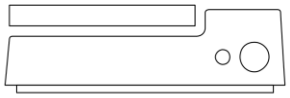


Graduated Cylinder

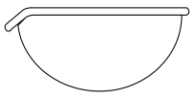
Buret



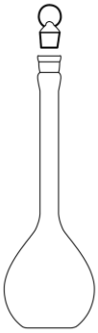
Electronic Balance



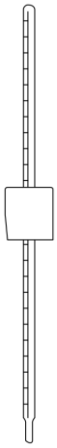
Stirrer/Hot Plate



Evaporating Dish



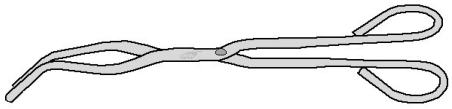
Volumetric Flask



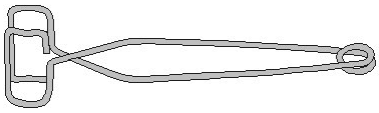
Thermometer

Pipet

Watch Glass



Crucible Tongs



Wire Test Tube Clamp

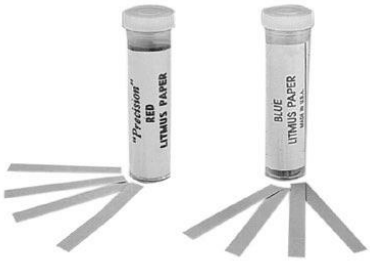
Dropper Bottle

Glass Stirring Rod

Spatula

Stir Bars

Test Tube Brush



Red and Blue Litmus Paper

CH 111 Laboratory Module 1

Density and Measurement

Week 1: Sink or Float: A Study of Bowling Balls and Eggs

Week 2: Coke vs. Diet Coke

Week 3: Determination of Sugar Content in Sodas Using Density

Skills for this module: In this module you will perform a variety of measurements and draw conclusions based on the resulting data. In the process you will learn the following techniques:

1. Determination of volume using a graduated cylinder, a pipet, and a buret.
2. Using standard deviation to determine precision of measurements.
3. Using a spreadsheet to graph data and perform calculations.
4. Using a standard curve for determining an unknown value.

Outcomes: By the end of the module you should have:

1. Determined the relationship between mass and volume of an object.
2. Determined the relative accuracy and precision of a variety of glassware.
3. Determined the relative density of Coke vs. Diet Coke.
4. Determined the sugar content of a variety of drinks using a standard curve.

Final Product: At the end of this module, you will submit a modified lab report that describes the results you obtained in Weeks 2 and 3, as well as a discussion of them. See page 29 for more information.

You will record your data in table-form in your notebook, and you will create graphs with said data using Excel. Each table/graph should include:

Table	Graph
(i) Title	(i) Title
(ii) Column Headings	(ii) Axes labels
(iii) Caption	(iii) Caption
(iv) Author	(iv) Author
(v) Lab partner	(v) Lab partner
(vi) Date	(vi) Date

CH 111 Laboratory Module 1: Density and Measurement

Week 1: Sink or Float?

Objective: In this week's experiment we are going to investigate factors which determine whether an object sinks or floats.

Prelab assignment: Complete the questions on pages 15-16 to be turned in at the beginning of the lab period. You will also need to read over this week's lab.

Skill Box: Calculating Standard Deviation

When you have a set of data, one important piece of information is the precision of the measurements. The precision tells you how large the deviation of the data is from the average value. To report the precision of your data you need to determine the standard deviation.

1. First determine the average or mean, $\bar{x}$, of your data set. Add your values and divide by the number of measurements.
2. Then find the deviation for each measured value by subtracting the mean from each value.
3. Square each of the deviation values (this eliminates any negative signs) and add them up.
4. Take the value from step 3 and divide by the total number of measurements minus 1. Then take the square root of this value. This is your standard deviation. Most calculators have a standard deviation function that you can use. You can also use excel using a formula (STDEV).

Example:

Data	Deviations	(Deviation)^2
12.11	12.11 - 12.14 = -0.03	$(-0.03)^2$ = 0.0009
12.15	12.15 - 12.14 = 0.01	$(0.01)^2$ = 0.0001
12.12	12.12 - 12.14 = -0.02	$(-0.02)^2$ = 0.0004
12.17	12.17 - 12.14 = 0 03	$(0.03)^2$ = 0.0009
12.14	12.14 - 12.14 = 0 00	$(0.00)^2$ = 0.0000
60.69		0.0023

$$\sqrt{\frac{0.0023}{4}} = 0.024$$

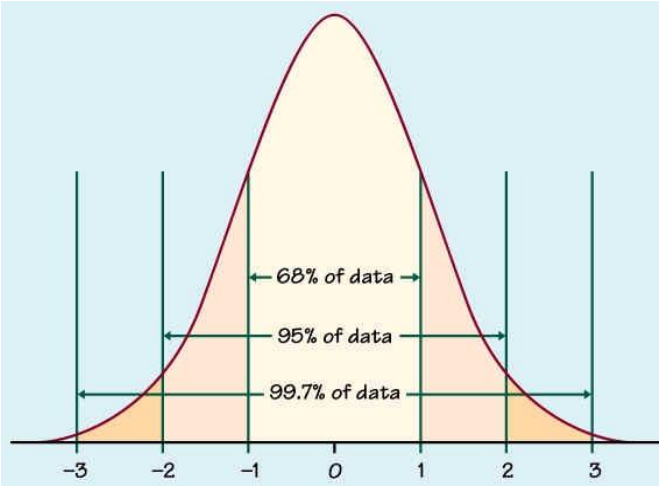
60.69/5

$\bar{x}$ = 12.14

This measurement would be reported as 12.14 $\pm$ 0.024 (the 0.004 is not significant but one extra figure is usually carried for statistical purposes). It would also be appropriate to report the measurement as 12.14 $\pm$ 0.02. The standard deviation is a quantitative measure of the spread of the data. The larger the spread of the data, the lower the precision.

Below is a normal distribution (or bell-shaped curve) for a set of data illustrating the percentage of the data captured by the standard deviation. For a normal distribution of data, 68% of the values are expected to be one standard deviation from the mean (+ or -), 95% is expected to be within two standard deviations, and 99.7% is expected to be within three standard deviations.

Therefore, in the example on the previous page, 68% of the data is expected to fall (assuming a normal distribution) within 12.12 and 12.16.



Name_____ **Lab section**_____

Prelab for Week 1 (turn in this page at beginning of lab):

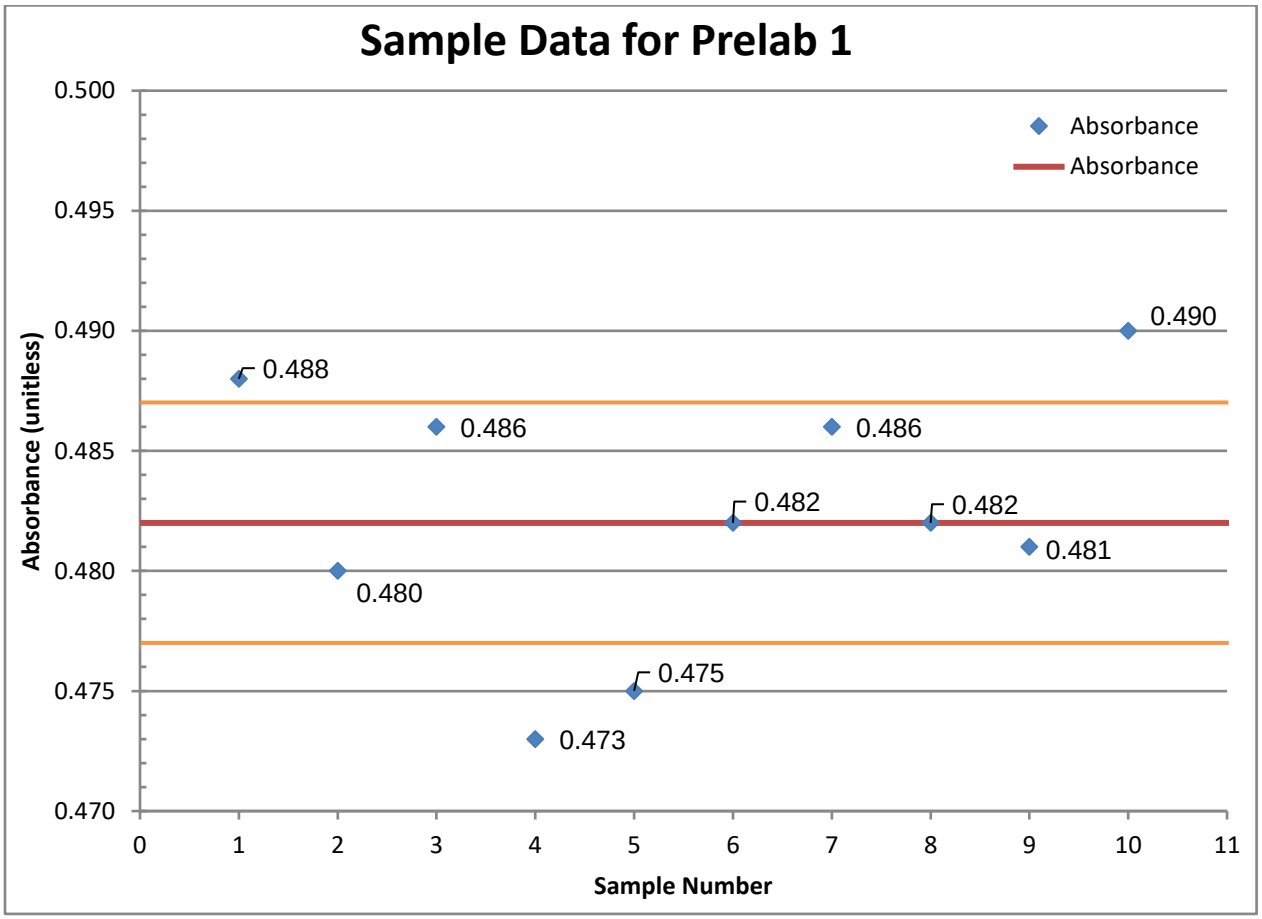
1. Given the following data, calculate an average and standard deviation for the data set: **Show your work below.**

Sample #	Absorbance
1	0.488
2	0.480
3	0.486
4	0.473
5	0.475
6	0.482
7	0.486
8	0.482
9	0.481
10	0.490

Average = _____ ± **Std Dev =** _____

(*Turn over! More work on back page!)*

2. The following is a plot of the same data as listed in part 1. The average is shown as a straight line through the data. Based on your calculation for the standard deviation of the data set:
(a) Circle all points that fall within one standard deviation of the average.
(b) Put a triangle around all points that were not marked above, but all within two standard deviations of the average.



Part 1: **Will the bowling ball sink or float[1]?**

Bowling balls are rather complicated objects. The outer shell of the ball is made of polyester or polyurethane while the inner core is made of a composite material that is usually proprietary. The core of the ball has a block made of denser material to compensate for the loss of mass due to the drilling of holes. Depending on the positioning of the denser material, the ball may rotate differently causing it to hook.

You and your lab group will be assigned a bowling ball. You will be provided scales, string, and rulers. Use these items to design a procedure and collect data to determine whether your ball will sink or float in tap water. You must do this without actually putting the bowling ball in water. Once all group members have written up a procedure in their lab notebook, you should have it approved by your instructor before proceeding. You can request additional materials from your instructor if needed. Each measurement should be performed independently by each group member and recorded in your notebook as data. Record all your calculations and results in your notebook as well (see notebook instructions below). Record your prediction in your notebook. The average of your group's values, and your prediction, will be added to the class spreadsheet. You will test your prediction by placing your bowling ball in water at the end of part 1.

WARNING: Bowling balls are heavy and can easily roll. Do not place your bowling ball on the lab bench without securing it and do not place bowling balls on the electronic balance.

Lab notebook instructions for Part 1:
Heading: Title, Date, Lab partners

Procedure: Write out a detailed stepwise procedure for your measurements. Be sure you have enough detail that someone reading it could repeat your procedure.

Data: Record the measured data that you and your group members collect on your bowling ball. You should do several trials to confirm your measured values. All data should be in proper units and significant digits.

Calculations and Results: Show your calculations with number substitutions. Be sure to give any formulas you used and clearly define the variables. All calculations should include proper units and significant digits with **final values circled**. Based on your calculations, what do you predict will happen? Record your prediction and actual result in your lab notebook.

Conclusions Part 1:

a. Did all the floating bowling balls have the same amount of ball above the surface of the water? What determines how much of the ball is above the water?
b. Identify two sources of error. Sources of error are sources of uncertainty in your **measurements**. Every measurement, no matter how precise we might think it is, contains some uncertainty, simply based on the way it is measured. Accordingly, calculation mistakes and not following the procedure do not count as sources of error.
c. Which of the two measurements, mass or volume, limits the precision of your final value? Explain your answer.

[1] Adapted from Holley, K.; Mason, D.; Hunter, K. *J. Chem. Educ.* **2004**, 81, 9, 1312

***Part 2*: The Floating Egg**[2]

You and your group will need to determine the density of an egg using a salt solution. When the density of the egg and salt solution are the same, the egg will begin to float. This means the top of the egg will touch the top of the solution without any significant portion of the egg protruding from the surface.
To measure volume, you will use a **graduated cylinder**. Be sure to carefully look at the markings on the cylinder. The liquid in the cylinder will dip slightly towards the center forming a **meniscus.** You should measure the volume from the bottom of this meniscus. Note that the last value you record will be estimated between the graduated markings. Be sure you record all measurements to the proper accuracy in your lab notebook.

To measure the mass, you will use an **electronic balance**. This is a very delicate (and expensive) piece of equipment that needs to be treated with care. You will use weigh boats to hold the chemicals you are massing. **Do not add chemicals to the weigh boats while they are on the balance.** If you need to add more of a substance, first remove the weigh boats from the balance before adding. If you do spill some chemicals on the balance, please contact your lab instructor or TA immediately so that it can be cleaned up. Even simple table salt can corrode the balance if left there for any significant period of time.

Plan your experiment with your lab group. Seek approval from your instructor before beginning. Record your final values in the class data *Excel* spreadsheet table on the computer. Calculate the standard deviation of the class data (see skill box on pages 13-14).

Lab notebook for Part 2:
Heading: Title, Date, Lab partners

Procedure: Write out a detailed stepwise procedure for your measurements. Be sure to have enough detail that someone reading it could repeat your procedure.

Data: Record the measured data that you collect on your solution. Be sure all measured values are given to the proper significant digits and have units.

Calculations and Results: Show your calculations with number substitutions. Be sure to give any formulas you used and clearly define variables. All calculations should include proper units and significant digits and your **final values circled**. Record the density of your egg in your lab notebook. Record the mean and standard deviation of the class density values.

Conclusions for Part 2:

- **a.** Quantify (compare numerically) the differences between your egg density and that of the class. Is your density within one standard deviation of the class standard deviation? Explain any differences you may observe.
- **b.** Look at the different masses and volumes measured by your classmates. Do you observe the same variation in calculated egg density? Explain why this is the case.

[2] Adapted from Wink, D. J.; Gislason, S. F.; Kuehn, J. E. *Working with Chemistry; A Laboratory Inquiry Program;* W. H. Freeman and Company: New York, 1999.

c. Would you conclude the variation in the egg density is due more to differences between the individual eggs or differences in the measurements taken by your class members? Explain.

d. Which of the two measurements, mass or volume, limits the precision of your final value? Explain your answer.

e. If you assume that the mixture of salt and water in the ocean is homogeneous, is it possible to measure the density of the salt water in the ocean? How?

CH 111 Laboratory Module 1: Density and Measurement

Week 2: Coke vs. Diet Coke[3]

Objective: In this experiment you will determine the densities of Coke and Diet Coke. You will also determine how the density varies with sample size.

Prelab assignment: Before coming to lab you should read over the lab and prepare a procedure and data tables in your notebook. Be sure to leave space for making additions or corrections to your procedure. You will need to save your data electronically so bring a flash drive to lab.

To practice using Excel, watch the following video: https://www.youtube.com/watch?v=-KRtKU98i50 (link is also posted on Moodle). Using the instructions, make a scatterplot for the following Coke data:

volume (mL)	mass (g)
10.00	10.398
14.00	14.222
16.00	16.687
20.00	21.042
24.00	25.102

- Be sure that volume is on the x-axis and mass is on the y-axis
- After you have made the scatterplot, fit the data using a trend line and have the equation for the line displayed on the graph. Be sure to also add the R^2 value.
- Label your axes with units.
- Give the graph an appropriate title that will provide another person (who is not in this lab) with enough information to understand what the graph is showing.
- Move the graph to its own page and print the graph on a full page to be turned in for your pre-lab.

Part 1: Does glassware impact a measurement?

Your group will be given a sample of degassed Coke and Diet Coke. You will determine the volume of the two samples using three different types of glassware: a pipet, a buret, and a graduated cylinder. Your instructor will demonstrate how to use each piece of glassware. The masses of the beverages will be measured using an electronic balance. Be sure to record all measured values to the proper number of significant digits.

Each student should measure out 25 mL of Coke or Diet Coke using each piece of glassware for a total of 3 samples per student. You may want to practice using the pipet several times with water before doing your measurements on the soda samples. Your data table for Part 1 should include columns for recording the mass of the empty beaker, mass of beaker and soda, mass of

[3] Adapted from Herrick, R. S.; Nestor, L. P., Benedetto, D. A. *J. Chem. Educ.* **1999**, 76, 10, 1411

soda, and volume of soda for each sample you measure. Make sure you record your volumes with the correct number of decimals.

Calculate the densities of each sample from the measured mass and volume. Be sure to designate which piece of glassware was used to measure volume in each case. Add your group data to the class database. From the class data calculate the mean and standard deviation for the density based on each type of glassware. Which type of glassware is the most precise? List in your lab notebook any observations and conclusions you can draw from the class data.

Laboratory notebook outline for Part 1:

Heading: Title, Date, Lab partners

Procedure: Write out a detailed stepwise procedure for your measurements.

Data: Make a data table for the masses and volumes of each of your samples using each piece of glassware. Record data with proper number of significant digits and units.

Calculations and Results: All calculations should include proper units with **final values circled.** Be sure to record the mean and standard deviation of the class values. The class data will be posted on Moodle for use in your module lab report.

Conclusions:

a. Quantify (compare) numerically the differences between your data and that of the class. Be clear in your answer by stating what samples you are comparing and including the class standard deviation in your response. Explain any differences you may observe.
b. Which beverage is the most dense? Give possible explanations for this.
c. Which glassware gives the most precise values for density? How did you determine this?
d. Which features of the glassware account for the differences in precision seen for the different types of glassware? Comment on how these differences are affected by both instrumentational design and ease of use.
e. Is it possible for a measuring device to be precise but not accurate? Explain.

Part 2: **Does density vary with sample size?**

Each group will determine the density of Coke *or* Diet Coke (to be assigned by your instructor) using a variety of different sample sizes. Each student will need to collect at least three different data points at three different volumes for your assigned beverage. All of the volume measurements within a group must be different. Therefore, if you are in a group of two, you will have six different volume measurements. Which glassware should be used to measure volume? What would happen to the significant figures of your calculated density if you use a volume less than 10.00 mL? Decide as a group how you will collect the data. Record the data you collect in your lab notebook and make an Excel spreadsheet including all the data for your group. Calculate the average density and standard deviation of your group data using the spreadsheet.

Be sure to record all measured and calculated values using the correct number of significant digits.

As a group you need to decide the best way to graph the data to present your results. You need to show how the mass varies with sample volume. When making graphs, the variable that you control in the experiment is called the independent variable and should be graphed on the X-axis. The measured variable that results from your independent variable is called the dependent variable and is plotted on the Y-axis. Fit your data to a trendline (line of best-fit) and display an equation for the line with an R^2 value. The R^2 value is called the coefficient of determination. If $R^2 = 1$, the measurements all fall on the trendline (and therefore is considered a perfect fit). The closer R^2 is to 1, the better the trendline fits the data. Record your average density value on the class data table to compare your values with those obtained by other groups.

Clean Up
All solutions can go down the sink. Be sure to rinse your glassware well with distilled water (faucet with white handle). **Do not remove burets from stand** but instead rinse them with squirt bottles. Store them upside down on the stand with stopcock opened.

Laboratory notebook outline for Part 2:

Heading: Title, Date, Lab Partners

Procedure: Write out a detailed stepwise procedure for your measurements.

Data: Make a data table for the mass and volume of each of your samples in your lab notebook. Include all data from your group on a spreadsheet. Be sure all data has units.

Calculations and Results: All calculations should include proper units. For any multiple measurements, you should calculate the average and standard deviation (can be calculated in Excel). Include a plot for your group's data. Graphs must include a meaningful title and the axes must be labeled with units. A copy of the plot should be saved and **one printed copy turned in with your carbon copies**. Add your results to the class data spreadsheet, and record the class average and standard deviation for your beverage in your notebook.

Conclusions:

- **a.** Quantify (compare) numerically the differences between your data and that of the class. Explain any differences you may observe.
- **b.** What does the R^2 value for your linear fit tell you about your data.
- **c.** Does the density of a substance depend on the sample size? Explain based on your data and what you know about density.
- **d.** How can you determine the density of your beverage using your graph? Compare your calculated average density with the value from your graph. Which method of determining density do you think is better and why?

CH 111 Laboratory Module 1: Density and Measurement

Week 3: Determination of Sugar Content in Commercial Beverages[4]

Objective: In this experiment you will use density to estimate the sugar content in a variety of commercial beverages. By comparing your values to those given on the label, you will determine how accurate your estimates are.

Prelab assignment: This week you will be using density to determine the amount of sugar in commercial beverages. Before lab you will need to do the following in your notebook:

1. Write up a procedure to make your standard sugar solutions. The solutions are named "standard" because the amount of sugar in each is known. You will need 4 solutions in the range of 4.0-18% sugar by mass using 50 mL of water. You will be provided with 10- and 25-mL pipets, a buret, and the glassware in the drawers. **Calculate the specific amount of sugar you will use in each sample and show your work**. Record this information and calculations in your lab notebook before lab. You may assume that the water you use to make up the solution has a density of 1.00 g/mL. An example calculation for a 2.00% sugar by mass solution is provided below.

$$\text{Mass \%} = \frac{\text{mass solute}(\mathbf{sugar})}{\text{total mass of solution } (\mathbf{sugar} + \mathbf{water})} \times 100$$

To calculate the amount of sugar (x) needed to make a 50.0 mL 2.00% by mass sugar solution:

$$2.00 = \frac{\text{x}}{\text{x} + 50.0} \times 100$$

Divide both sides by 100 to get,

$$0.0200 = \frac{\text{x}}{\text{x} + 50.0}$$

Multiply both sides by (x + 50.0) to get,

$$(\text{x} + 50.0)\ 0.0200 = \text{x}$$

Multiply (x + 50.0) by 0.0200 using distribution to get,

$$0.0200\text{x} + 1.00 = \text{x}$$

Subtract 0.0200x from both sides to get,

$$1.00 = 0.980\text{x}$$

Divide both sides by 0.980 to get,

$$\text{x} = 1.02\ \text{g}$$

(*Turn over! More work on back page!)*

[4] Adapted from Henderson, S. K.; Fenn, C. A.; Domijam, J. D. *J. Chem Educ.* 75, 9, 1122.

2. A 12.0 fl. oz. can of Coke contains 39.0 grams of sugar. Assuming that sugar and water make up the vast majority of the mass, what is the mass % of sugar in Coke? The Coke has a density of 1.040 g/mL. Note that a fluid oz is a unit of volume and is not the same as an ounce used to measure mass. **Show all work** including any equations or conversion factors you use.
3. Find, and write in your notebook, a definition for the scientific term "aliquot".
4. Bring in a commercial beverage in which sugar is the primary ingredient. This can be a soda, sports drink, or fruit juice (without pulp). **The second ingredient (after water) should be high fructose corn syrup or sucrose.** A 12-oz or 20-oz sample is sufficient.

In class:
If you are testing a carbonated drink, you will need to degas it by stirring it on a stir plate until the bubbles are gone. To degas, use a beaker or flask and cover it with a watch glass. This should take about 20 minutes, so go ahead and do it at the beginning of lab.

You will discuss your approach for making up your standard sugar solutions as a class at the beginning of lab. You will then discuss what 4 solutions to make with your group. Do not choose % sugar values that are clustered close together; spread them out in the 4-18% range. In your notebook, record any corrections or adjustments from your prelab. Note that any changes must be made on a new notebook page so that the copy can be turned in. Then make 4 different sugar solutions and record the exact amount of sugar used in your notebook. Be sure all of the sugar is dissolved before doing any measurements. Calculate percent sugar using the exact amount of sugar used. For each standard solution you will need to determine the density of **three separate aliquots** of the solution. Discuss with your group the best way to do this. After recording data in your notebook, your group should use a spreadsheet for organizing your data and doing calculations. Prepare a graph including all of your data and do a linear fit (trendline) of the data (see page 28 as an example). Convert the equation to scientific notation to obtain proper significant figures. Include the equation for the line and the R^2 value on your graph.

The graph you just created is called a **standard curve**. This information will be used to determine the sugar content of your beverage by measuring its density. You may use the drinks you brought to class or the ones provided in the lab. Be sure your group tests a variety of different beverages, but it is also a good idea for two students in the class to independently test the same beverage (if possible). For each beverage you test, you need to do at least 3 density determinations and calculate an average value and standard deviation. Use the average density and the linear fit equation from your standard curve to calculate the mass % sugar for your beverage. Mark your average density on the best-fit line on your graph and confirm your calculated mass % sugar. From your experimental results, you also need to calculate the grams of sugar per serving. In order to compare class values, we will assume a serving size is 12 fl. oz. In your notebook you should also record the label value for grams of sugar per 12 fl. oz for comparison. If the listed serving size is not 12 fl. oz. you will need to do an additional calculation. Record your results for your commercial beverages (density, mass % sugar, grams of sugar, label value) on a class spreadsheet. As a class, discuss the results and conclusions. Are there any trends in the data? Compare your experimental results to the sugar values given in the nutritional information (actual value) and calculate a % error.

$$\% \text{ Error} = \frac{\text{Experimental Value} - \text{Actual Value}}{\text{Actual Value}} \times 100$$

Note: % error can have a negative value.

Laboratory notebook outline for Week 3:

Heading: Title, Date, Lab partners

Procedure: Write out a detailed stepwise procedure for your work. The procedure for preparing standard solutions should be completed before class followed by the pre-lab question. If any changes were made to your procedure, I must be able to see these (record on new page).

Data: Make a data table for the mass and volume of each of the standards measured by your group and the beverage you independently measured. Be sure to include the name of your specific beverage.

Calculations and Results: Clearly show calculations in your notebook. Be sure to give any formulas you used and clearly define the variables. All calculations should include proper units and significant digits, with **final values circled**. Include the graph for your group's data for the standard curve with the linear fit, equation, and R^2. Mark your average density on the best-fit line on your graph and confirm your calculated mass % sugar. Graphs must include a meaningful title and the axes must be labeled with units. A copy of the plot should be saved and one hard copy turned in with your copies. You must also include a copy of the spreadsheet values that were used to generate the plot. Include your beverage results in a class spreadsheet.

Conclusions: Answer the following in complete sentences:

a. Which drinks had the highest sugar content? Is there a particular category of drink (sodas, sports drinks, juices, etc.) that are higher in sugar content?

b. How did your experimental results compare to the sugar content given on the label (be quantitatively specific, do not just say they were close)? Explain any differences.

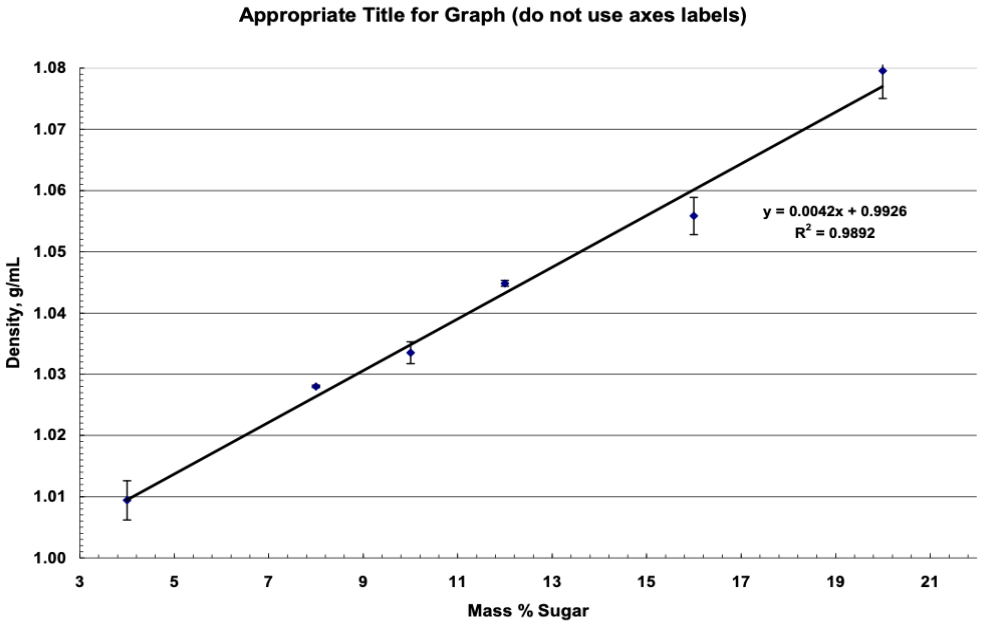
c. What is a standard curve? How did you use the standard curve in this experiment?

d. Based on the class results, is the method used in this lab for determining sugar content in beverages an accurate method? Think about an assumption you made using this procedure. Explain why this assumption is reasonable or not.

e. List potential sources of error. Do not simply state human error. Instead describe the inherent error associated with the instrumentational limits, experimental design, or unfamiliarity with laboratory equipment utilization.

f. If a student does not degas a soda before doing their measurements, do you think the calculated amount of sugar would turn out to be too high or too low? Explain your answer.

Example of Graph Format with a Trendline:



CH 111 Laboratory Module 1 Abbreviated Lab Report

Density and Measurement: Results/Discussion Assignment
Check with your instructor for the due date of this Report.

At the end of Module 1, you will electronically submit an abbreviated laboratory report detailing your results and a discussion of them from Weeks 2 and 3 of this module. The format is as follows:

All sections should be double-spaced.

Title page:
This page should include a meaningful title, class and section, date, full names of lab partners for Weeks 2 and 3. The title page should not be numbered, but all other pages should have a page number.

Results and Observations:

This should give the results of your experiments and **not** be a discussion of why they occurred. The Results and Observations section should have three paragraphs: one for Week 2 part 1, Week 2 part 2, and Week 3. The associated tables or figures for each section should be inserted within each paragraph. Provide details of your results and any observations or problems that were encountered. **You should describe any trends in your data**. Any tables or graphs should have a meaningful title or caption and be clearly labeled (see examples under "Notes"). The reader should be able to independently read the table or graph and get all the information needed without having to read the laboratory report. The results section of your report should **not** simply be a list of graphs and tables; **it should include text that describes what is shown** and addresses the quality of your data. Provide all major calculations that you performed including the equations for density and mass percentage. Avoid using the first and second person unless you are contrasting your group's data with the class data.

There are several specific pieces of data you should be sure to include in this portion of your paper:

Week 2, Part 1:

- Table showing your **group's** density values for Coke/Diet Coke and the **class** averages and standard deviations using the graduated cylinder, pipet, and buret. Note: class averages and standard deviations are included on sheet 1 of week 2 data.
- Figure showing scatter plot of **class** data showing density of Coke and Diet Coke using different glassware. Note: this is the scatter plot on sheet 2 of week 2 data.

Week 2, Part 2:

- Table showing the volume, mass, and density of Coke, Diet Coke, or water from your **group** data. Add class average and standard deviation to bottom of table for comparison. Note: the class average and standard deviation are included on sheet 3 of week 2 data.

- Figure showing the scatter plot with the trendline, line of best fit equation, and R^2 value of the mass vs. volume of your **group's** beverage data (Coke/Diet Coke/water). Note: this is the scatter plot that was turned in with part 2 of your week 2 lab report.

Week 3:

- Figure showing scatter plot for the density vs. mass % standard curve for your **group's** standard sugar solutions. This should include the trendline, line of best fit equation, and R^2 value. Note: this is the scatter plot that was turned in with your week 3 lab report.
- Table of **class** data table showing calculated values of the different commercial beverages studied. Highlight the row showing your group's data. Note: this is the table of class data sent out with the week 3 data.

Hint: You have already created most of these tables and graphs in lab! Just be sure that they are formatted and labeled/captioned properly. (Again, see "Notes.") Make sure you include **correct units** and **sig. figs**. for your values! In your paper there should be no page breaks within tables or graph. Use page breaks before a graph or table if needed. It is better to have some blank space on the page than to have a table or graph split between two pages.

Discussion:

In this section you will discuss your results. **How did your experimental values compare to the expected values?** How did the results compare between different class members? What could account for these differences (**do not just say human error**). In addition, describe how you used the results from each week to design your protocols. Be as specific as possible about any assumptions or approximations you have made in your analysis of results and how they might affect your outcome. Your discussion should be in paragraph form.

Hint: Go back and look through your answers to the Conclusion questions from the end of each week. Incorporate the answers to these questions into your discussion of your results.

Notes:

- Students should review the definition of plagiarism in the BSC Honor Code. If you are uncertain, ask for help at the writing center or from your instructor. Ignorance is not an excuse. **Students should not be using laboratory reports from previous classes as a guide for this assignment**. If you need clarification about the assignment, contact your instructor.

- All tables included in your report should be numbered (i.e. Table 1) and have a meaningful title shown above the table. Table headings are single spaced. See example on the following page.

Table 4. Spectrophotometer readings for water, epicatechin, and tea samples at 750 nm

Sample Tested	**Absorbance**
Water	0.0320
Epicatechin (50 μM)	0.2067
Epicatechin (100 μM)	0.2509
Epicatechin (200 μM)	0.5401
Epicatechin (250 μM)	0.6118
5% Tea	0.1583
10% Tea	0.3148
20% Tea	0.5449

- Graphs and figures **should not be titled at the top or on the graph**, but they should include a detailed caption below. Figure captions are single-spaced. The caption should also include a graph/figure number that follows in succession with the others in your paper.

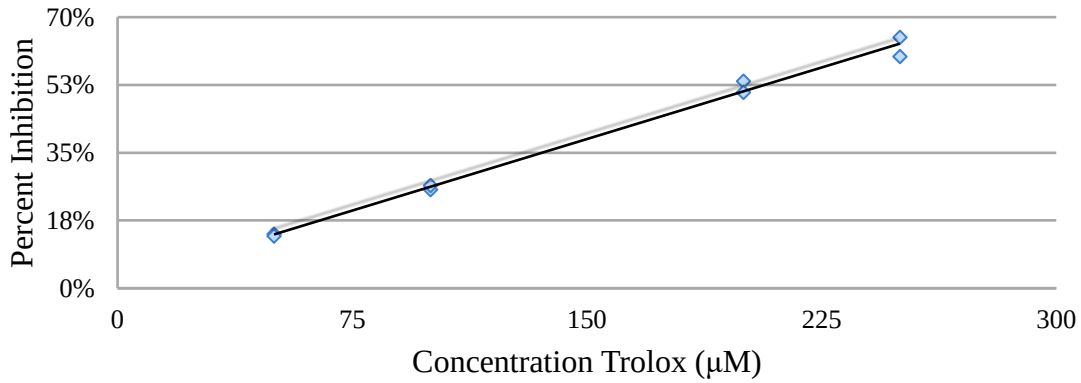


Figure 2. Effect of the concentration of Trolox in a 25-mL sample of black tea on the percent inhibition. Each tea sample was measured in duplicate.

- Table headings and figure captions should be single-spaced. Only the first word should be capitalized in each sentence. Typically, headings and captions do not begin with a complete sentence. Do not begin a caption with "This figure shows...". The caption should be understandable without reference to the text.

- Equations or reactions should be indicated with a number in parenthesis on the right side:

$$\Delta A_{ABTS^{\cdot+}} = A_{735}Control - A_{735}Test \qquad (1)$$

- All tables, graphs, and figures should be referred to in the body of the paper and should not be broken by a page break. The reader should be able to independently read the table or graph and get all the information needed without having to read the laboratory report.

Module 1 Abbreviated Lab Report Grading Rubric

Title page (3 points)

_____ Meaningful title

_____ Full names of all students in your group

_____ Class name and date

Results and Observations (54 points)

***Tables and Graphs* (44 points):**

_____ No page breaks within tables or graphs. (2 points)

A. Table showing your **group's** density values for Coke/Diet Coke and the **class** averages and standard deviations using the graduated cylinder, pipet, and buret. Note: class averages and standard deviations are included on sheet 1 of week 2 data.

_____ Proper sig figs used in table (2 points)

_____ Class average and standard deviation included (2 points)

_____ Proper formatting of table heading (2 points)

_____ Appropriate column headings with units (2 points)

B. Figure showing scatter plot of **class** data showing density of Coke and Diet Coke using different glassware. Note: this is the scatter plot on sheet 2 of week 2 data.

_____ Proper figure caption (2 points)

_____ Axes formatted properly with units (2 points)

_____ Descriptive legend (2 points)

C. Table showing the volume, mass, and density of Coke, Diet Coke, or water from your **group** data. Add class average and standard deviation to bottom of table for comparison. Note: the class average and standard deviation are included on sheet 3 of week 2 data.

_____ Proper sig figs used in table (2 points)

_____ Proper formatting of table heading (2 points)

_____ Appropriate column headings with units (2 points)

_____ Averages and Standard Deviations (group and class) included (2 points)

D. Figure showing the scatter plot with the trendline, line of best fit equation, and R^2 value of the mass vs. volume of your **group's** beverage data (Coke/Diet Coke/water). Note: this is the scatter plot that was turned in with part 2 of your week 2 lab report.

_____ Proper figure caption (2 points)

_____ Axes formatted properly with units (2 points)

_____ Trendline with linear equation and R^2 value (2 points)

E. Figure showing scatter plot for the density vs. mass % standard curve for your **group's** standard sugar solutions. This should include the trendline, line of best fit equation, and R^2 value. Note: this is the scatter plot that was turned in with your week 3 lab report.

_____ Proper figure caption (2 points)

_____ Axes formatted properly with units (2 points)

_____ Trendline with linear equation and R^2 value (2 points)

F. Table of **class** data table showing calculated values of the different commercial beverages studied. Highlight the row showing your group's data. Note: this is the table of class data sent out with the week 3 data.

_____ Proper sig figs used in table (2 points)

_____ Proper formatting of table heading (2 points)

_____ Appropriate column headings with units (2 points)

_____ Student value highlighted. (2 points)

***Text* (10 points):**

This should give the results of your experiments and **not** be a discussion of why they occurred. The Results and Observations section should have three paragraphs: one for Week 2 part 1, Week 2 part 2, and Week 3. The associated tables or figures for each section should be inserted within each paragraph. Provide details of your results and any observations or problems that were encountered. Provide all major calculations that you performed including the equations for density and mass percentage.

<u>Discussion</u> (35 points)

Use the following questions to guide you. Your discussion should refer to the data presented in the results section when addressing these issues. Give quantitative results when appropriate and avoid vague, general statements when analyzing the data.

Week 2 Part 1 **(10 points):**

- How does your group data compare to the class data for Coke and Diet Coke?
- Which beverage is most dense and why?
- Which glassware is most precise and how do you determine this?
- Which features of the glassware account for the differences in precision seen for the different types of glassware? Comment on how these differences are affected by both instrumentational design and ease of use.

Week 2 Part 2 **(10 points):**

- How does your group data compare to the class data?
- What does the R^2 value indicate about the quality of your data?
- How does density depend on sample size? How do you know?
- How can you determine the density of your beverage using your graph? Compare your calculated average density with the value from your graph. Which method of determining density do you think is better and why?

Week 3 **(15 points):**

- Which drinks in class study had the highest sugar content?
- How did experimental results compare to label values?
- Was the method used effective for determining sugar content in drinks?
- What approximations or assumptions are made using this technique?
- Potential sources of error. Do not simply state human error. Instead describe the inherent error associated with the instrumentational limits, experimental design, or unfamiliarity with laboratory equipment utilization.

<u>General</u> (8 points)

_____ Equations included and properly formatted (2 points)

_____ Report double-spaced (2 points)

_____ Proper use of grammar and spelling (4 points)

CH 111 Laboratory Module 2

Synthesis and Empirical Formulas

Week 4: Synthesis of Model Compounds

Week 5: Synthesis of Amino Acid Complexes

Week 6: Titration and Spectroscopy of Model Compounds

Week 7: Titration and Spectroscopy of Amino Acid Complexes

Skills for this module: In this module you will perform a variety of measurements and draw conclusions based on the resulting data. In the process you will learn the following techniques:

1. Preparing and isolating a chemical compound using gravity filtration
2. Preparing and isolating a chemical compound using vacuum filtration.
3. Determining the equivalence point of an acid/base titration.
4. Preparing a standard curve generated by absorbance spectroscopy.
5. Using mass measurements in a gravimetric analysis.

Outcomes: By the end of the module you should have:

1. Synthesized at least one model compound.
2. Synthesized at least one novel amino acid complex.
3. Determined the mass % of each component in the synthesized compounds.
4. Calculated the empirical formula for each synthesized compound.
5. Calculated the % yield for each synthesis.
6. Used the model compounds to predict the formula for the novel amino acid complexes and rationalize this prediction using chemical literature.

Final Product: At the end of this module you will turn in a formal laboratory report for the synthesis and empirical formulas module. The format for your paper is discussed on pages 69-73.

Background for Module 2

One important area of science is bioinorganic chemistry. This field studies the role of metal ions in biology. What is the role of iron in hemoglobin or magnesium in chlorophyll? More importantly for this module, how do metal ions get into living organisms? Roughly speaking, metal ions that are critical for living organisms to function properly are called nutritional minerals. Animals must consume nutritional minerals through a proper diet and plants must have them available through uptake in the soil. Sometimes artificial mineral supplements for humans, animals, or plants can be developed to correct for any deficiencies in natural uptake.

These dietary supplements can take various forms, but the key aspect is that they should be metabolized similarly as when natural forms are consumed. Metal ions found in foods generally exist in a complex matrix of proteins, carbohydrates, and fibers that must be digested properly before the ions can be absorbed. If the metal ions are to be consumed from sources other than food, they must be designed carefully to be **bioavailable**. Nutrition scientists have created several types of metal ion formulations to maximize bioavailability. It is rare that a particular mineral can be supplemented using the metal alone. For example, people would absorb only a small amount of iron by eating metal shavings from iron nails.

Two common approaches are using sugars or amino acids to bind the metal ions. The older approach was to use sugars because it was believed that sugars are metabolized quickly, and the metal ion would be available for cellular uptake quickly. These supplements are referred to as **metal polysaccharide complexes**. Polysaccharides are complex sugars, and metal ions bind to these sugars in a variety of mechanisms including covalent bonds, adsorption processes, and ion-dipole attractions. Although polysaccharides are cheap and easily available for use in nutritional supplements, the complexity of their binding to metal ions makes it difficult to design mineral supplements in a rational fashion other than trial and error.

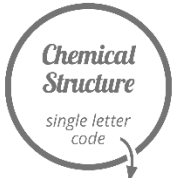
Amino acids, however, bind to metal ions in a more understood fashion. Over the last few years, nutritional science research has focused on using **metal amino acid chelates** as supplements. Amino acids form very specific covalent bonds to metal ions through nitrogen and oxygen atoms in the amino acid structure. Because these bonds are well characterized, scientists can design mineral supplements more specifically.

The overall purpose of this module is to understand which amino acids are most useful for complexing specific metal ions. Although some research has already been done by nutrition scientists, commercial mineral supplements are still limited to using only one or two amino acids. While mineral supplements can be useful for human health, their use in agriculture (plants and animals) is the more important market. Hopefully, our work can be used in creating better mineral supplements for nutrition.

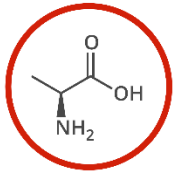
A GUIDE TO THE TWENTY COMMON AMINO ACIDS

AMINO ACIDS ARE THE BUILDING BLOCKS OF PROTEINS IN LIVING ORGANISMS. THERE ARE OVER 500 AMINO ACIDS FOUND IN NATURE - HOWEVER, THE HUMAN GENETIC CODE ONLY DIRECTLY ENCODES 20. 'ESSENTIAL' AMINO ACIDS MUST BE OBTAINED FROM THE DIET, WHILST NON-ESSENTIAL AMINO ACIDS CAN BE SYNTHESISED IN THE BODY.

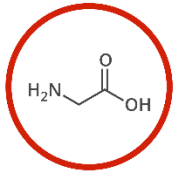
Chart Key: ALIPHATIC · AROMATIC · ACIDIC · BASIC · HYDROXYLIC · SULFUR-CONTAINING · AMIDIC · NON-ESSENTIAL · ESSENTIAL



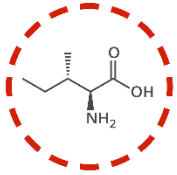
NAME (A)
three letter code
DNA codons



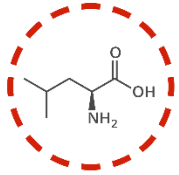
ALANINE (A)
Ala
GCT, GCC, GCA, GCG



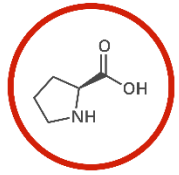
GLYCINE (G)
Gly
GGT, GGC, GGA, GGG



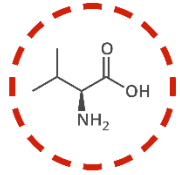
ISOLEUCINE (I)
Ile
ATT, ATC, ATA



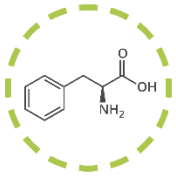
LEUCINE (L)
Leu
CTT, CTC, CTA, CTG, TTA, TTG



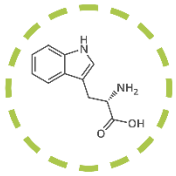
PROLINE (P)
Pro
CCT, CCC, CCA, CCG



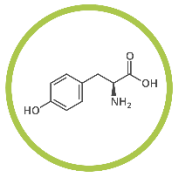
VALINE (V)
Val
GTT, GTC, GTA, GTG



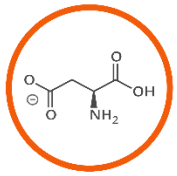
PHENYLALANINE (F)
Phe
TTT, TTC



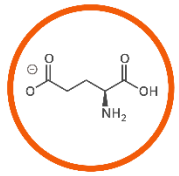
TRYPTOPHAN (W)
Trp
TGG



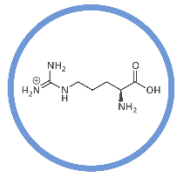
TYROSINE (Y)
Tyr
TAT, TAC



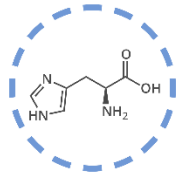
ASPARTIC ACID (D)
Asp
GAT, GAC



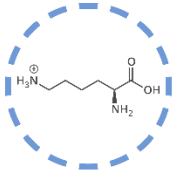
GLUTAMIC ACID (E)
Glu
GAA, GAG



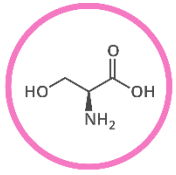
ARGININE (R)
Arg
CGT, CGC, CGA, CGG, AGA, AGG



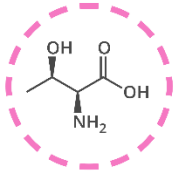
HISTIDINE (H)
His
CAT, CAC



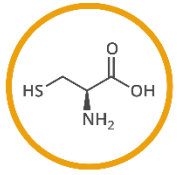
LYSINE (K)
Lys
AAA, AAG



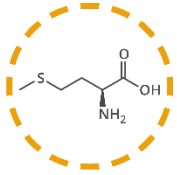
SERINE (S)
Ser
TCT, TCC, TCA, TCG, AGT, AGC



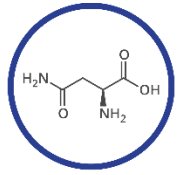
THREONINE (T)
Thr
ACT, ACC, ACA, ACG



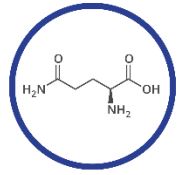
CYSTEINE (C)
Cys
TGT, TGC



METHIONINE (M)
Met
ATG



ASPARAGINE (N)
Asn
AAT, AAC



GLUTAMINE (Q)
Gln
CAA, CAG

Note: This chart only shows those amino acids for which the human genetic code directly codes for. Selenocysteine is often referred to as the 21st amino acid, but is encoded in a special manner. In some cases, distinguishing between asparagine/aspartic acid and glutamine/glutamic acid is difficult. In these cases, the codes asx (B) and glx (Z) are respectively used.

CH 111 Laboratory Module 2: Synthesis and Empirical Formulas

Week 4: Synthesis of Model Compounds

Objectives: In this experiment you will prepare a copper compound with a well-known empirical formula. You will become familiar with the laboratory equipment used to measure reagents as well as the equipment used to filter and isolate the compound you prepare.

One of the most important attributes of chemistry is the ability to design and produce new substances. The study of this particular area of chemistry is called synthesis. New chemical bonds will be formed as a larger molecule is created by joining smaller ones together. This particular experiment is considered an inorganic synthesis because bonds will be formed to a transition metal. Synthesis is not a random trial and error process, but a careful procedure based on chemical predictions. Because this is your first synthesis, we will not be exploring the theoretical background of why the specific compound forms, but rather concentrate on using laboratory equipment and protocols. It can be compared to learning to cook. Most people learn to make eggs and toast before thinking about caramelization reactions in the bread or denatured proteins in the eggs.

Model compounds are substances whose chemical formulas are already well known. Model compounds are prepared to practice your techniques and calculations. Once you are confident that you can synthesize a compound with an expected chemical formula, you can move on to synthesizing compounds whose chemical formulas are not known in advance. Chemical synthesis is an enormous enterprise and includes synthesis of pharmaceuticals, paints, dyes, foodstuffs, and preservatives. Virtually every aspect of modern life relies on synthetic compounds, including mimics of naturally occurring substances that are often difficult to obtain (penicillin for example).

In this experiment, you will synthesize a model compound by adding ammonia to an aqueous solution of copper sulfate. Three principle species are present initially in the reaction mixture: copper(II) ions (Cu^{2+}), ammonia molecules (NH_3), sulfate ions (SO_4^{2-}) and water. As you mix the reactants together, the marked color change that occurs is an important observation that a product is being formed. You will filter and isolate a deep blue solid product that is quite different from the sky blue reactant with which you started.

Based on the analysis of the model compound for Cu^{2+}, NH_3, and SO_4^{2-}, you will be able to calculate its empirical formula. The compound that you are making today is somewhat unusual from the perspective of a beginning chemist as it is an ionic compound with an anion and complexed cation. The anion is clearly SO_4^{2-}, but the complexed cation is different from what we've talked about in class. Ammonia molecules are able to form covalent bonds to a metal ion such as Cu^{2+} creating what is known as a complex ion: $[Cu_x(NH_3)_y]^{2+}$. While it may seem unusual to you now, it is not all that important at this point.

Your ultimate goal is to determine x, y, and z subscripts in the formula $Cu_x(NH_3)_y(SO_4)_z$.

Prelab Assignment: (to be turned in on a separate sheet)

Read the background information for this module on page 39 and the Week 4 Objectives on the prior page. Answer the following questions to be turned in at the beginning of lab:

1) What are the bioavailability differences in consuming metal ions from food versus from nutritional supplements?
2) Define the word chelate.
3) How do metal polysaccharide complexes differ from metal amino acid chelates? What are the advantages/disadvantages of each?
4) Find a reference that discusses one of the topics listed below. Include a citation for your source and briefly summarize the document in 5-6 sentences.
    a. Metal amino acid complexes
    b. The nutritional importance of metals such as copper, nickel, zinc, or chromium
    c. Bioavailability of chelated minerals versus non-chelated or inorganic minerals

In Class:

A. Synthesis of $Cu_x(NH_3)_y(SO_4)_z$ Model Compound

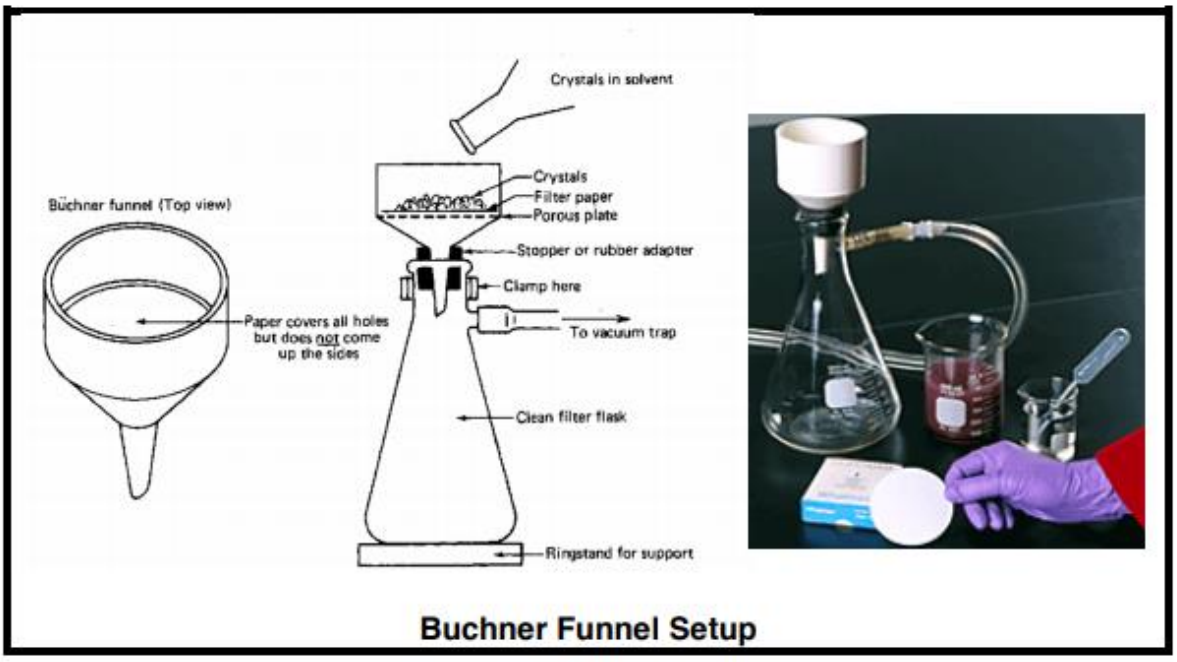
1. Weigh 10.0 grams of copper sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$, starting material. RECORD the exact mass that you use on page 55 of the lab manual (see 1-MC) as well as in your notebook. Note the color of the salt you are using. Place the crystals in a 250 mL beaker.

2. Add 15 mL of deionized water to the solid and heat mildly to dissolve. Cool back to room temperature by placing the beaker on the counter top.

3. In a fume hood, slowly add 30 mL of 14 M NH_3 (concentrated ammonia). This solution has an extreme odor, so be sure to handle it inside the fume hood. Initially, as the NH_3 is added, you might see a pale blue precipitate form. The precipitate should dissolve as you continue to add NH_3. If the pale blue precipitate is still present, add more NH_3 until it disappears.

4. Over a period of about 1 minute, add 25 mL of 95% ethanol (ethyl alcohol) to the solution, stir, and place the beaker in an ice bath for 20 min to allow the crystals to precipitate. While the crystals are precipitating, place an additional 30 mL of ethanol in a small beaker and place this solution in the ice bath as well. Do the crystals that form have the same color as the salt you started with? Why not?

5. Obtain a piece of filter paper and set up a Buchner vacuum funnel as shown below. Be sure to moisten the filter paper so that it adheres to the funnel.



6. When you are ready to filter your sample, slowly turn on the vacuum, and then pour your sample into the Buchner funnel. This will go more quickly if you first decant the bulk of the supernatant, the transparent liquid portion at the top of the sample, through the funnel before transferring the crystals from the beaker. Use a spatula and wash bottle to help move the crystals from the beaker. Be careful not to tear the wet filter paper, else you'll have to get another paper and start filtering again.

7. Turn off the vacuum and carefully pour 10 mL of the cold ethanol onto the crystals. Slowly turn on the vacuum again to remove the liquid. Repeat this washing procedure twice with two more 10 mL portions of the cold ethanol. To remove any last traces of solvent from your solid, draw air through the crystals for at least 5 minutes.

8. Carefully transfer the crystals onto evaporating dish, then put the dish into a plastic storage bin labelled colored tape and your initials plus lab section. You will weigh the crystals next period to obtain the mass of the model compound you prepared.

CH 111 Laboratory Module 2: Synthesis and Empirical Formulas

Week 5: Synthesis of Amino Acid Compound

Objectives: A) You will first conduct a gravimetric analysis to determine the mass % sulfate in the model compound prepared last week. B) Next, you will prepare a new compound using a slightly different procedure than the one you used previously to prepare the model compounds. This procedure will combine copper(II) ion and alanine, an amino acid.

In order to determine the empirical formula for the compounds you are preparing, we must analyze the compound for the mass % of each of its components. There are three analyses to be performed:

1) Gravimetric analysis – you will determine the mass % of sulfate by precipitating the sulfate from the compound and determining its mass.

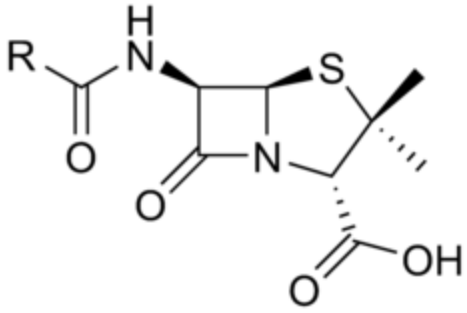
2) Volumetric analysis (also called titration analysis) – you will determine the mass % of ammonia using a titration. The titration reaction stoichiometry will allow you to calculate the mass of ammonia in the compound.

3) Spectroscopic analysis – you will determine the mass % of copper(II) ion in your compound by measuring the amount of colored light absorbed by your compound.

For today, we will only do the gravimetric analysis to determine the mass % of sulfate. More information on the other techniques will be given when needed.

Prelab assignment: (to be turned in on a separate sheet)

Here is the skeletal structure for penicillin, with the R substituent on the left being replaced by various atoms to create different antibiotics such as amoxicillin or ampicillin.



Penicillin was one of the first antibiotics to be widely used. Initially isolated from molds by Alexander Fleming in 1928, it became extremely important during World War II in preventing infections in wounded soldiers. It was first synthesized in 1957 by John Sheehan and became widely available to the public.

1) Using the molecular formula, $C_9H_{11}N_2O_4S$, for penicillin, calculate the mass % for each element in penicillin.

2) Write a paragraph about nutritionally important metal ions and how the bioavailability of metal ions differs based on complexation with polysaccharides or amino acids.

In Class:

A) **Gravimetric analysis**
Weigh and RECORD in <u>your notebook</u> the mass of an empty storage vial. Remove your evaporating dish with the crystals of model compound you prepared from the storage bin. Place a small plastic funnel into the storage vial. Carefully scrape the crystals from the evaporating dish through the funnel and into the storage vial. Once you have all the compound into the vial, reweigh and RECORD in <u>your notebook</u> the mass of the vial plus compound. Calculate the mass of the compound you prepared by subtracting the mass of the empty vial from the mass of the vial plus compound. RECORD the mass of the compound you prepared on page 55 of the lab manual (2-MC) as well as in your notebook. LABEL YOUR STORAGE VIAL USING COLORED TAPE! Use your initials and Cu-MC.

1. Weigh a 0.9 – 1.1 gram portion of your model compound into a tared empty 100 mL beaker. RECORD this mass on page 55 of the lab manual (3-MC) as well as your notebook. Dissolve the model compound with about 10 mL of 6 M nitric acid (HNO_3) [Wear gloves!].

2. Obtain 10 mL of saturated lead(II) acetate solution [$Pb(C_2H_3O_2)_2$] using a 10-mL graduated cylinder and add it dropwise to the acid solution. The reaction occurring is:

$$Pb^{2+}(aq) + {SO_4}^{2-}(aq) \rightarrow PbSO_4(s)$$

The lead(II) sulfate will be a white powder.

3. Weigh a piece of filter paper and RECORD the mass of the filter paper on page 55 of the lab manual (5-MC) as well as in your notebook. Use a funnel and an Erlenmeyer flask for gravity filtration (not vacuum filtration). Fold the filter paper into a cone (ask your instructor), place it into the funnel, moisten it with a little water, and adjust it so that it fits into the funnel snugly. Be careful not to tear the paper. Slowly pour the barium sulfate-water slurry from the precipitation beaker into the filter cone until about half filled. Wait until it has drained nearly empty and repeat. The goal is to collect all the white powder by filtering all the blue liquid through the filter paper. Continue until all the barium sulfate white powder is on the filter paper. Use a water squirt bottle to rinse any remaining white particles of barium sulfate from the beaker into the filter cone. It is <u>imperative</u> for this analysis that all the barium sulfate white powder be captured by the filter cone. If the filter paper leaks and you see any white cloudiness in the blue liquid being collected in the Erlenmeyer, you will need to filter again.

4. If the gravity filtration is slow, you can begin the amino acid synthesis while the filtration is still ongoing.

5. After all the precipitate has been isolated, cautiously rinse the filter cone and the white precipitate with water from a wash bottle. You do not want any trace of blue color. Then carefully rinse the precipitate with 10 mL of acetone.

6. When the liquid from the last washing has drained out, remove the funnel with filter paper and stand it inside a small beaker. Place the beaker with the funnel and filter paper into the oven to heat overnight.

B) **Synthesis of $Cu_x(C_3H_7NO_2)_y$ Amino Acid Compound**

1. Place 100 mL of 0.27 M alanine, $C_3H_7NO_2$, solution into a 250 mL beaker and begin warming on a hot plate. RECORD on page 65 of the lab manual which amino acid you are using as well as in your notebook.

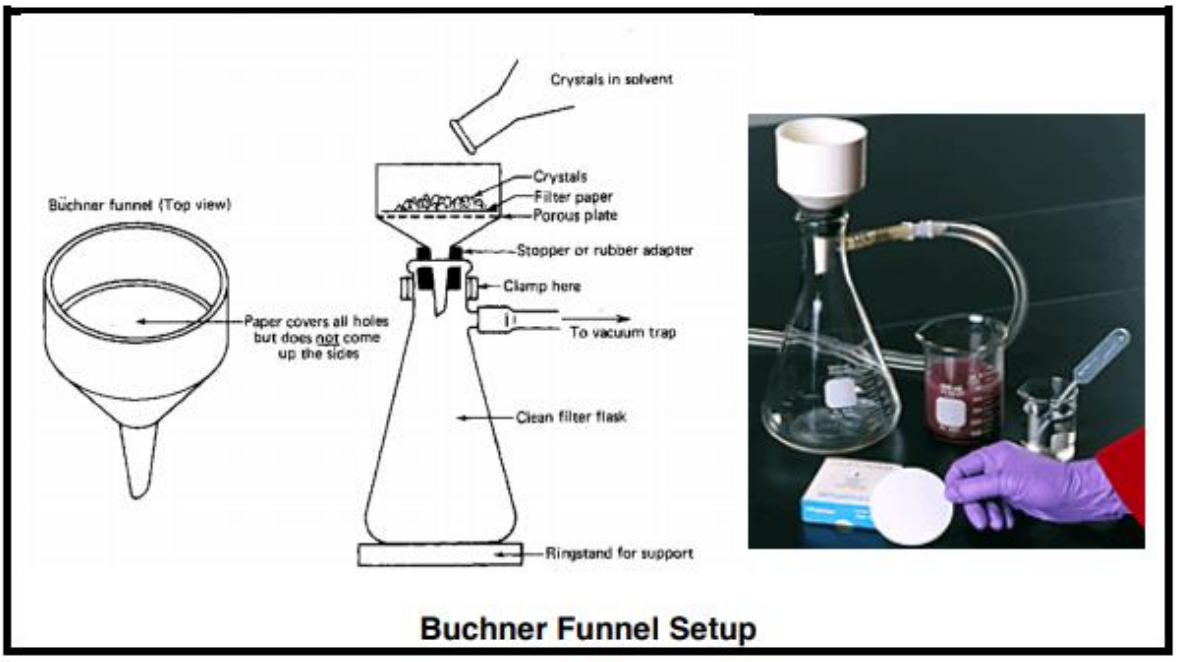
2. Weigh about 1.4 grams of copper(II) hydroxide, $Cu(OH)_2$, starting material and add it to the beaker containing the warm alanine solution. RECORD the exact mass of the solid $Cu(OH)_2$ on page 65 of the lab manual (1-AA) as well as in your notebook. What color is the solid $Cu(OH)_2$? Write it down. Color is an important observation.

3. Continue warming the solution until the maximum amount of $Cu(OH)_2$ solid has disappeared. What color is the solution now?

4. Raise the temperature of the hot plate until the reaction solution is at a low boil. Continue boiling until the total volume has been reduced by about 50%. Carefully remove the beaker from the hot plate (use tongs or insulated gloves), place it on the countertop and allow it to cool for a few minutes.

5. After the solution has cooled for a few minutes, add about 40 mL of 95% ethanol. Place the beaker in an ice bath for 20 min to allow the crystals to settle out.

6. Obtain a piece of filter paper and set up a Buchner vacuum funnel as previous and as shown below. Be sure to moisten the filter paper so that it adheres to the funnel.



7. When you are ready to filter your sample, slowly turn on the vacuum, and then pour your sample into the Buchner funnel. This will go more quickly if you first decant the bulk of the supernatant through the funnel before transferring the crystals from the beaker. Use a spatula and wash bottle to help move the crystals from the beaker into the funnel.

8. Turn off the vacuum and carefully rinse the crystals the crystals with a few mL of acetone twice. Slowly turn on the vacuum again to draw any remaining acetone the sample. Then continue to draw air through the solid for several minutes.

9. Carefully transfer the crystals onto an evaporating dish, then place the dish into your labelled storage bin. You will weigh the crystals next period to obtain the mass of the amino acid compound you prepared.

CH 111 Laboratory Module 2: Synthesis and Empirical Formulas

Week 6: Titration and Spectroscopy of Model Compounds

Objective: A) Complete the model compound gravimetric analysis from last week by determining the mass of the $BaSO_4$ precipitate. Also determine total mass of the amino acid compound prepared last week.
B) **One partner** conducts the titration analysis of a model compound and the **other partner** conducts the spectroscopy of the same model compound.
C) Combine the mass % values determined from the titration and spectroscopy to determine the empirical formula of your model compound. Recall that your model compound is $Cu_x(NH_3)_y(SO_4)_z$. You are finding the subscript x, y, and z in the compound.

First, the white powder precipitate from last week's gravimetric analysis will be weighed.

Then the amount of ammonia (NH_3) in your model compound will be determined by an acid-base titration. HCl will be added dropwise from the buret to spur the reaction below:

$$NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$$

Note that the reaction is 1:1 between NH_3 and HCl. At the equivalence point of the titration, when we observe the proper color change, we will be able to calculate the moles of HCl added from the volume added from the buret. Because the reaction is 1:1, we will then know the moles of NH_3 present.

Spectroscopy is the science that studies how light interacts with matter. Consider a colored material. The color arises because some wavelengths of visible light are reflected by the material and other wavelengths are absorbed by the material. Absorbance spectroscopy measures the intensity of light absorbed by a colored solution. When metal ions are dissolved in solution, the solution is often colored. In this analysis, the amount of metal ion in your model compound will be determined by the amount of light absorbed by a solution created by dissolving some of the compound. Simply put, you are measuring the intensity of "color" in the solution. For example, is it dark green (absorbs lots of light), emerald green (absorbs some light), or very pale green (absorbs a very small amount of light)? To quantify the color intensity, we will use a spectrometer to measure light absorbance. The spectrometer will determine a numerical value corresponding to the amount of metal ion present.

Prelab assignment: (to be turned in on a separate sheet)

Complete Equation Formatting Assignment from Moodle. Print the completed assignment to be turned in before lab.

In Class:

A) Weighing amino acid compound

Weigh and RECORD in your notebook the mass of an empty storage vial. Remove the evaporating dish from the storage bin that has the crystals of amino acid compound you prepared last week. Place a small plastic funnel into the storage vial. Carefully scrape the crystals from the filter paper, through the funnel and into the storage vial. Once you have all the compound into the vial, reweigh and RECORD in your notebook the mass of the vial plus compound. Calculate the mass of the compound you prepared by subtracting the mass of the empty vial from the mass of the vial plus compound. RECORD the mass of the amino acid compound you prepared on page 65 of the lab manual (2-AA) as well as in your notebook. LABEL YOUR STORAGE VIAL USING COLORED TAPE! Use your initials and Cu-AA.

B) Gravimetric analysis of model compound

Using tweezers, remove the filter paper with the white $BaSO_4$ powder from last week's precipitation. Weigh the combined filter paper/solid and RECORD the mass on page 55 of the lab manual (4-MC) as well as your lab manual. You should have previously weighed and recorded the mass of the filter paper last week before beginning the gravimetric analysis. Calculate the mass of $BaSO_4$ solid by subtracting the mass of the filter paper from the total mass of filter paper + white powder that you weighed today. RECORD the mass of $BaSO_4$ solid in the lab manual and in your notebook.

C) Titration analysis of model compound

1. Add 30 mL of DI water to a 125 mL Erlenmeyer flask. Add 7 drops of methyl orange indicator. This should turn the solution yellow. Fill the buret with standard HCl and titrate the indicator solution until it turns neon orange (only 1 or 2 drops of HCl are required). If the solution turns peach, you have added too much HCl. If too much HCl has been added, dispose of the peach solution, and repeat the process using less HCl until a neon orange sample is obtained. Once the neon orange sample is obtained, stopper the flask, and use this color as a guide for the remaining titrations. You do not need to record the amount of HCl used for this indicator titration.

2. Refill the buret with standard HCl and <u>RECORD</u> an initial reading; typically 0.00 mL (see lab manual page 56). The acid concentration is approximately 0.1 M; the exact concentration will be on the bottle. Be sure to record it! See lab manual page 56.

3. Weigh a 0.1 gram portion of your model compound (Cu-MC) into a second 125 mL Erlenmeyer flask. RECORD the exact amount in your lab manual on page 56 of your lab manual (6-MC) as well as in your notebook. Add 30 mL of water to the sample in the Erlenmeyer flask. Place the Erlenmeyer flask into a sonicator and sonicate the sample until it dissolves.

4. After sonicating, add 8 drops of methyl orange indicator to flask containing dissolved model compound. Titrate with the HCl, continuously swirling the solution, until the color of the solution matches the color of your indicator titration (neon orange) in step 1.

Record the volume of HCl delivered from the buret in both your lab manual (page 56) and in your notebook. Remember to read the buret to two decimal places!

5. Conduct the titration of your model compound a second time (repeat steps 3 and 4). Record all amounts for sample 2 in your lab manual (page 56) and in your notebook. If your two titration volumes differ by more than 2 mL, do an additional titration.

6. Use your titration data to calculate the moles of ammonia (NH_3) in your sample for each of your titrations by filling out the tables on page 56 of your lab manual. Convert the moles of ammonia into grams of ammonia, determine the mass % of ammonia in your sample for each titration, and calculate the average mass % ammonia as prompted by the table.

7. Obtain your partner's spectroscopy data so you will be able to determine the empirical formula for your compound.

D) Spectroscopic analysis of model compound

1. Obtain seven cuvettes and label them 1 through 7. Five of these cuvettes will be used with reference solutions and two of them will be used with your sample.

2. Find the blue Cu^{2+} ion standard solution and prepare the test tubes according to the directions below:

Table 1: Preparing Calibration Standards and Samples for Spectroscopy

Cuvette ID	Cuvette Contents
1	Use a plastic pipet to fill cuvette 1 with 1 M HNO_3
2	Measure 3.0 mL of Cu^{2+} ion standard solution into a 10.0 mL grad cylinder and measure 7.0 mL of 1 M HNO_3 into a second 10.0 mL grad cylinder. Pour together into a small beaker and mix well using a plastic pipet. Use the plastic pipet to fill cuvette 2 with this solution.
3	Measure 5.0 mL of Cu^{2+} ion standard solution into a 10.0 mL grad cylinder and measure 5.0 mL of 1 M HNO_3 into a second 10.0 mL grad cylinder. Pour together into a small beaker and mix well using a plastic pipet. Use the plastic pipet to fill cuvette 3 with this solution.

4	Measure 7.0 mL of Cu^{2+} ion standard solution into a 10.0 mL grad cylinder and measure 3.0 mL of 1 M HNO_3 into a second 10.0 mL grad cylinder. Pour together into a small beaker and mix well using a plastic pipet. Use the plastic pipet to fill cuvette 4 with this solution.
5	Use a plastic pipet to fill cuvette 5 with Cu^{2+} ion standard solution
6	Place a small funnel into a 10.00 mL volumetric flask. Weigh and record 0.2 grams of your model compound (Cu-MC) into the funnel (page 57 of lab manual, 8-MC). Dissolve the solid with 3-4 mL of 1 M HNO_3 into the flask. Remove the funnel and add 1 M HNO_3 to the proper calibration mark. Mix well. Fill cuvette 6 with solution from this flask using a plastic pipet.
7	Place a small funnel into a 10.00 mL volumetric flask. Weigh and record 0.3 grams of your model compound (Cu-MC) into the funnel page 57 of your lab manual, 8-MC). Dissolve the solid with 3-4 mL of 1 M HNO_3 into the flask. Remove the funnel and add 1 M HNO_3 to the proper calibration mark. Mix well. Fill cuvette 7 with solution from this flask using a plastic pipet.

Be sure to RECORD the concentration of the Cu^{2+} ion standard solution.

Chemistry note: When the solid sample for cuvettes 6 and 7 is mixed with nitric acid (HNO_3), the compound is destroyed and reverts back to the original reactants. Observe the color change when HNO_3 comes into contact with the solid. The moles of Cu^{2+} ion that was in the compound are still present, however, and the concentration is measured using the spectrometer.

3. Locate the laptop computer and a Vernier spectrometer box in the fume hood. Fill a cuvette about ¾ of the way with DI water and remove any fingerprints from the smooth surface with a KimWipe. This is called a blank.

When placing a cuvette into the spectrometer, make sure the sides of the cuvette with ridges are facing left and right, ensuring that the beam of light will pass through the smooth sides.

- Plug the spectrometer into the laptop and open LoggerPro. You should see a rainbow gradient on the screen; if not, open the Experiment drop-down menu and click Data Collection. Change the mode to "Full Spectrum".

- Place the blank into the spectrometer, click Experiment, hover over "Calibrate" and select Spectrometer 1. Allow the spectrometer to warm up and then click "Finish Calibration". When the numbers stop changing, press OK. Remove the cuvette from the instrument.

- Place cuvette 1 into the spectrometer, and press the Collect Data button (green play button) in the top right area of the screen. Wait about 5 seconds and click the Stop button. Scroll down the wavelength values until you find the value for 700 nm. RECORD the corresponding absorbance value at 700 nm in the table on page 57.

- Repeat the above procedure for all the remaining cuvettes and RECORD the absorbance value at 700 nm for each cuvette.

4. Remember that the first 5 cuvettes contain reference solutions (which will be referred to as calibration standards for the remainder of these instructions) and the last two cuvettes contain metal ions from your compound. You will need to calculate the Cu^{2+} ion molarity in each of the first 5 cuvettes. Hint: cuvette 1 is zero molar in metal ion and cuvette 5 is the same as the Cu^{2+} ion standard solution that you have already recorded. The Cu^{2+} ion molarity in cuvettes 2, 3, and 4 can be calculated using the dilution equation $C_1V_1 = C_2V_2$ because they were prepared using the Cu^{2+} ion standard solution.

5. Using the paired data of absorbance and concentration for each of the 5 calibration standards (first 5 cuvettes), prepare a scatter plot using Excel with concentration on the x axis and absorbance on the y axis. Be sure to add the Trendline and the R value on the graph. RECORD the equation of the trendline on page 58. Save the graph onto a jump drive or email it to yourself so you will have it for the formal paper. Print the graph to hand in at the end of the lab period.

6. You can now use the calibration curve to calculate the Cu^{2+} ion molarity of cuvettes 6 and 7 (ie, from your sample). Use the absorbance value for each test tube as the "y" value in your Trendline equation and solve for the "x" value. The x value is the concentration (molarity). RECORD the concentrations of cuvettes 6 and 7 on page 58.

7. Now that you have the molarity of each test tube, utilize the table on page 58 to calculate the moles of Cu^{2+} ion present. Remember that the sample was dissolved in 10.00 mL which is 0.01 L. Having both the volume and the molarity of solution, you can calculate moles of Cu^{2+} ion and then convert moles to mass.

8. Lastly, calculate the mass % of Cu^{2+} ion from each volumetric flask and average the two results. If the results seem widely divergent, check with your instructor.

9. Obtain your partner's titration data so you so you will be able to determine the empirical formula for your compound.

10. If there is not enough time to finish the empirical formula calculations during lab, you must complete them before the next lab period.

Data and Analysis for Model Compound

Synthesis

(1-MC) Mass of $CuSO_4 \cdot 5H_2O$ used in synthesis. _____ g

(2-MC) Mass of model compound prepared. _____ g

Gravimetric Analysis of Model Compound for Sulfate

Data

	Sample 1	Sample 2 (from partner)
(3-MC) Mass of model compound used		
(4-MC) Mass of $BaSO_4$ + filter paper		
(5-MC) Mass of filter paper		
Mass of $BaSO_4$		

Calculations

	Sample 1	Sample 2
Moles of $BaSO_4$		
Moles of SO_4^{2-}		
Mass of SO_4^{2-}		
Mass % SO_4^{2-} in model compound		
Average Mass % SO_4^{2-}		

Titration Analysis of Model Compound for Ammonia

The concentration of standardized HCl solution is _____ M
(This value is on the stock bottle of acid in the laboratory. Don't forget to write this down!)

Data

	Sample 1	Sample 2	Sample 3 (if needed)
(6-MC) Mass of sample used			
Final buret reading (mL)			
Initial buret reading (mL)			
Amount of HCl added (mL)			

Calculations

	Sample 1	Sample 2	Sample 3 (if needed)
Moles of HCl used in titration			
Moles of NH_3 (1:1 rxn between HCl and NH_3)			
Mass of NH_3			
Mass % of NH_3 in model compound			
Average Mass % NH_3			

Spectroscopic Analysis of Model Compound for Cu^{2+} Ion

The concentration of the metal ion standard solution is _____ M

Concentration Table for Calibration Standards

Cuvette Number	mL metal ion standard	mL of 1 M HNO_3	Molarity of Cu^{2+} ion
1	0.0	10.0	0.0
2	3.0	7.0	
3	5.0	5.0	
4	7.0	3.0	
5	10.0	0.0	

Mass data table of model compound used in 10.00 mL volumetric flask and transferred to cuvette

Cuvette Number	(8-MC) Mass of Model Compound used
6	
7	

Spectroscopic data at selected wavelength

Cuvette Number	Concentration (from prior table)	Absorbance
1		
2		
3		
4		
5		
6	Calculated below	
7	Calculated below	

Calculations

Using the Calibration curve – Graph the concentration (x-axis) vs absorbance (y-axis) paired data of test tubes 1-4 from the previous data table. Add trendline and R^2 value to the graph. Save the graph (or email to yourself). Print the graph to hand in.

Write the Trendline from your graph here:

Concentration of cuvette 6 from Trendline: _____ M

Concentration of cuvette 7 from Trendline: _____ M

	Cuvette 6	Cuvette 7
Moles of Cu^{2+}		
Mass of Cu^{2+}		
Mass % Cu^{2+} in model compound		
Average mass % Cu^{2+}		

Calculation of Empirical Formula ($Cu_x(NH_3)_y(SO_4)_z$)

Based on the mass percentages of Cu^{2+} ion, NH_3, and SO_4^{2-} that you have determined, calculate the moles of each component assuming 100 grams of the model compound. Find the smallest whole number mole ratios of each component. Show this calculation below and write the final formula.

CH 111 Laboratory Module 2: Synthesis and Empirical Formulas

Week 7: Titration and Spectroscopy of Amino Acid Compounds

Objective: A) One partner conducts the titration analysis of the amino acid compound and the other partner conducts the spectroscopy of the same amino acid compound.
B) Combine the mass % values determined from part A to determine the empirical formula of your amino acid compound. Recall that your amino acid compound has the general formula $Cu_x(C_3H_7NO_2)_y$. You are again finding the subscript x and y in the compound.

Complexes are comprised of a central atom, typically a transition metal cation, bound to ions or molecules called ligands. These metal cations and ligands are bound together using coordinate covalent bonding. A coordinate covalent bond occurs when one of the atoms in a bond provides both bonding electrons. In complex ions, each ligands provides the two electrons used to form the bond between itself and the metal cation. These bonding locations on the central metal where the ligands attach are called chelation sites.

Metal cations can bind to various numbers of ligands depending on the chemical nature of the metal cation and ligands being bound. For example, copper is known to have 4 or 6 chelation sites depending on the nature of the ligands being complexed. Additionally, some ligands can occupy multiple chelation sites. A ligand that binds to the central metal cation through one electron-pair donating atom and thus occupies only one chelation site is known as a monodentate ligand. Bidentate ligands have two electron-pair donating atoms which allows them to occupy two chelation sites on the central metal cation.

Prelab assignment: (to be turned in on a separate sheet)

1. The known empirical formula of the model compound is $Cu(NH_3)_4SO_4$. Using this empirical formula, write the balanced synthesis reaction for the formation of the model compound. Remember, $CuSO_4•5H_2O$ reacted with some number of NH_3 to yield the model compound. In addition to the model compound, what is the other product formed in the synthesis?

2. Use the synthesis equation from question 1 and the mass of the $CuSO_4•5H_2O$ (2-MC on page 55 in lab manual) to calculate the theoretical yield for your model compound, $Cu(NH_3)_4SO_4$. Assume that the $CuSO_4•5H_2O$ is the limiting reactant.

3. Use the theoretical yield of your model compound, $Cu(NH_3)_4SO_4$, from question 2 and your actual yield of the model compound (3-MC on page 55 in lab manual) to calculate the % yield for your model compound.

4. Hypothesize possible empirical formulas for the amino acid compound made in Week 5. Remember that copper is known to have either 4 or 6 chelation sites and that alanine may be a monodentate or bidentate ligand. Using this information, predict four possible empirical formulas for the amino acid compound.

In Class:

Obtain the storage vial containing the copper amino acid compound (Cu-AA) you prepared. Decide which partner is conducting the titration and which partner is conducting the spectroscopy analysis.

A) Titration analysis of Amino Acid compound

1. Add 30 mL of DI water to a 125 mL Erlenmeyer flask. Add 7 drops of methyl orange indicator. This should turn the solution yellow. Fill the buret with standard HCl and titrate the indicator solution until it turns neon orange (only 1 or 2 drops of HCl are required). If the solution turns peach, you have added too much HCl. If too much HCl has been added, dispose of the peach solution, and repeat the process using less HCl until a neon orange sample is obtained. Once the neon orange sample is obtained, stopper the flask, and use this color as a guide for the remaining titrations. You do not need to record the amount of HCl used for this indicator titration.

2. Refill the buret with standard HCl and RECORD an initial reading; typically 0.00 mL (see lab manual page 65). The acid concentration is approximately 0.1 M; the exact concentration will be on the bottle. Be sure to record it! See lab manual page 65.

3. Weigh a 0.1 gram portion of your amino acid compound (Cu-AA) into a second 125 mL Erlenmeyer flask. RECORD the exact amount in your lab manual on page 65 of your lab manual (3-AA) as well as in your notebook. Add 30 mL of water to the sample in the Erlenmeyer flask. Place the Erlenmeyer flask into a sonicator and sonicate the sample until it dissolves.

4. After sonicating, add 8 drops of methyl orange indicator to flask containing dissolved amino acid compound. Titrate with the HCl, continuously swirling the solution, until the color of the solution matches the color of your indicator titration (neon orange) in step 1.

Record the volume of HCl delivered from the buret in both your lab manual (page 65) and in your notebook. Remember to read the buret to two decimal places!

5. Conduct the titration of your amino acid compound a second time (repeat steps 3 and 4). Record all amounts for sample 2 in your lab manual (page 65) and in your notebook. If your two titration volumes differ by more than 2 mL, do an additional titration.

6. Use your titration data to calculate the moles of alanine ($C_3H_7NO_2$) in your sample for each of your titrations by filling out the tables on pages 65 and 66 of your lab manual. Convert the moles of alanine into grams of alanine, determine the mass % of alanine in your sample for each titration, and calculate the average mass % alanine as prompted by the table.

7. Obtain your partner's spectroscopy data so you will be able to determine the empirical formula for your compound.

B) Spectroscopic analysis of Amino Acid compound

1. Obtain seven cuvettes and label them 1 through 7. Five of these cuvettes will be used with reference solutions and two of them will be used with your sample.

2. Find the blue Cu^{2+} ion standard solution and prepare the test tubes according to the directions below:

Table 1: Preparing Calibration Standards and Samples for Spectroscopy

Cuvette ID	Cuvette Contents
1	Use a plastic pipet to fill cuvette 1 with 1 M HNO_3
2	Measure 3.0 mL of Cu^{2+} ion standard solution into a 10.0 mL grad cylinder and measure 7.0 mL of 1 M HNO_3 into a second 10.0 mL grad cylinder. Pour together into a small beaker and mix well using a plastic pipet. Use the plastic pipet to fill cuvette 2 with this solution.
3	Measure 5.0 mL of Cu^{2+} ion standard solution into a 10.0 mL grad cylinder and measure 5.0 mL of 1 M HNO_3 into a second 10.0 mL grad cylinder. Pour together into a small beaker and mix well using a plastic pipet. Use the plastic pipet to fill cuvette 3 with this solution.
4	Measure 7.0 mL of Cu^{2+} ion standard solution into a 10.0 mL grad cylinder and measure 3.0 mL of 1 M HNO_3 into a second 10.0 mL grad cylinder. Pour together into a small beaker and mix well using a plastic pipet. Use the plastic pipet to fill cuvette 4 with this solution.
5	Use a plastic pipet to fill cuvette 5 with Cu^{2+} ion standard solution
6	Place a small funnel into a 10.00 mL volumetric flask. Weigh and record 0.2 grams of your amino acid compound (Cu-AA) into the funnel (page 66 of lab manual, 4-AA). Dissolve the solid with 3-4 mL of 1 M HNO_3 into the flask. Remove the funnel and add 1 M HNO_3 to the proper calibration mark. Mix well. Fill cuvette 6 with solution from this flask using a plastic pipet.
7	Place a small funnel into a 10.00 mL volumetric flask. Weigh and record 0.3 grams of your amino acid compound (Cu-AA) into the funnel page 66 of your lab manual, 4-AA). Dissolve the solid with 3-4 mL of 1 M HNO_3 into the flask. Remove the funnel and add 1 M HNO_3 to the proper calibration mark. Mix well. Fill cuvette 7 with solution from this flask using a plastic pipet.

Be sure to RECORD the concentration of the Cu^{2+} ion standard solution.

Chemistry note: When the solid sample for cuvettes 6 and 7 is mixed with nitric acid (HNO_3), the compound is destroyed and reverts back to the original reactants. Observe the color change when HNO_3 comes into contact with the solid. The moles of Cu^{2+} ion that was in the compound are still present, however, and the concentration is measured using the spectrometer.

3. Locate the laptop computer and a Vernier spectrometer box in the fume hood. Fill a cuvette about ¾ of the way with DI water and remove any fingerprints from the smooth surface with a KimWipe. This is called a blank.

When placing a cuvette into the spectrometer, make sure the sides of the cuvette with ridges are facing left and right, ensuring that the beam of light will pass through the smooth sides.

- Plug the spectrometer into the laptop and open LoggerPro. You should see a rainbow gradient on the screen; if not, open the Experiment drop-down menu and click Data Collection. Change the mode to "Full Spectrum".

- Place the blank into the spectrometer, click Experiment, hover over "Calibrate" and select Spectrometer 1. Allow the spectrometer to warm up and then click "Finish Calibration". When the numbers stop changing, press OK. Remove the cuvette from the instrument.

- Place cuvette 1 into the spectrometer, and press the Collect Data button (green play button) in the top right area of the screen. Wait about 5 seconds and click the Stop button. Scroll down the wavelength values until you find the value for 700 nm. RECORD the corresponding absorbance value at 700 nm in the table on page 67.

- Repeat the above procedure for all the remaining cuvettes and RECORD the absorbance value at 700 nm for each cuvette.

4. Remember that the first 5 cuvettes contain reference solutions (which will be referred to as calibration standards for the remainder of these instructions) and the last two cuvettes contain metal ions from your compound. You will need to calculate the Cu^{2+} ion molarity in each of the first 5 cuvettes. Hint: cuvette 1 is zero molar in metal ion and cuvette 5 is the same as the Cu^{2+} ion standard solution that you have already recorded. The Cu^{2+} ion molarity in cuvettes 2, 3, and 4 can be calculated using the dilution equation $C_1V_1 = C_2V_2$ because they were prepared using the Cu^{2+} ion standard solution.

5. Using the paired data of absorbance and concentration for each of the 5 calibration standards (first 5 cuvettes), prepare a scatter plot using Excel with concentration on the x axis and absorbance on the y axis. Be sure to add the Trendline and the R value on the graph. RECORD the equation of the trendline on page 67. Save the graph onto a jump drive or email it to yourself so you will have it for the formal paper. Print the graph to hand in at the end of the lab period.

6. You can now use the calibration curve to calculate the Cu^{2+} ion molarity of cuvettes 6 and 7 (ie, from your sample). Use the absorbance value for each test tube as the "y" value in your

Trendline equation and solve for the "x" value. The x value is the concentration (molarity). RECORD the concentrations of cuvettes 6 and 7 on page 67.

7. Now that you have the molarity of each test tube, utilize the table on page 67 to calculate the moles of Cu^{2+} ion present. Remember that the sample was dissolved in 10.00 mL which is 0.01 L. Having both the volume and the molarity of solution, you can calculate moles of Cu^{2+} ion and then convert moles to mass.

8. Lastly, calculate the mass % of Cu^{2+} ion from each volumetric flask and average the two results. If the results seem widely divergent, check with your instructor.

9. Obtain your partner's titration data so you so you will be able to determine the empirical formula for your compound.

10. If there is not enough time to finish the empirical formula calculations during lab, you must complete them before the next lab period.

Determination of Amino Acid compound empirical formula.
Obtain your partner's data so you so you will be able to determine the empirical formula for your compound. Record your subscript values on the class spreadsheet. Record your predicted subscript values on the class data sheet. Are there differences between your experimental subscript values and your predicted subscript values? Be sure to explain any differences in the discussion section of your formal lab paper.

Data and Analysis for Amino Acid Compound

Synthesis

Name of amino acid used:

(1-AA) Mass of $Cu(OH)_2$ used in synthesis. _____ g

(2-AA) Mass of $Cu_x(AA)_y$ prepared. _____ g

Titration Analysis of Amino Acid Compound for Alanine

The concentration of standardized HCl solution is _____ M
(This value is on the stock bottle of acid in the laboratory. Don't forget to write this down!)

Data

	Sample 1	Sample 2	Sample 3 (if needed)
(3-AA) Mass of model compound used			
Final buret reading (mL)			
Initial buret reading (mL)			
Amount of HCl added (mL)			

Calculations

	Sample 1	Sample 2	Sample 3 (if needed)
Moles of HCl used in titration			
Moles of Alanine (1:1 rxn between HCl and amino acid)			

Mass of Alanine			
Mass % of Alanine in compound			
Average Mass % of Alanine			

Spectroscopic Analysis of Amino Acid Compound for Copper(II) Ion

The concentration of the metal ion standard solution is _____ M

Concentration Table for Calibration Standards

Cuvette Number	mL metal ion standard	mL of 1 M HNO_3	Molarity of Copper(II) ion
1	0.0	10.0	0.0
2	3.0	7.0	
3	5.0	5.0	
4	7.0	3.0	
5	10.0	0.0	

Mass data table of Amino Acid Compound used in 10.00 mL volumetric flask and transferred to test tube

Cuvette Number	(4-AA) Mass of Amino Acid Compound used
6	
7	

Spectroscopic data at selected wavelength

Cuvette Number	Concentration (from prior table)	Absorbance
1		
2		
3		
4		
5		
6	Calculated below	
7	Calculated below	

Calculations

Using the Calibration curve – Graph the concentration (x-axis) vs absorbance (y-axis) paired data of cuvettes 1-5 from the previous data table. Add trendline and R^2 value to the graph. Save the graph (or email to yourself). Print the graph to hand in.

Write the Trendline from your graph here:

Concentration of cuvette 6 from Trendline: _____ M

Concentration of cuvette 7 from Trendline: _____ M

	Cuvette 6	Cuvette 7
Moles of Cu^{2+}		
Mass of Cu^{2+}		
Mass % Cu^{2+} in model compound		
Average mass % Cu^{2+}		

Calculation of Empirical Formula $Cu_x(C_3H_7NO_2)_y$

Based on the mass percentages of Cu^{2+} ion and alanine, $C_3H_7NO_2$, that you have determined, calculate the moles of each component assuming 100 grams of the model compound. Find the smallest whole number mole ratios of each component. Show this calculation below and write the final formula. Write out the synthesis equation for the formation of the amino acid compound. Use this synthesis equation to calculate the theoretical yield of the amino acid compound. Calculate the percent yield of the amino acid compound.

CH 111 Laboratory Module 2: Synthesis and Empirical Formulas

Writing a Defense Paper

At the end of Module 2, you will turn in a typed defense paper detailing your results from the Synthesis and Empirical Formulas module. Check with your instructor for the due date of the paper for this lab project. The paper should be uploaded to Moodle. The format is as follows:

Title Sheet (3 pts)

This cover page should include a title, lab section, date, and the full names of the investigators involved.

Results and Observations (15 pts)

This should give the results of your experiments and not be a discussion of why they occurred.

Include the synthesis equation for the model compound and amino acid compound. Include your group's data tables for all components, sample calculations for one trial of each component, calibration curves for both the spectroscopy analyses, and the class data tables for both compounds. You also need to include the calculations used to determine your empirical formula from your raw data for both compounds and calculate your percent yields for both compounds. For the investigations you did, you should detail your results and any observations or problems you encountered. See notes below and directions for your first lab report for information on proper formatting.

Discussion (20 pts)

In this section you will discuss your results for all parts of the study.

Using the true percentages for the model compound compare your group's mass percentages with the true mass percentages. For each of the three components of the model compound, which sources of error account for differences between your group's mass percentages and the true mass percentages. For the amino acid compound, compare your group's mass percentages with the class average mass percentages. For each of the two components of the amino acid compound, which sources of error account for differences between your group's mass percentages and the class average mass percentages?

Grammar and Spelling (10 pts)

Are basic rules of grammar and syntax used? Is the paper readable, or does awkward phrasing or language distract from the content? Laboratory reports should be clear and concise. Avoid flowery or unnecessary wording.

Notes:

- Students should review the definition of plagiarism in the BSC Honor Code. If you are uncertain, ask for help at the writing center or from your instructor. Ignorance is not an excuse. **You may not look at defense papers of other students** (former or present) in preparing your report. Your report will be submitted to Turnitin.com to check for similarities between papers.

- All tables included in your paper should be numbered (i.e. Table 1) and have a meaningful title shown above the table. Graphs and figures should also be numbered and have a detailed caption below the figure. See the Module 1 report instructions for formatting instructions. Equations or reactions should be indicated with a number in parenthesis on the right side. All tables, graphs, and figures should be referred to in the body of the paper and should not be broken by a page break. The reader should be able to independently read the table or graph and get all the information needed without having to read the laboratory report. **Refer back to the instructions for the Module 1 report for examples.**
- Scientific papers generally do not use direct quotes. Paraphrase your sources being sure to use proper citations.
- Do not capitalize element or compound names.
- Use leading zeros for numbers less than 1. (0.45 not .45)

Module 2 Defense Paper Grading Rubric

Title page (3 points)

_____ Meaningful title (1 point)

_____ Full names of all students in your group (1 point)

_____ Class name and date (1 point)

Results and Observations (67 points)

***Data, Tables, and Graphs* (58 points):**

A. Model compound

_____ Synthesis equation for the formation of the model compound (2 points)

_____ Mass table of model compound used in copper determination (3 points)

_____ Calibration curve used in copper determination (3 points)

_____ Spectroscopic data table used in copper determination including concentrations from cuvettes 6 and 7 (3 points)

_____ Sample calculation for mass percent of copper in one trial (3 points)

_____ Data table for determination of average mass percent of ammonia (3 points)

_____ Sample calculation for mass percent of ammonia in one trial (3 points)

_____ Data table for determination of average mass percent of sulfate (3 points)

_____ Sample calculation for mass percent of sulfate in one trial (3 points)

_____ Calculations showing using the three mass percentages to determine the empirical formula of the model compound (3 points)

_____ Class model compound data table. Highlight the row showing your group's data (3 points)

B. Amino acid compound

_____ Synthesis equation for the formation of the amino acid compound (2 points)

_____ Mass table of model compound used in copper determination (3 points)

_____ Calibration curve used in copper determination (3 points)

_____ Spectroscopic data table used in copper determination including concentrations from cuvettes 6 and 7 (3 points)

_____ Sample calculation for mass percent of copper in one trial (3 points)

_____ Data table for determination of average mass percent of alanine (3 points)

_____ Sample calculation for mass percent of alanine in one trial (3 points)

_____ Calculations showing using the two mass percentages to determine the empirical formula of the amino acid compound (3 points)

_____ Class amino acid compound data table. Highlight the row showing your group's data (3 points)

***Text* (9 points):**

This should give the results of your experiments and **not** be a discussion of why they occurred. The associated tables or figures for each section should be inserted within each paragraph. Provide necessary details of your results and any observations or problems that were encountered.

Discussion (21 points)

A. Model compound

_____ Using the true percentages for the model compound provided in bold on the week 6 class spreadsheet, compare your group's mass percentages with the true mass percentages. (3 points)

_____ For each of the three components, which sources of error account for differences between your group's mass percentages and the true mass percentages? (9 points)

B. Amino acid compound

_____ Using the true percentages for the model compound provided in bold on the week 6 class spreadsheet, compare your group's mass percentages with the true mass percentages. (3 points)

_____ For each of the two components, which sources of error account for differences between your group's mass percentages and the true mass percentages? (6 points)

General (9 points)

_____ No page breaks within tables or graphs (2 points)

_____ Equations included and properly formatted (3 point)

_____ Report double-spaced (1 point)

_____ Proper use of grammar and spelling (3 point)

CH 111 Laboratory Module 3: Calorimetry

Week 8: Introduction to Calorimetry[5]

Objective: In this experiment you will determine the enthalpy change associated with two different dissolution reactions.

If we want to determine the enthalpy change of a chemical reaction we cannot measure it directly. Instead, we can use a technique called **calorimetry** to measure the change in temperature associated with the reaction. Although temperature change is related to the heat transfer, heat and temperature are not the same thing. We have to consider other factors as well. In this experiment, you will investigate how temperature and heat are related and what other variables also need to be considered in finding the enthalpy change.

In these experiments you will be using an insulated test tube called a **calorimeter** to minimize heat transfer to outside of the vessel. In these experiments the calorimeter will contain water. If the reaction is endothermic, the water will provide heat for the reaction and the temperature will decrease. If the chemical reaction is an exothermic process, the water will absorb the heat that is released and the temperature will increase. You can assume for these experiments that the water has a density of 1.00 g/mL and a specific heat of 4.184 J/g°C. Remember: you are measuring the heat of the solution, but you will need to calculate the heat of the reaction (or enthalpy change). Assume that the heat capacity of the calorimeter is negligible.

Prelab assignment: (to be turned in on a separate sheet)

The function of the Results and Observations section is to objectively present your key results, WITHOUT INTERPRETATION, in an orderly and logical sequence using both text and illustrative materials (Tables and Figures). The Results and Observations section always begins with text, reporting the key results and referring to your figures and tables as you proceed. The Results and Observations section should be organized around Tables and/or Figures that should be sequenced to present your key findings in a logical order. The text of the Results and Observations section should be crafted to follow this sequence and highlight the evidence needed to answer the question/hypothesis you investigated.

In your Results and Observations section, you should include ALL data generated in Weeks 4-7 and all relevant calculations resulting from the data. You will need to decide whether the data will be best represented in a table, in a figure, or as text. For example, the mass of your starting metal hydroxide material and the volume of ammonia that you added to it can be included effectively in a sentence. However, the absorbances and concentrations from your metal standard solutions are likely best represented in a table, and the graphical relationship between the absorbance and concentration of the metal standard solutions is best represented in a figure.

[5] Adapted from Teichert, M. A.; Stacy, A. M.; Rico, A. C.; Kegley, S. E.; Molinaro, M.; Walden, S. E. *Computer Chip Thermochemistry; How Can We Create an Integrated Circuit from Sand?* W. W. Norton & Company: New York 2003.

In addition to your data, you will also need to include ALL RELEVANT calculations resulting from your data. For example, in addition to your titration data such as the standardized HCl concentration, mass of sample used, and initial and final buret readings, you should also include the calculations leading from that data to the mass percentage of ammonia. If a technique or procedure is performed multiple times or in a similar manner, do not write out the procedure multiple times. Instead, refer the reader back to when you previously discussed the procedure and mention all relevant changes. For example, after you've shown the calculation required to get from the titration data to the mass percentage of ammonia, you don't have to include all those calculations again. Instead, refer the reader back to your ammonia analysis and mention that the mole ratio between the HCl and amino acid is different than that between HCl and ammonia, and state what that difference is. Make sure to include the data and relevant calculations for the syntheses of both compounds, determination of the mass percentages of the components of both compounds, determination of the empirical formulas and percent yields of both compounds, and class data for both compounds.

Using the guidelines above, write the Results and Observations section for the synthesis, analysis, empirical formula determination, and percent yield determination of the model compound, $Cu(NH_3)_4SO_4$, including text, tables, and figures.

In class:

Part I. How is the enthalpy change of a reaction related to temperature change?

Section A:
You will work in pairs for this experiment. If your lab session is using the LabQuest2, make sure your temperature probe is hooked into the "CH1" port prior to data collection. If you are using a laptop, be sure to hook the temperature probe into the "CH1" port on the LabQuest Mini, which in turn should be plugged into the USB port on your laptop. Regardless of which instrument you are using, check that that blank graph displayed is labeled correctly: temperature on the Y axis and time on the X axis.

Begin your experiment by adding a measured volume of water into your calorimeter and placing the temperature probe inside. Make sure you record the volume of water you used in your notebook. Next, measure out a sample of $CaCl_2$ and record its mass. Press the Collect Data button on your instrument, and add the $CaCl_2$ to the calorimeter. Not sure how much solute to start with? Try about a gram and record the exact mass you use in your notebook. *Is all of the solute immediately dissolving upon being added to the water? Would stirring the solution affect the temperature change of the solution? How?* Record the initial temperature of your water and the highest temperature you reach after adding the salt. The change in temperature should be at least 3°C, and if it is not, adjust the mass of your next sample. Your lab group should do a total of three samples using different masses of $CaCl_2$ using the same volume of water and with each ΔT value being at least 3°C.

Calculate the q for each reaction. Remember that you are not measuring the q of the reaction directly, but the q of the aqueous solution. Then calculate the change in enthalpy of the reaction (ΔH) for each reaction.

Section B:
Next, your group will do three trials in which the mass of $CaCl_2$ is constant, but the mass of water in the calorimeter varies. Since you are assuming the density of water to be 1.00 g/mL, you can measure the volume of water instead of the mass for each trial. Once again, aim for a ΔT of at least 3°C. Be sure to record your constant mass of $CaCl_2$ as well as your three different masses of water. You should also clearly take note of which runs correspond with the different masses of water and solute you've used for your trials in both Part A and B. Again, calculate the q and ΔH for each reaction.

Section C:
Using your data from sections A and B, your group should be able to predict the composition of two solutions with different masses of calcium chloride and water that would give the same temperature change. You should record your prediction in your notebook and then perform the experiment using several trials to test your predictions. Calculate q and ΔH for each reaction.

Using the group data, calculate an average ΔH and standard deviation for the dissolution of $CaCl_2$ in water. Each group will present their results to the class and the data between different groups would be compared.

Part II. How does the identity of the solute affect the enthalpy change?

Once the class has calculated the ΔH for the dissolution of $CaCl_2$, your group will perform a similar experiment to determine the ΔH for the dissolution of ammonium nitrate. Repeat the experiment with a several different volumes of water and masses of solute. Again, make sure the ΔT for each trial is at least 3°C, and record the masses of water and solute you used for each trial in your notebook. Calculate an average and standard deviation of your results and compare them to those collected by other groups.

Laboratory notebook outline for week 8:

Heading: Title, Date, Lab partners

Procedure: Write out a detailed stepwise procedure for your measurements. Be sure to include the specific glassware and measuring devices you will use and the amount of reagents.

Data: Since most of your data will be collected by either the LabQuest2 or a laptop, you should only record the mass of solute and volume of water for each trial you run. For example, you may want to make a table similar to the following:

Run #	Mass H_2O	Mass Solute	Initial Temp	Final temp

Calculations and Results: Show your calculations. Be sure to give any formulas you used and clearly define variables. All calculations should include proper units. For this lab you need to calculate ΔH for the dissolution of $CaCl_2$ and NH_4NO_3. Describe how your actual results for Part I, Section C compare to your predictions. Include any class data ΔH values with standard deviations.

Conclusions:

1. How do each of the following factors relate to each other (directly proportional, indirectly proportional, no relation)?
   - **a)** ΔT and the mass of the reactant
   - **b)** ΔT and mass of water in calorimeter
   - **c)** ΔH and the mass of the reactant

2. In Part I, Section C, you devised two trials that would give the same temperature change. When ΔT is the same in these trials, is the amount of heat released the same? Explain why or why not?

3. Discuss how your results for ΔH compare numerically to those of your classmates. Explain any differences you observe.

4. How does the sign of ΔH for dissolution compare to the sign of ΔT? Explain your answer.

5. If you wanted to raise the temperature of 125 g of water from 25°C to 50°C, how many grams of $CaCl_2$ would you need to add? Use your class average data to answer this question. Show your calculations.

CH 111 Laboratory Module 3: Calorimetry

Week 9: The Acidity of Vinegar

Objective: In this experiment, you will determine the acetic acid concentration (in molarity) of a commercial vinegar using calorimetry.

You are going to use the techniques and calculations you learned last week to find the concentration of acetic acid in a sample of vinegar.

You will be provided with a temperature probe, a calorimeter, pipets, burets, standardized solutions of approximately 1 M NaOH and 1 M CH_3COOH, and a variety of vinegar solutions. This reaction is exothermic.

$$CH_3COOH(aq) + NaOH(aq) \rightarrow NaCH_3COO(aq) + H_2O(l) \quad (\mathbf{1})$$

Prelab assignment:
For this experiment, you will be developing the experimental protocol using your understanding of calorimetry. To help guide your protocol development you will need to complete the worksheet for this experiment on pages 83-86. Think about what you learned last week and how it might be applied to meet the objective of this lab. Consider what variable will be changing (independent variable) and what you will be measuring with the calorimeter (dependent variable). There are multiple ways to use calorimetry to meet the objective, so do not be concerned if your experimental design is different from others. You will turn in this worksheet at the beginning of lab.

Name_____ Lab Section_____

Protocol Development worksheet
(due at the beginning of lab)

The following questions should help you in developing your experimental procedure.

1) Based on the information on page 81, state what you are trying to determine in this lab. Include relevant chemical names and techniques. (One sentence)

2) Consider the lab earlier this semester when you determined the sugar content of your commercial beverage. How did you use solution(s) of a known concentration to find the unknown concentration that you were trying to determine? Describe this approach in 4-5 sentences.

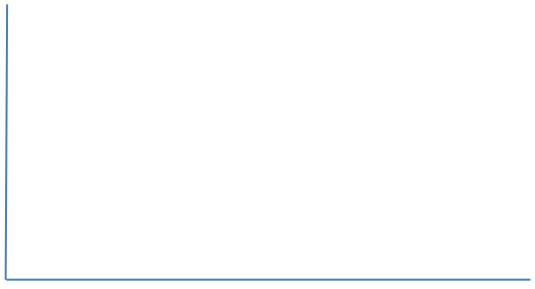
3) In this experiment, you will be given a vinegar and standard solutions of approximately 1 M NaOH and 1 M CH_3COOH, along with a calorimeter and various measuring devices (pipet, buret, thermometer …). Think back to the calorimetry experiment last week. How can you use calorimetry and these known concentrations to find the unknown concentration of acetic acid in the vinegar? Which property will you need to measure, and how can that property be used to find the concentration of the acetic acid in the vinegar? Describe a **general method** in 4-5 sentences.

4) In the experiment described in question 3, what are your independent and dependent variables. Remember that the independent variable is **the one you change** in your various trials, and the dependent variable is **what you measure** in response to that change.

Independent variable:

Dependent variable:

5) On the graph below, put your independent variable on the x-axis and your dependent variable on the y-axis. Include units in your axis labels. Sketch a line or curve to describe how changing your independent variable should change the dependent variable.



6) How will you calculate the concentration of acetic acid in vinegar from the measurement of your dependent variables? Describe your approach in 4-5 sentences. Write down any equations that you will need for this calculation.

7) Think more specifically about the experimental protocol. Which factors should remain constant and which should change? What amounts should you use? How many trials need to be performed. Map out a more detailed protocol.

8) To calculate the percent error for your experiment, you will need to compare your experimental concentration of acetic acid to the one given on the bottle. Most types of vinegars are 4-6% acetic acid by mass. If your vinegar has a mass percent of 5% acetic acid, what is its concentration in molarity? You can assume that the vinegar has a density of 1.00 g/mL. To get started in this calculation, write out the equations for mass % and molarity with the proper units. Show work.

In class:

In your groups, decide on a final procedure and update your notebooks. Discuss your protocol with your instructor or TA. Be sure to accurately record your experimental procedure in your lab notebook, along with all data you collect.

Laboratory notebook outline for Week 9:

Heading: Title, Date, Lab Partners

Procedure: Write out a detailed stepwise procedure for your measurements. Be sure to include the specific glassware and measuring devices you will use and the amount of reagents.

Data: Make a data table for your calorimetry measurements. Graphs must include a meaningful title and the axes must be labeled with units.

Calculations and Results: Show your calculations. Be sure to give any formulas you used and clearly define variables. All calculations should include proper units. Your final calculations will include determining the molarity of your assigned vinegar solutions, and the % acidity of each. Calculate the average and standard deviation if you perform multiple trials. Be sure **all final results are circled** and clearly labeled in your lab notebook. Compare your results to those given on the label of the vinegar and calculate the % error. Any graphs or tables you constructed should be stapled to your lab notebook and another turned in with your carbon copies. Include a table of the class results for the different types of vinegars.

Conclusions:

1. Using the class data, how did the acetic acid concentration values vary within a given type of vinegar? Quantify your comparisons.

2. How do the average acetic acid concentration values between different types of vinegars differ? Quantify your comparisons.

3. What is the largest source of error in your experiment? Explain your answer. (Do not say human error.)

4. If you were going to perform this experiment again, what modifications would you make to the procedure that you had not originally considered when designing your protocol?

CH 111 Laboratory Module 3: Calorimetry

Week 10: What Properties Make a Good Fuel?

Objectives: In this experiment you will determine the $\Delta H_{combustion}$ for several different types of fuels. Then by comparing the chemical structure to the amount of heat released you will determine what chemical properties are required to make a good fuel.

With the ever-increasing cost of petroleum products, scientists are actively pursuing possible alternative forms of fuel. These include oxygenated fuels such as ethanol from corn, or biomass derived from animal or vegetable waste. Some people have even converted their automobile to burn used cooking oil discarded from restaurants. Before designing an alternative fuel we need to first understand what chemical properties are needed to give the most amount of heat in the smallest possible mass. You will do this by measuring the heat released in the combustion reaction for a variety of fuels and compare these values to the number and types of bonds that make up the fuel. All of the fuels we will be studying will produce water and CO_2 upon combustion.

Pre-lab assignment (answer in your notebook):

1. The fuels we will be using in this lab are listed below along with their skeletal structure for the carbon and oxygen atoms. Draw the Lewis structure for each compound using the concept of formal charge to give the best structure. You will need to **draw in the missing hydrogen atoms**. All of these compounds obey the octet rule and only contain single bonds.

a. Methanol CH_4O

C O

b. Ethanol (also used in Sterno) C_2H_6O

C C O

c. Isopropanol C_3H_8O

C C C
O

d. Butanol $C_4H_{10}O$

C C C C O

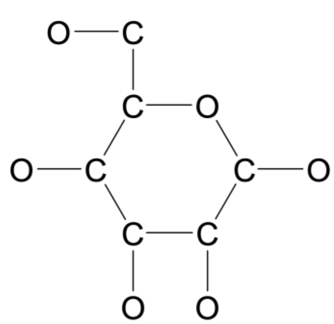
e. Lamp oil $C_{12}H_{26}$ (Dodecane)

C C C C C C C C C C C C

f. Paraffin or candle wax $C_{40}H_{82}$

C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C C

g. Wood - cellulose a polymer of glucose (shown below) $C_6H_{12}O_6$



(Note: Hydrogens are missing from structure)

2. For each of the fuels listed in Question 1 write a **balanced** combustion reaction in your laboratory notebook. (Hint: What are the products for all of these combustion reactions?)

In class:

In this experiment you use a series of fuels to heat a sample of water. By measuring the mass and the temperature change of the water, you can calculate the heat absorbed.

$q_{water} = m \times c \times \Delta T$ for water c = 4.184 J/g °C

Since the water is absorbing heat, q_{water} should be a positive value. Theoretically the quantity of heat given off by the combustion of fuel is equal to the heat absorbed by the water, but in reality some of the heat will be lost to the surroundings. The heat of the combustion reaction, q_{comb}, should be negative since this is an exothermic process.

Before beginning the experiment you will need to record the mass of the burner you are using and the mass of water you will be heating. You should use approximately 100 grams of water in the metal can you are using for heating. Record the initial temperature of the water and then light your fuel burner. Monitor the temperature and let it rise by approximately 20°C. Adjust the flame to minimize the amount of soot formed during combustion. Extinguish the burner and record the **highest temperature** of the water obtained. Record any observations about the combustion in your lab notebook. Record the final mass of the burner to determine the amount of fuel used. For each fuel tested you continue doing trials until your instructor tells you to switch fuels. For each fuel calculate q_{comb} / g fuel used, ΔH_{comb}, and the grams of CO_2 released per kJ. You will use an Excel spreadsheet for these calculations. For some fuels you will be using an approximate molecular formula since the fuel may be a mixture of different compounds. **Take a photo of your experimental setup for your poster.**

As a class you will analyze the results of these reactions. How does the molecular structure relate to the amount of heat released by each fuel? Compare characteristics such as length of carbon chain, types of bonds, and number of oxygen atoms. Using your balanced equations from the pre-lab calculate the grams of CO_2 released per kJ of energy released.

Laboratory notebook outline for Week 10:

Heading: Title, Date, Lab partners

Procedure: Write out a detailed stepwise procedure for your measurements. Be sure to include the specific glassware and measuring devices you will use and the amount of reagents.

Data: Make data tables for each set of reactions your group performed. Also record any observations you make for the combustion reactions. Be sure your values are recorded with the proper accuracy and units.

Calculations and Results: Show sample calculations for each step, but use an Excel spreadsheet to calculate all of the trials for your group. Be sure to give any formulas you used and clearly define the variables. All calculations should include proper units. For this lab you need to calculate q_{comb}/ g fuel, ΔH_{comb}, and the grams of CO_2 released per kJ of energy released. Each student must calculate an average and standard deviation for all their trials of the same fuel.

Record your results on a class data table for the various fuels and use these values to make your conclusions.

Conclusions:

1. Find a reference source that gives the actual value for the heat of combustion for your fuels. (Give a citation for your source). How does your experimental value compare? If you cannot find a value, you can calculate the ΔH value for the combustion reaction using Hess's Law or Standard Heats of Formation. Be sure to use the proper states (s, l, g) for each product or reactant. What might account for the difference between the experimental value you obtained and the reference value?

2. Which fuel released the most heat per gram?
Which fuel released the least heat per gram?
What structural characteristics were common to the fuels that gave off the most heat per gram?

3. Which fuel had the largest ΔH_{comb}?
Was the fuel the same as your answer for #2?
Explain why or why not?

4. Which fuel gives off the least amount of CO_2 per kJ of energy released?
Are fuels with less released CO_2 more or less efficient in terms q_{comb} / mass of fuel?

5. Many states require cars to use gasoline containing oxygenated fuels.
What would be the advantages of using this type of fuel?
How would it affect the miles per gallon?

6. When comparing alcohols, how does the number of carbons impact the ΔH_{comb}?

CH 111 Laboratory

Week 11: Molecular Modeling

Objective: In this exercise you will use ball and stick models and the computer modeling program Spartan to determine the shape and properties of a variety of molecules.

Part I: Ball and Stick Models

When determining the shape of a molecule you must go through the following steps:

A. Draw the Lewis Structure minimizing formal charge.

B. Determine the number of electronic groups around the central atom. An electronic group may be a bond (single, double or triple), a lone pair of electrons, or a single unpaired electron.

C. Determine the Electron Group Geometry from the number of electronic groups.

Number of electron groups	Electron Group Geometry
2	Linear
3	Trigonal Planar
4	Tetrahedral
5	Trigonal Bipyramidal
6	Octahedral

D. Determine the shape by looking at the number of bonding and non-bond groups. **[Consult your lecture textbook.]**

Prelab assignment:

In class you will be building models for the molecules listed in Table 1. Before lab, complete **only the second column (Lewis Structure)** of the table by drawing the Lewis structure for each molecule, including lone pairs of electrons. You can complete this assignment by drawing directly in the following table. Be sure to use the concept of formal charge to find the best Lewis structure for each compound or ion. Some compounds may violate the octet rule when it is appropriate.

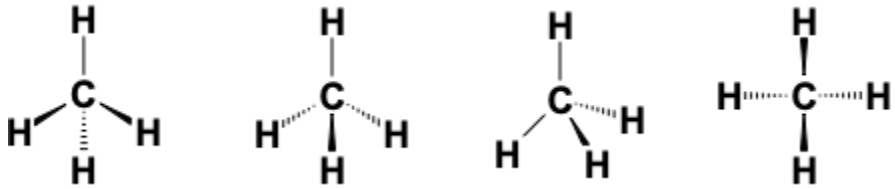
Table 1. Shapes of molecules

Molecule	Lewis Structure	3-D Projection (Wedge Structure)	Molecular Shape
CO_2			
O_3			
H_2O			
NO_3^-			
SCN^-			
NH_3			
SF_6			
XeF_4			
BrF_3			

In Class:

Part I-A. Simple Molecular Structures

Using the Lewis structures you drew in the Prelab assignment, build a model for each of the molecules in Table 1. Be sure you are using a ball for the central atom with the correct number of holes for your electron group geometry. You should have an empty hole for each lone pair of electrons. For multiple bonds, use the longer more flexible bonds that can bend to make a double or triple bond. Your instructor can demonstrate this for you. **After you have built the model, draw its 3-D structure in the next column of Table 1 using a projection or wedge structure.** The tetrahedral molecule CH_4 is drawn below as an example. The tetrahedral shape is three-dimensional. The shape can be drawn by a projection into two dimensions on paper. We will use a wedge to indicate a bond coming out of the paper, a solid line to indicate a bond in the plane of the paper, and a dotted line to indicate a bond going into the paper. Build the model of CH_4 and see if you can determine which projection of the molecule corresponds to each drawing.

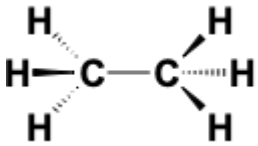


Also give the appropriate name for the shape of every molecule in Table 1.

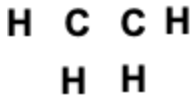
Part 1-B. Bond Rotations

Make a model of ethane (C_2H_6) using the atomic positioning below as a guide.

Notice that the CH_3 groups are free to rotate with respect to each other. This is because there is free rotation around a single bond. Most of the time the ends will position themselves so that they are staggered (rather than the hydrogens lining up) as shown in the three-dimensional drawing.

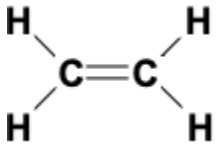


A double bond, however, is rigid and there is no free rotation. To illustrate this, make a model of



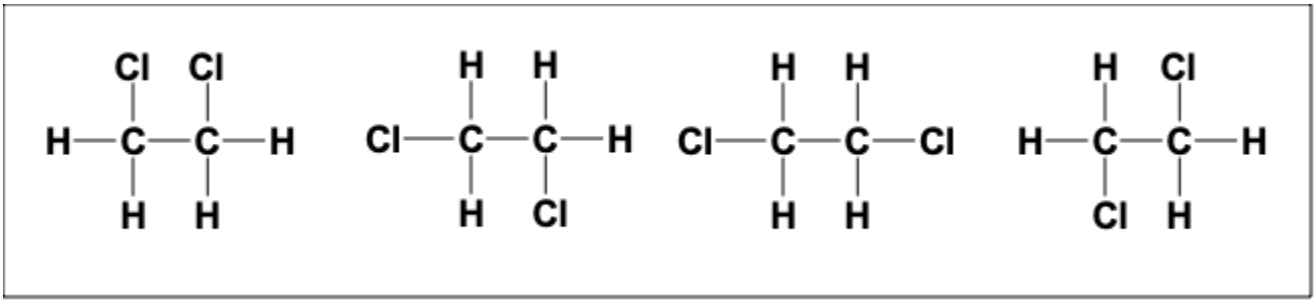
ethene (C_2H_4).

As you can see, it is necessary to connect the two carbon atoms with a double bond. Since there is no free rotation around this double bond, the molecule is quite different from ethane. The H-C-H angle is 120°.

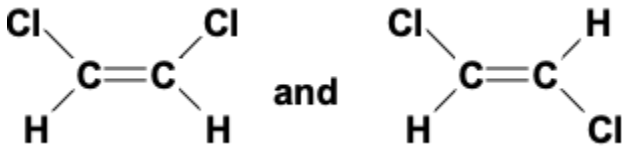


In your notebook, draw the 3-D projections of ethane and ethene. Underneath each molecule, list the molecular geometry. Which molecule is flat (write in notebook)?

Due to free rotation around a single bond, the structures below are identical compounds



but

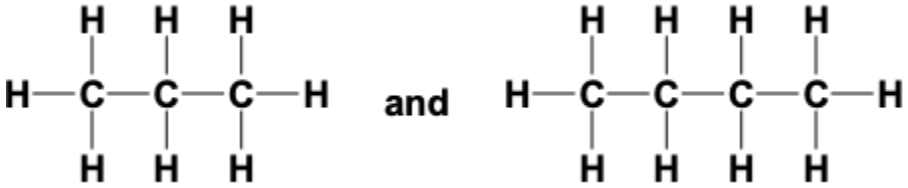


cis trans

are different compounds. Use the models to convince yourself of these points. Note that if you change the relative positions of the atoms in a molecule *without* breaking any bonds (such as by moving it in space or twisting bonds), the molecule has not changed.

Part 1-C: **Chains**

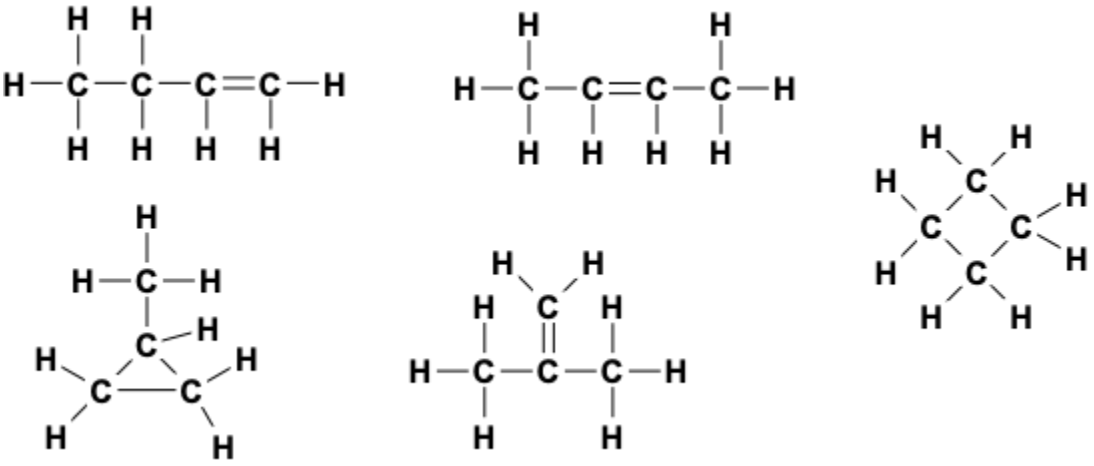
Make a model of the structures below:



Draw the molecules in your laboratory notebook using the 3-D wedge structure. Are carbon-carbon chains in these molecules straight? If not, how would you describe the shape (write in your notebook).

Part 1-D: **Isomers**

When there is more than one way to arrange the atoms in a molecule, we call these different structures isomers. For example, the empirical formula, C_4H_8, has the following isomers:

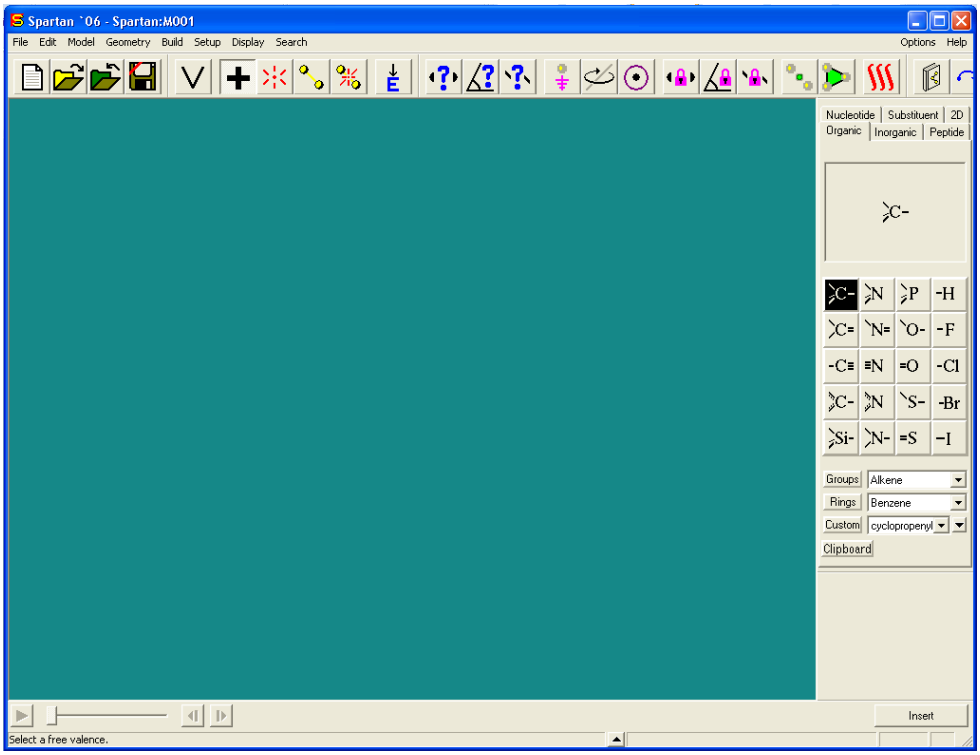


Let's try making different isomers of C_5H_{12}. There are three different isomers of this compound. **In your notebook, draw the 3 different isomers. To save time you can draw them as Lewis structures (like shown above) rather than 3-D projections.** Be careful that you do not have any identical structures. Use the modeling kit for help.

Next consider C_5H_{10}. There are 12 isomers of this compound. **Draw a minimum of 6 isomers of that compound in your lab notebook.** Once again you can draw them as Lewis structures, but be careful not to repeat isomers.

Part II. **Molecular Modeling using Spartan '08**

Please ask questions if you are getting stuck using this modeling program. Follow the directions below to build molecules. **Record responses (when prompted) and answer all questions in your lab notebook.** Once you have completed this exercise you may build more molecules on your own. The following is a view of the main window when Spartan '08 is opened:



The icons in the tool bar at the top are displayed below:

 **New**- Opens new molecule window

 **Open**- Opens previously saved window

 **Close**- Closes current window without closing program

 **Save**- Saves current window

 **View**- Finalized molecule

 **Add**- Allows addition of new atoms to current molecule

 **Remove**- Removes atoms

 **Add Bond**

 **Remove Bond**

 **Minimize**- Calculates most stable structure

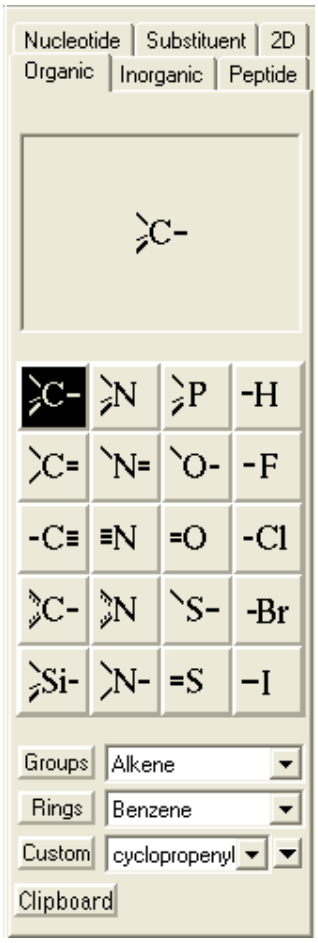
 **Distance**- measure length of bond between two selected atoms

 **Angles**- measure angle between three selected atoms

Record all responses in your laboratory notebook.

To start the program:

- Double click Spartan '08 icon on desktop
- Click on the **New** icon, the entry model kit will appear at the right of the screen (shown at right)



1) Build CH_4

- Click the **Add** icon on the top toolbar.
- Select the "Organic" tab on the toolbar on the right side of the screen.
- Click on the button displaying a carbon atom with four single bonds on the entry model kit.
- Click on the main screen. A carbon atom with four available single bonds will appear.
- Click the hydrogen button from the entry model kit.
- Add a hydrogen atom to each of the available single bonds (available bonds should appear yellow on the main screen) by clicking on each bond.
- Now that your molecule is built, click the **Minimize** icon (**E**) on the top toolbar to put your molecule in its most stable form.
- Click the **View** icon (**V**) to finalize your molecule.
- Once finalized, look at several different representations of your molecule by using the "*Model*" menu at the top of the screen and selecting from different views such as "*wire*," "*ball and wire*," "*tube*," or "*space filling*," from the dropdown menu.
- Return to "*Ball and spoke*" view.
- Left click, hold, and drag the mouse on the main molecule screen to rotate the molecule in three dimensions. Right click, hold, and drag the mouse to move the molecule to a different location on the screen. Choose a good clear view of your molecule.
- Now measure the hydrogen-carbon-hydrogen bond angle. This is done by first selecting the **Angle** icon from the top toolbar. Then, you select a hydrogen atom (by clicking directly on the atom), followed by the carbon atom, and followed by another hydrogen atom. The selection must be done in this order for correct calculation of the desired angle. The associated angle value will appear in the lower right hand corner of the Spartan '08 screen. Record it in your notebook.

Question 1: What is the overall shape of the CH_4 molecule? What is the expected bond angle for this molecule? Was the observed bond angle the same?

Open a new molecule screen by clicking the **Close** icon (Discard) and then the **New** icon.

2) Build CF_2Cl_2

- Build this molecule in the same manner as CH_4.

- Use the Chlorine and Fluorine buttons from the entry model kit.
- To erase errors, use the **Remove** and **Remove Bond** icons to remove erroneous atoms and bonds. Once the specific icon is selected, click on the molecule or bond that you wish to remove.
- Use the **Minimize** icon (**E**) to determine the most stable structure and finalize the molecule using the **View** icon (**V**).
- Determine all the bond angles for this compound and **record them in your notebook**. There should be three unique bond angles.

Question 2. Do the bond angles vary between CH_4 and CF_2Cl_2? Explain why they would be the same or different.

3a) Build CH_3CH_3

- Build this molecule in the same manner as above.
- Determine the most stable structure of the molecule and finalize it.
- Now measure the length of the bond between the carbon atoms. This is done by first selecting the **Distances** icon from the top toolbar. Next, select both of the carbons that share the single bond. The length of the bond will appear in the lower right-hand corner of the Spartan '08 screen. The length is calculated in Angstroms (Å), which is equal to $1x10^{-10}$ meters. **Record this measurement in your notebook**.

3b) Build CH_2CH_2

- Build this molecule in the same manner as above.
- For the double bonded structure of this molecule ($H_2C=CH_2$), you have two options:
  1) Use the button depicting a carbon atom with a double bond in the entry model kit. Bind the two carbons together with the double bonds.
  2) Use the single bonded carbon button to connect two carbons. Then use the **Add Bond** icon to connect two of the free bonds. Once the icon is selected, click the end of a free bond from each of the adjacent carbons. This will combine the bonds into one double bond.
- The double bond should be visible as two thinner cylinders between the atoms.
- Add H atoms and minimize (**E**) your structure.
- Now measure the length of the bond between the two carbon atoms. **Record this value in your notebook.**

3c) Build CHCH

- Build this molecule in the same manner as above.
- For the triple bonded structure of this molecule (HC≡CH), use the carbon atom with a triple bond in the entry model kit.
- Add H atoms and minimize your structure.
- Now measure the length of the triple bond between the two carbon atoms. Record this value in your notes.

Question 4: How do the bond lengths of H_3CCH_3, H_2CCH_2, HCCH differ? Why?

4a) Build C_6H_{12} ring (Cyclohexane)

- Connect six carbons together in a ring. Connect any broken bonds using the **Add Bond** icon. (Unconnected bonds remain yellow. Connected bonds are gray. Make sure that all bonds in the ring are gray before proceeding.)
- Add H atoms and minimize (**E**) your structure.

Question 5: Is the molecule planar (flat)?

- View the ring molecule in the "Space-filling" view.

Question 6: Is there much room in the center of the ring?

4c) Build C_6H_{10} (Cyclohexene)

- Connect six carbons together in a ring.
- Combine two free bonds from adjacent carbons together using the **Add bond** icon. This will create the needed double bond.
- Add H atoms and minimize your structure.

Question 7: Is the structure of the ring planar?

5) Build C_6H_6 ring (Benzene)

- To make this ring (a benzene ring), connect 6 carbons using the carbon button displayed to the right. This button signifies the alternation of a double bond between two bonds on the carbon atom. This alternation is present in this type of ring.

- Make sure that all of the alternating double bonds are bound (no yellow).
- Add H atoms and minimize your structure.
- Measure and **record the length of all the carbon to carbon bonds in the ring in your notebook**

Question 8: Is benzene planar?

Question 9: Are all of the carbon to carbon bonds in benzene the same length? How do the lengths of these bonds compare to the length of carbon to carbon single, double, and triple bonds that you measured previously? Why?

6) Build CH_3COCH_3 (Acetone)

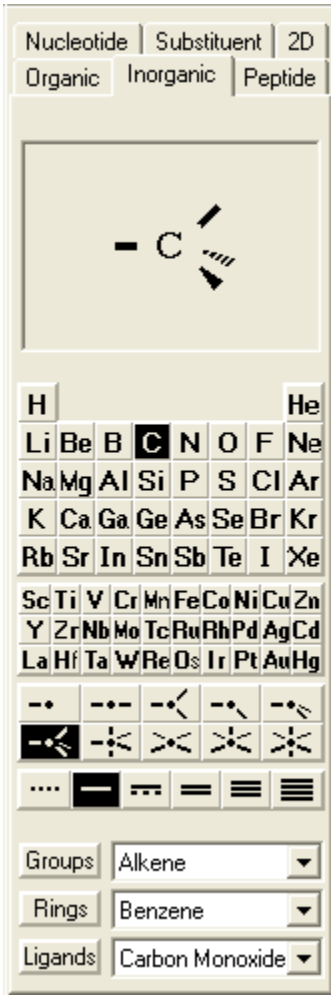
- Build this molecule by first selecting the carbon atom with one double bond and two single bonds.
- Now attach an oxygen atom with a double bond to the double bond of the carbon atom.
- Attach two additional carbon atoms to the central carbon by selecting the carbon with four single bonds.

- Add H atoms and minimize your structure.
- Now measure the oxygen-carbon-carbon and the carbon-carbon-carbon bond angles using the **Angle** icon on the top toolbar. Make sure that you select the atoms in consecutive order. **Record the two angles in your notebook.**

Question 10: What is the shape of acetone around the central carbon atom? What is the expected bond angle for this geometry? Were the observed bond angles the same? Why, or why not?

7a) Build NF_3 and calculate its dipole moment.

- To build this molecule must first click on the "Inorganic" tab on the entry model kit. The entry model kit should change to look like the image to the right.
- Use the  button on the "Inorganic" tab to make the center nitrogen atom with three bonds. Make sure that the other atoms are restricted to only one bond by using the  button.
- Once the molecule is built minimize the structure.
- Begin the dipole moment calculation by clicking the "Setup" menu from the top toolbar and then selecting the "Calculations…" option. This should open the Calculations window.
- Leave all of the values in their default form.
- Click the "Submit" button.
- Save the file as "NF3" to start the calculation. A window should pop up, letting you know that the calculations have started. The calculation takes a few seconds, during which nothing should happen on screen. At the conclusion, another pop-up window will let you know that the calculation is complete. This molecule may shift its form.
- Click on the "Display" menu from the top toolbar and select the "Properties" option. This should open the Molecule Properties window.
- Click on the box labeled "Display Dipole Vector" to show the molecule's dipole moment on the main Spartan '08 window. **Record this value in your notebook.**



Question 11: What is the overall shape of this molecule? Does it have a dipole moment? Why, or why not?

- Close the molecule, and open a new window.

7b) Build BCl_3 and calculate its dipole moment

- You must use the "Inorganic" tab for this molecule

- Make sure that you use the boron atom and use the  button to make the three bonds. Also make sure that the chlorine atoms only have one bond by using the  button.
- Once the molecule is built, minimize the structure.
- Calculate the dipole moment and **record it in your notebook**. Save the file as "BCl3" for the calculation.

Question 12: What is the overall shape of this molecule? Does this molecule have a dipole moment? Why, or why not?

- Close the molecule, and open a new window

7c) Build BrF_5 and calculate its dipole moment.
- Build this molecule in the same manner as above.
- Use the  button on the "Inorganic" tab to make the center bromine atom with five bonds. Make sure that the other atoms are restricted to only one bond by using the  button.
- Calculate the dipole moment and **record it in your notebook**. Save the file as "BrF5" for the calculation.

Question 13: What is the overall shape of this molecule? Does it have a dipole moment? Why, or why not?

- Close the molecule, and open a new window.

7d) Build $SiBr_2F_2$ and calculate its dipole moment.
- Use the  button on the "Inorganic" tab to make the center silicon atom with four bonds. Make sure that the other atoms are restricted to only one bond by using the  button.
- Calculate the dipole moment and record it in your notebook. Save the file as "SiBr2F2" for the calculation.

Question 14: What is the overall shape of this molecule? Does it have a dipole moment? Why, or why not?

- Close the molecule, and open a new window.

7e) Build SF_6 and calculate its dipole moment.
- Build this molecule in the same manner as above.
- Use the  button on the "Inorganic" tab to make the center sulfur atom with six bonds. Make sure that the other atoms are restricted to only one bond by using the  button.

- Calculate the dipole moment and **record it in your notebook**. Save the file as “SF6” for the calculation.

Question 15: What is the overall shape of this molecule? Does it have a dipole moment? Why, or why not?

CH 111 Laboratory Module 3: Calorimetry

Week 12: Group Work on Poster

At the end of module 3, your lab group for Week 11 will produce a poster presentation of your results from your fuel properties experiment. **The poster should be uploaded to Moodle by the deadline discussed in class.** The poster will be created on a single PowerPoint slide using a template provided on Moodle. You can cut and paste text and figures on the template slide using the appropriate font sizes. Your group's poster should contain the following sections. A grading rubric is also included in the following pages.

Title

Your poster should have meaningful title and include the full names of all students who are in your group.

Abstract

Give a concise summary of the project in one paragraph.
What were you trying to accomplish in this laboratory project?
What was the result?

Introduction

Give an overview of the background information necessary for the reader's understanding of the significance of the experiment: background on different fuels, information on CO_2 emissions from different fuels, differences between oxygenated and deoxygenated fuels, etc. In this section you must use outside sources and should cite any references used.

Experimental Procedure

Unlike a lab paper, you do not have to give every experimental detail in this section. You do want to give the reader a basic understanding of what you did. **Give a balanced equation for all reactions you performed.** You will want to give a general description of your experimental apparatus and may want to include a sketch or photo. This section should be written in the past tense and in passive voice (no personal pronouns).

Results and Observations

This should give the results of your experiments and not be a discussion of why they occurred. You should include tables and/or graphs for all of your results that are numbered and have meaningful captions. Include both a class data table and a table with your group data. Briefly (one or two sentences) highlight the most important results. Describe the major calculations here.

Discussion

In this section you will discuss your results. Use bulleted sentences to draw the reader to the important points instead of paragraphs. Include the standard deviations from your group's trials, and describe the general trends of the class data. How did your experimental values compare to the expected values? Can

you explain any trends you observed in your results? Revisit your post-lab questions; many of them cover topics that would be appropriate to mention. What kinds of properties should be considered when developing a fuel?

Conclusion

Give a brief paragraph summarizing your final conclusions. Talk about how your data compares to that of your classmates. Overall, this section should tell us how all of the information you presented previously led you to meeting the outcome desired for the lab project. Summarize the final outcomes you obtained.

References

List any references you used in introduction or discussion section using ACS format. You do need to have some references for your background information. These should be edited or peer reviewed sources (print or web) and not propaganda web sites such as you might find on a corporate or environmental web sites.

Notes:

- Students should review the definition of plagiarism in the BSC Honor Code.
- Format your tables, graphs, and equations appropriately; see the instructions for the Module 1 report for a review.
- When using references, they should be presented in American Chemical Society format. You may use either endnotes or footnotes but indicate where the reference goes using a superscript in the text[1]. Be very careful in using sources from the web. All sources should be reviewed (a scientific journal), from an edited publication (such as a textbook, Time magazine, or Scientific American), or a government website (such as Environmental Protection Agency or Food and Drug Administration). Wikipedia is **not** an appropriate reference for a formal lab report. Also, your BSC lab manual is NOT a reference. You must have at least 3 references

Books:
Author (Last name, Intials; separate with semicolon if more than 1). Title (in italics); Publisher: City, year; p. #.

Example:
Anthony, S; Brauch, T. W.; Longley, E. J. What Should We Do About Global Warming?; Wiley: New York, 1998; pp. 150-153.

Journal:

Author (same as above). Journal name(abbreviated and in italics). Year (bold), volume, page.

Example:
Porter, D. J.; Stewart, A. T.; Wigal, C. T. *J. Chem. Educ*. **1995**, 72, 1039.

Web:

Author (if any). Title of Site. URL (accessed Month Day, Year), other identifying information (if any).

Example:
International Union of Pure and Applied Chemistry Home Page.
http://www.iupac.org/dhtml_home.html (accessed April 24, 2005).

Module 3 Poster Grading Rubric

_____ Meaningful title with all group members names (2 points)

Abstract (8 points)

_____ Summarizes project (3 points)

_____ Gives important results (3 points)

_____ Proper format (2 points)

Introduction (15 points)

_____ Provides proper context for experiment (4 points)

_____ Background information on fuels (4 points)

_____ Information on CO_2 emissions from fuels and oxygenated vs deoxygenated (4 points)

_____ References outside sources (3 points)

Experimental Procedure (12 points)

_____ Includes balanced reactions (4 points)

_____ Includes general description to give reader basic understanding of procedure (3 points)

_____ Includes general description of experimental apparatus (3 points)

_____ Written in past tense and passive voice (2 points)

Results and Observations (16 points)

_____ Class data table included (3 points)

_____ Table of group data (3 points)

_____ Appropriate table headings or figure captions (3 points)

_____ Proper units and sig figs used (2 points)

_____ Describe any major calculations you performed (2 points)

_____ Brief description of results including the consistency your experimental values for a given fuel. (one or two sentences) (3 points)

Discussion (17 points)

_____ Used bullets to summarize key ideas. (2 points)

_____ What trends in fuels are observed in terms of kJ/gram? kJ/mol? (3 points)

_____ What trends in fuels are observed for the amount of CO_2 formed per kJ? (3 points)

_____ How does the carbon to oxygen ratio in the fuel affect the heat output? (3 points)

_____ How do your experimental results compare to published values? For the class data, are the trends in experimental values similar to the trends in published values? (3 points)

_____ Possible sources of error (3 points)

Conclusion (6 points)

_____ Final conclusions summarized (3 points)

_____ Gives properties that must be considered when developing a fuel. (3 points)

References (4 points)

_____ Uses American Chemical Society format (2 points)

_____ References from appropriate sources (2 points)

Overall Quality (8 points)

_____ Proper grammar and spelling (5 points)

_____ Organized so poster is easy to read (3 points)

Participation (12 points)

_____ Student participated in work on the poster (6 points)

_____ Student attended lab for poster preparation (or had an excused absence) (6 points)