EXPERIMENT 4
Thermochemistry

Introduction

WARNING – If you have a nut allergy you may not enter the lab room. Email your TF before lab to inform them of your allergy and get data to write the Lab Report.

Thermochemistry is the study of the enthalpy (heat) changes which accompany a chemical reaction. In this experiment you will investigate a common chemical process: the oxidation (burning) of fats to produce carbon dioxide and water. This process takes place when you metabolize fatty foods—the fat is "burned" in the body and the energy released is used to support our many life functions. This process also takes place when fatty foods are burned—literally—in the air. In that case, the energy is released in the form of heat and light: **fire**. Because of the laws of thermodynamics, the same quantity of energy must be released whether the fats are "burned" in the body or literally burned in a fire. Thus by burning a food item we can figure out how much energy will be released when that food is consumed.

Chemists measure heat energy in units of calories, with 1 calorie = 4.184 Joules. Nutritionists measure the energy content of foods in units of Calories (with a capital C), which are actually *kilo*calories, with 1 food Calorie = 1000 chemical calories. In this experiment you will burn a nut and collect the heat released by the flame. By measuring this quantity of heat you can determine how much food energy your body will obtain from metabolizing the same nut.

Discussion

Nuts contain a good deal of protein, some carbohydrate, and a significant quantity of oil (fat). The oil is readily flammable, and it is this oil which burns when the nut is ignited. (It may surprise you how well these nuts burn once they get started!) The concept behind this experiment is straightforward: you will ignite a nut underneath an aluminum soda can filled with water. The heat released by the burning nut will warm the water in the can, and by measuring the temperature increase of the water you can determine the quantity of heat released by the nut. Food scientists perform similar experiments using expensive, sensitive calorimeters, but the basic principles remain the same: when food is burned in oxygen, the same amount of heat is released whether the "burning" takes place in the body or in a fire.

As a second part of this experiment, you will determine the enthalpy change of a chemical reaction. The neutralization of citric acid with NaOH releases heat, and the temperature increase of a reaction solution can be measured to determine the heat released per mole of reactant.

Procedure

Waste Disposal

All waste from this experiment can go either into the drain or into the trash can.

Setting up the Calorimeter

Data, Observations, and Notes

Obtain a cork from the center bench. Insert a piece of copper wire into the small end of the cork and bend it so that the bent wire forms a small "cradle" in which a nut can be placed.

Take a nut and make sure that it can be adequately supported by your improvised cradle. Make note of the type of nut you are using (they will be labeled on their containers.) Using the analytical balance, determine the mass of the nut. (Use a weighing dish—don't place anything directly on the balance pan.) Return the nut to the cradle.

Type of nut:
Mass of nut:

Take an empty soda can and rinse it once with water. Using the **top-loading digital balance**, determine the mass of the empty can. Then fill the can approximately 2/3 full with distilled water and measure the mass of the can with the water.

Mass of empty can:
Mass of can with water:

Using a large three-prong clamp, clamp the can to suspend it above the nut so that there is about an inch of space between the nut and the bottom of the can. Everything should be near the sink. (Your TF will show a demonstration setup.)

Burning the Nut

Place a digital thermometer in the can and record the initial temperature of the water.

Initial water temperature:

Light the nut and gently slide it under the can. Run the match under water to extinguish it, then dispose of the wet match in the trash.

As soon as the nut stops burning, stir the water in the can using the thermometer probe and record the final water temperature.

Final water temperature:

Carefully carry the burned residue over to an analytical balance (you may want to carry it in a weighing boat) and measure the mass of the residue. Break up the residue with a spatula and examine it, then discard the residue in the trash.

Mass of residue:

Appearance of residue:

Empty the can into the sink and wipe the soot off the bottom of the can with a wet paper towel. Return the can to the center bench.

Burning Another Nut

Repeat the entire procedure using another nut. You may choose the same kind of nut if you like, or try something different. Does the size or type of nut seem to affect how well it burns?

Data, Observations, and Nuts

Type of nut:
Mass of nut:
Mass of empty can:
Mass of can with water:
Initial water temperature:
Final water temperature:
Mass of residue:

Other observations:

Calorimetry of a Chemical Reaction

In this part of the experiment, you will measure the enthalpy of reaction between citric acid and sodium hydroxide using a procedure of your own design. You will be given 0.50 *M* solutions of each, a digital thermometer, and Styrofoam® coffee cups. Your goal is to mix them to give a total of 50.0 mL of reaction mixture in such a way that the maximum heat is evolved.

As part of your prelab report you will provide a detailed procedure for this part of the experiment. You may find it helpful to examine the portion of your textbook that deals with calorimetry.

As part of your prelab, set up a data table in the space below in which you can record all the necessary data for this portion of the experiment.

Lab Report

1. Identify the types of nuts you used, and calculate the quantity of heat released by the burning of each, in calories. Recall that the specific heat of water is 1.0 cal/g·°C; ignore the heat capacity of the aluminum can.

Identity of Nut#1:	Identity of Nut #2:
Heat from Nut#1:	Heat from Nut #2:

2. Determine the mass of oil burned in each case. (Assume that all the mass lost in combustion was oil.)

Mass of oil from Nut#1:	Mass of oil from Nut #2:

3. Calculate the heat released, in calories per gram of oil, for each of the nuts.

cal/g from Nut#1:	cal/g from Nut #2:

Add these values to those on the blackboard (take care to list them with the correct type of nut!)

4. Determine the enthalpy of reaction (ΔH) **in kJ/mol** for the reaction of citric acid with NaOH.

ΔH =

TF: ___________________ ✍ 4/4 Name: ___________________________

Prelab

1. Given the following data:

   Initial mass of nut: 0.9873 g
   Final mass of residue: 0.4568 g
   Mass of water in can: 249.7 g
   Initial temperature: 24.8 °C
   Final temperature: 33.2 °C

   Calculate the heat released, in calories per gram of oil, for this nut.

cal/g from this nut:

2. Write out a detailed procedure for determining the enthalpy of reaction between citric acid (H_3Cit) and sodium hydroxide (NaOH). Note that the neutralization reaction is:

$$H_3Cit + 3\ NaOH \longrightarrow Na_3Cit + 3\ H_2O$$

Be sure to calculate what volume of each 0.50 *M* solution should be mixed to give a total volume of 50.0 mL **and** the reactants in the correct stoichiometry. Also write a data table in the space given on the appropriate page.