CHEM 105: BIOCHEMISTRY AND SOCIETY

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Lab6: Alcohol and Energy

INTRODUCTION

To decrease reliance on "foreign" oil, which is needed by the US and China, people are turning to using ethanol to power cars. Ethanol is combusted (an oxidation reaction) to produce CO_2 and H_20. We also can obtain energy from ethanol by metabolizing it in the body. Most of the energy we get from our food is supplied by carbohydrates and fats. These food molecules are broken down in our cells in oxidation reactions. In the presence of excess oxygen, the food molecules react in a complex series of reactions to produce CO_2 and H_20. We breathe in oxygen to sustain this process and exhale carbon dioxide and water vapor as reaction products. The energy released in these reactions fuels our basal metabolism (the chemical reactions constantly occurring to maintain basic body functions) and our physical activity. Because the products of these oxidation reactions are the same when food is burned in a calorimeter as when it is metabolized in the body, we can approximate the energy value of carbohydrates and fats in our bodies by doing a simple calorimetry experiment.

Food chemists use a bomb calorimeter to measure the energy evolved from the combustion of food. A bomb calorimeter is a sealed steel vessel or "bomb" designed to withstand high pressures and surrounded by a known volume of water—a sealed container at constant volume. The quantity of energy (measured in joules or calories) produced by the combustion of a known amount of food inside the bomb can be calculated from the temperature increase of the water. Note that this approximation does not work as well for proteins because their nitrogen is released as N_2 in a bomb calorimeter whereas the body produces mainly urea, $(NH_2)_2C0$. In addition, laboratory measurements of the energy content of foods tend to be higher than the energy obtained by the body because a small percentage of food is not digested or absorbed as it moves through the digestive tract. This percentage varies depending on the efficiency of a person's digestive system. Finally, a portion of the food's energy must be used for the process of digestion and metabolism.

In this lab, you will quantitatively determine the energy per unit mass released by the combustion of ethanol and nuts. You will combust these substances and capture the heat energy released, as best as you can, by using it to warm water in an aluminum soda can. By measuring how much the water warms, you can calculate a value for how much heat energy is released on combustion of the ethanol and food.

Procedure

A minimal set of materials will be provided. You are responsible for designing your apparatus and setting the parameters for the experiment. For your lab write-up, describe and sketch your apparatus.

Ethanol

Fill a soda can with exactly 200 mL of tap water. **Clamp it directly** to a ring stand. Next obtain an alcohol bottle from your lab TA. It contains 95% ethanol, 5% water. Take the mass on the analytical balance to 0.01 g. Place the burner under your soda can. Light the burner and heat the water. DO NOT leave the thermometer in the can while the ethanol is burning, unless you can suspend the thermometer so it does not touch the bottom of the can. Take the mass of the burner after the water is heated. Record your data in the table. Repeat once. Use new tap water for each trial.

Nuts

Using a butterfly clip construct a nut “support stand” to hold the food item. Fill a soda can with exactly 200 mL of water. Carefully light the food on fire and measure the temperature change in the water that results from the heat given off. Stir the water thoroughly to be sure that it has a uniform temperature. The ash left after burning the food is very sooty, so try not to get it on your clothes. Repeat each trial, using fresh tap water in the can each time.

After conducting the experiment once, speculate on the sources of error. Will each of these errors increase or decrease the measured temperature change? Because you are not burning the food in a sealed and insulated bomb calorimeter, your results will not be entirely precise or accurate. However, there are many ways to refine this experiment to decrease error.

Data

Trial	$mass_{init}$ (g)	$mass_{final}$ (g)	mass (g)	T_{in} (^oC)	T_{fin} (^oC)	T (^oC)
EtOH						
EtOH						
nut						
nut						

In the Laboratory report, you will use the above data to calculate the number of calories of heat energy released on the burning of 1 gram of sample. For your calculations, you will need the following information.

Useful Information

- 1 calorie (cal) is the amount of energy required to raise the temperature of 1 gram of water 1 degree Celsius.
- The density of water is 1 gram/mL
- A chemist’s calorie (lowercase c) is different from a food Calorie (capital C). A food Calorie is actually a chemist’s Kilocalorie. 1 Calorie = 1 Kilocalorie = 1000 calories. FOR SIMPLICITY WE WILL USE THE CHEMISTS calorie (cal) and the Kcal.

LABORATORY REPORT

Experiment 7: Energy and Alcohol

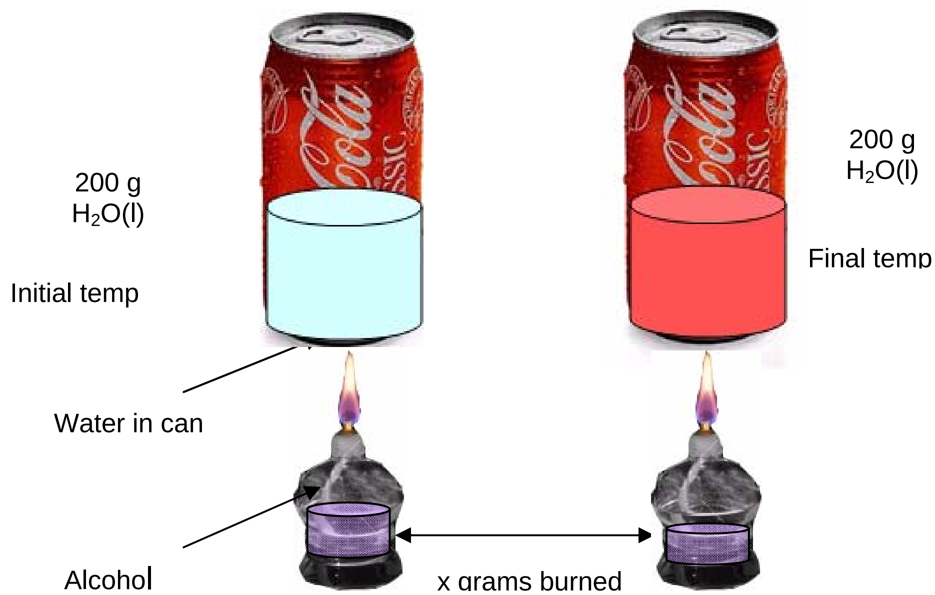
Names: ____________________ ___________________________

Date: ____________

1. Draw a diagram to the right of the sample apparatus you used to combust your **food** samples.

2. What are some sources of error in this experiment? Which were you able to correct for as you redesigned the experiment? Which are inherent in the technique? Speculate on a technique that would minimize most sources of error.

Calculations: The diagram and question below should help you in performing your calculations.



Remember that 1 ml of water has a mass of 1.00 g. Calculate the values by using simple proportions. For a start, fill out the blanks below.

Given: It takes 1 cal of heat to raise the temperature of 1 g of water, 1 degree Celsius.

It would take ____ cal of heat to raise the temperature of 200 g of water **1** C^o.

It would take ____ cal of heat to raise the temperature of 200 g of water **10** C^o.

It would take ____ cal of heat to raise the temperature of 200 g of water by **y** C^o.

You burned your samples and will determine how many calories of heat were released to raise the temperature of the water in the can by the number of degrees observed. That number of calories arose from the burning of a certain number of grams of the sample. One sample is pure (ethanol). The others are not, and contain carbohydrate, protein, and fat.

3. Ethanol analysis.

a. Calculate the number of calories of heat energy released on the burning of 1 gram of ethanol for each of your duplicate samples, and the average value. You must show your work below.

Trial 1: Trial 2: Avg:

b. How close is your average value to others in the class? To the "actual" value? It would seem logical than the more times you did the experiment, the closer your calculated average might be to the actual value. We will use all the average values from each group in the lab to determine a class **mean** (another word for average) and **standard deviation** which gives a sense of the spread of the group averages around the mean. If all the group averages were identical, there would not be any "deviation" from the mean. How is the standard deviation calculated? First calculate the **deviation** = Gp avg – Class mean (column 3) for all the Gp avgs. This value would be positive or negative. Then determine the **square of the deviations** to get all positive numbers (column 4). Fill out the chart below

Gp Initials	Gp Avg (cal/g)	(Gp Avg – Class Mean)	(Gp Avg – Class Mean)^2
	1452		
	3022		
	3066		
	1894		
	3215		
	Sum = Σ	=	=

Next determine the sum (Σ) of the deviations in column 3 and of the (deviations)^2 in column 4. Note that the sum of all the deviations must be 0 since half are positive numbers and half are negatives, but the sum of the deviations squared (Σ(deviations)^2) is not.

Next determine the **standard deviation SD** which is approximately the square root of the average of the deviations squared. The average of the deviations squared would be the sum of all the (deviations)^2 divided by n, the number of measurements. In the actual formula, the sum of all the (deviations)^2 is divided by n-1. The standard deviation is the square root of this number. The formula is give below.

$$SD = \sqrt{\frac{\Sigma(deviations)^2}{n-1}} = \sqrt{\frac{\text{sum of}\,(deviations)^2\ \text{(from last column)}}{n-1}} =$$

Show your calculation.

c. The SD is a measure of the spread and hence uncertainty of your experimental value. The best value is determined from the class mean and is expressed as the

class mean $\pm$ SD

Look up the actual value for the heat released when one gram of ethanol is burned. Compare it to your experimental value. Does it fall within the class mean $\pm$ SD? Is your value lower or higher? Explain a reason that your value is either lower or higher than the actual value.

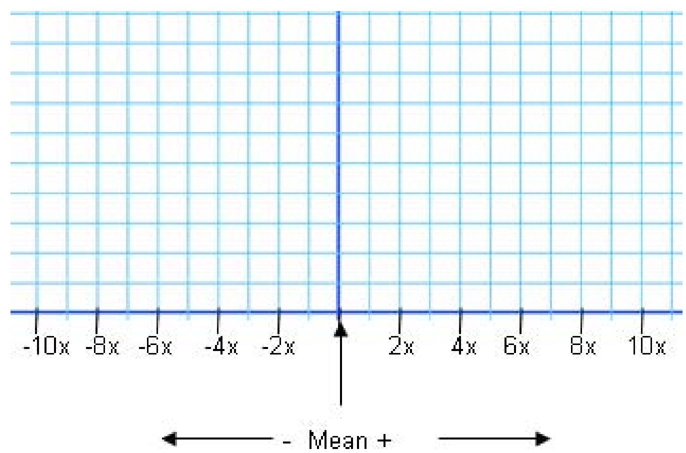
d. Find the minimum and maximum values for the group averages, and the difference between the minimum and maximum group averages.

Minimum gp avg: ______ Maximum gp average: ______ Difference: ________

Next divide the difference by 10. Call this number x. x = ____________

Now look at all the group average and determine how many of them are in the ranges shown in the table below. Draw a **bar** graph showing the number of Gp averages (on the y axis) falling in each range (on the x axis). Which ranges would probably contain a higher number of Gp avg in those range? Does the bar graph look like you expect it would? Explain under the graph.

Gp Avg Values in range btw.	# in range
(Mean -10x and Mean-8x)	
(Mean -8x and Mean-6x)	
(Mean -6x and Mean-4x)	
(Mean -4x and Mean-2x)	
(Mean -2x and Mean)	
(Mean to Mean + 2x)	
(Mean +2x and Mean + 4x)	
(Mean +4x and Mean + 6x)	
(Mean +6x and Mean + 8x)	
(Mean +8x and Mean + 10x)	



4. Calculate the **theoretical** values for **Kcal** of heat energy released for the walnuts using the data below

Per serving : 28 g; Calories (nutritional Cal = Kcal): 210
Total fat: 20 g; Total Carbohydrate: 3 g; Sugars 0 g; Protein 5 g.

a. If you burn 28 g of the walnut halves (3 g CHO, 20 g fat, 5 g protein), how many total Kcal of heat would be released? (use the figure of 9 Kcal/g fat, 4 Kcal/g CHO, 4 Kcal/g protein).

b. Now by simple proportions from (a) above, how many Kcal would you get if you burn 1 g of walnuts?

c. Calculate the **avg cal/g** from your experimental data. How does the energy released in your experiment compare with the value reported on the nutritional label or in a table of nutritional energy values? That is, how accurate are your results?