Experiment 14

Caloric Content of Food

Pre-Lab Assignment

Before coming to lab:

- Read the lab thoroughly.
- Answer the pre-lab questions that appear at the end of this lab exercise.

Purpose

The caloric content of a food item will be determined using "soda can" calorimetry, where the heat lost through combustion will be captured by a known amount of water kept in an aluminum can above. The corresponding increase in temperature of the water will be used to find the total energy lost by the food item, whose value will then be compared to that listed on the nutritional label.

Background

The formation of a chemical bond is an endothermic process, meaning that energy is absorbed and stored in the bond itself. Breaking chemical bonds is an exothermic process, meaning that the energy previously stored in the bond is now released as heat which can be trapped and absorbed by a known amount of water (q_{H2O}) which is contained in an aluminum soda can which will serve as the calorimeter (q_{can}). The can's and the water's temperature will increase proportionally to the energy gained, thus allowing the amount of energy originally contained in the bond (q_{fuel}) to be calculated by Eqn. 1.

$$- q_{fuel} = q_{H2O} + q_{can} \qquad \text{Eqn. 1}$$

This is assuming that all of the heat lost by the burning fuel is captured by the water and soda can and none is lost to the outside. The heat that the water and can absorb is equal to their individual masses, changes in temperature, and specific heat capacities, a tabulated, standardized value unique to the individual substance as seen in Eqns. 2 and 3.. For liquid water, its heat capacity is 4.184 J/g °C and for aluminum, 0.900 J g/°C.

$$q_{H2O} = m_{H2O}\, C_{s,\, H2O}\, \Delta T \qquad \text{Eqn. 2}$$

$$q_{can} = m_{can}\, C_{s,\, Al}\, \Delta T \qquad \text{Eqn. 3}$$

The change in temperature ($\Delta T = T_{final} - T_{initial}$) will be assumed to be the same for both the water and the soda can.

This type of analysis is known as calorimetry, as "calor" means heat and "metry" means study or measure, in Latin. Calorimetry can be used with all organic substances to determine how much chemical energy a substance contains and thus the maximum amount of work the substance will produce when burned.

Nutritional labels on common foodstuffs list the caloric content of the food, a direct measure of the energy content of the food's chemical bonds. Diet manuals and calorie counter books will, for many different types of foods, list the serving size and the approximate amount of calories that a person consumes when eating it. When eaten, food isn't actually burned inside the human body in the same manner as it is burned in a calorimeter. Instead, the food is chemically oxidized in one's sells to "burn" in a process called the Krebs Cycle, releasing chemical energy to be used to make compounds of importance to the body. The amount of energy released can be represented as the heat of combustion (ΔH) and is dependent on the amount of food consumed, as seen in Eqn. 4.

$$\Delta H = \frac{q_{rxn}}{g_{sample}} \qquad \text{Eqn. 4}$$

Nutritional energy is usually measured in units of kilocalories (kcal) or Calories (Cal.), which is 1000 calories (cal.). A calorie is the amount of heat required to raise one gram of water by one degree Celsius at one atmosphere of pressure. The official SI unit of energy is the Joule (J). One joule of energy is expended when one kilogram is moved one meter by a force of one Newton. One calorie is equivalent to 4.184 Joules.

Example Problem: Finding the heat of combustion for a food item

To a 10.9557 g aluminum can, approximately 100 mL of water was added to give a total weight of 106.4892 grams of can and water. A 2.5055 gram gummi bear was burned underneath the can and water, of which both were initially at 4.2°C. When the gummi bear was fully combusted, the temperature of the water increased to 60.5°C. Calculate the heat of combustion for the gummi bear, in Calories/serving. (1 serving is 40 grams, 130 Cal./serving)

Step 1: Find the mass of the water

$$106.4892 \text{ g} - 10.9557 \text{ g} = 95.5335 \text{ g}$$

Step 2: Find the heat absorbed by the water (q_{H2O})

$$q_{H2O} = (95.5335 \text{ g})(4.184 \text{ J/g °C})(60.5 - 4.2\text{°C}) = 2\underline{2}503 \text{ J}$$

Step 3: Find the heat absorbed by the can (q_{Al})

$$q_{Al} = (10.9557 \text{ g})(0.900 \text{ J/g °C})(60.5 - 4.2\text{°C}) = 5\underline{5}5 \text{ J}$$

Step 4: Find the total heat released by the fuel (q_{fuel})

$$q_{fuel} = -(q_{H2O} + q_{Al}) = -(2\underline{2}503 \text{ J} + 5\underline{5}5 \text{ J}) = -2\underline{3}058 \text{ J}$$

Step 5: Convert q_{fuel} into units of Calories

$$-23058 \text{ J} \times \frac{1 \text{ cal.}}{4.184 \text{ J}} \times \frac{1 \text{ Cal.}}{1000 \text{ cal.}} = 5.\underline{5}10 \text{ Calories}$$

Step 6: Find the heat of combustion in Calories/gram

$$\Delta H = \frac{-5.510 \text{ Calories}}{2.5055 \text{ g}} = -2.\underline{1}9 \text{ Cal./gram}$$

Step 7: Find the heat of combustion in Calories/serving

$$-2.19 \text{ Cal./g} \times \frac{40 \text{ grams}}{1 \text{ serving}} = -88 \text{ Cal./serving}$$

Step 8: Compare to the nutritional label

-88 Cal./serving released = 88 Cal./serving absorbed when consumed

$$\text{percent error} = \left| \frac{130 - 88}{130} \right| \times 100 = 32\% \text{ error}$$

Procedure

Part I: Finding the Heat of Combustion (∆H) for Food

1. Half-fill a 400 mL beaker with water and then fill the rest of it with ice. Set it aside.

Note: read Steps 2-5 and take all items listed with you to the balance room at the same time.

2. Prepare a soda can so it can be supported by a ring stand as shown in Fig. 1.

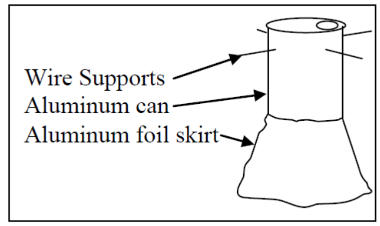

Fig. 1: Soda Can Set-Up

3. Weigh the dry soda can and the aluminum foil skirt on the balance. Record the mass on your data sheet.

4. From the cold water prepared in Step 1, measure out approximately 100 mL of water only (do not transfer ice) and add it to the soda can. Reweigh the can, skirt, and water, and record the mass on your data sheet.

5. Construct the support system shown in Fig. 2and weigh it. Record the mass on your data sheet. Add your food item (fuel) to the support system and reweigh both, recording the mass on your data sheet.

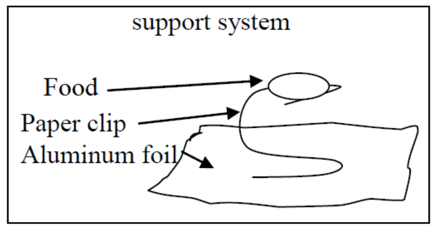

Fig. 2: Support System Set-Up

6. Using a split stopper over a glass thermometer, clamp the thermometer so that is about 2 cm from the bottom of the can and yet submerged in the water. Place the food item and the support system under the can and adjust the height of the can to about 3 cm above the food.

7. Record the initial temperature of the water in the can on your data sheet. It should not be above 10°C. If the temperature is above 10°C, cool the water and can in an ice bath and then dry the outside of the can and record the new initial temperature.

8. Light the food item and adjust the can so that the top of the flame is about 1 cm below the bottom of the can. Use the aluminum foil skirt to surround the bottom and trap the heat. Allow the food to burn until it goes out on its own.

9. Stir the water and measure the temperature until it stops rising. Record the maximum as your final temperature on your data sheet. This may take 20-30 seconds.

10. Weigh the support system and whatever remains of the food item on it if it did not fully combust. Record this mass on your data sheet.

11. Repeat Steps 1-10 for a second trial.

12. Calculate the heat of combustion (∆H) for the food item and compare it to the nutritional label value.

Part II: Find the Heat of Combustion (ΔH) for a candle

1. Repeat Part I, Steps 1-10 with a candle as fuel instead of food. In Step 8-9, blow the candle out once the temperature has increased by 20°C, then continue through Steps 9-10.

2. Calculate the heat of combustion (ΔH) for the candle and compare it to the food item.

Experiment 14—Data Sheet

Name: ____

Part I: Heat of Combustion of a Food Item

	Trial One	Trial Two
1. Mass of can and skirt (g)	__________	__________
2. Mass of can and skirt and water (g)	__________	__________
3. Mass of water (g)	__________	__________

show calculation:

4. Mass of can and skirt (g)	__________	__________
5. Mass of support system (g)	__________	__________
6. Mass of support system + food (g)	__________	__________
7. Mass of food (g)	__________	__________

show calculation:

8. Initial Temperature (°C)	__________	__________
9. Final Temperature (°C)	__________	__________
10. Mass of support system + food after burning (g)	__________	__________
11. Serving Size from label (g/serving)	__________	
12. Calories per serving from label (Cal./serving)	__________	
13. Change in Temperature (°C)	__________	__________

show calculation:

14. Mass of food burned (g)	__________	__________

show calculation:

15. Heat absorbed by the water (q_{H2O}, J) __________ __________

show calculation:

16. Heat absorbed by the can (q_{can}, J) __________ __________

show calculation:

17. Total heat released by the fuel (q_{fuel}, J) __________ __________

show calculation:

18. Total heat released by the fuel (q_{fuel}, Cal.) __________ __________

show calculation:

19. Heat of Combustion for the fuel (ΔH, Cal./g) __________ __________

show calculation:

15. Heat of Combustion per serving (ΔH, Cal./serving) __________ __________

show calculation:

16. Percent Error (%) __________ __________

show calculation:

Part II: Heat of Combustion for a Candle

1. Mass of can and skirt (g) ___________

2. Mass of can and skirt and water (g) ___________

3. Mass of water (g) ___________
show calculation:

4. Mass of can and skirt (g) ___________

5. Mass of support system (g) ___________

6. Mass of support system + candle (g) ___________

7. Mass of candle (g) ___________
show calculation:

8. Initial Temperature (°C) ___________

9. Final Temperature (°C) ___________

10. Mass of support system + candle after burning (g) ___________

11. Change in Temperature (°C) ___________
show calculation:

12. Mass of candle burned (g) ___________
show calculation:

13. Heat absorbed by the water (q_{H2O}, J) ___________
show calculation:

14. Heat absorbed by the can (q_{can}, J) ___________
show calculation:

15. Total heat released by the candle (q_{fuel}, J) __________
show calculation:

16. Total heat released by the candle (q_{fuel}, Cal.) __________
show calculation:

17. Heat of Combustion for the candle (ΔH, Cal./g) __________
show calculation:

Experiment 14—Post-Lab Assignment

1. List five sources of experimental error that may have caused your calculated heat of combustion per serving for your food item to differ from the value on the label.

2. How many times could a 70 kg person jump rope with the energy contained in one serving of gummi bear? Assume that each jump is 10.0 cm high and that the gummi bear energy (130 Calories/serving) is converted completely to potential energy. (Hint: PE = mgh where m is the mass of the person, g is the gravitational acceleration constant, 9.8 m/s^2, and h is the height of each jump. Recall that 1 Joule = 1 kg m^2 / s^2).

3. Using your data from Part I, calculate the heat of combustion for the food in Cal./serving while ignoring the heat absorbed by the soda can (q_{can}). Find the new percent error from the label's value. Would it be reasonable to ignore the heat absorbed by the soda can in your experiment? Why or why not?

Experiment 14—Pre-Lab Assignment

Name: ____

1. Why are you instructed to read Steps 2-5 before going to the balance room?

2. What is the purpose of the aluminum foil skirt?

3. What is the purpose of the support system?

4. Why is it important to keep the flame of the burning nut from touching the bottom of the can?

5. How is energy stored in organic compounds/food? Where did this energy originally come from?

6. A 1.000 g walnut is completely combusted and the heat is absorbed by a 10.562 g aluminum soda can and skirt containing 200.0 g of water. The temperature increased from 10.0°C to 45.0°C. Calculate the heat of combustion of the walnut in Cal./serving.