# CHM 130LL: Heat and Energy

## Introduction

**Energy** is defined as the ability to do work, and one form of energy is heat. **Heat** is defined as thermal energy flowing from an object at a higher temperature to one at a lower temperature. For example, if a chunk of metal at room temperature is placed in a beaker of boiling water, the metal will absorb heat from the water until it is at the same temperature as the boiling water.

Scientists also often study the heat associated with different physical and chemical changes. Ideally, the heat changes resulting from physical and chemical phenomena can be harnessed to do work. For example, the burning of gasoline and fossil fuels can be used to run our automobiles and heat our houses. However, in some cases, the heat associated with some processes is transferred to the environment; for example, 90% of the electricity going into traditional incandescent light bulbs generates heat rather than light. This waste of energy is the main reason that incandescent light bulbs are being phased out and replaced by more energy efficient light bulbs such as CFL's.

Most physical and chemical changes are either **exothermic** or **endothermic**. **Exothermic** reactions release energy or heat to increase the temperature of the surroundings; thus, the surroundings are hotter after an exothermic reaction. For example, nitroglycerine exploding is an extremely exothermic reaction. **Endothermic** reactions absorb energy or heat to decrease the temperature of the surroundings; thus, the surroundings are colder after the endothermic process. For example, cold packs used to relieve swelling joints or muscles often use chemicals that absorb heat when mixed, so the packs feel cold.

The amount of heat released when food is burned can even be used to determine the caloric content of food. The number of calories is a measure of the energy a person can get from consuming the food, so the number of calories in two different kinds of food will be compared.

In this experiment, you will:

- view an animation showing heat transfer between particles at different temperatures
- explain various physical changes in terms of heat transfer

You will also explore the heat associated with the following physical and chemical changes, then categorize each as exothermic or endothermic:

- The recrystallization of a supersaturated solution of sodium acetate
- The dissolution (or dissolving) of ammonium chloride in water
- The heat of reaction associated with an acid-base reaction
- The evaporation of isopropyl alcohol

Finally, you will burn a snack food and a nut to determine the number of calories in each, and then you will compare the amount of energy obtained from each type of food.

## *Procedure*

**A. Heat transfer**

1. Your instructor will demonstrate the HeatTransfer.MOV video (located in the CHM 130LL course folder) on the projection system.
2. Answer the questions regarding heat transfer.

**B. A supersaturated solution of sodium acetate, $NaC_2H_3O_2$**

1. Check the hotplate cord for any tears exposing wires. If you find any, ask your instructor for another hotplate. Plug in the hot plate. Turn the heat setting to 5.
2. Use your scoopula to add two large scoops of sodium acetate, $NaC_2H_3O_2$, to just below the 5-mL mark on a 10-mL Erlenmeyer flask. Use your deionized (DI) water bottle to add water to the 5-mL mark on the Erlenmeyer flask.

   ***Note: Your mixture should be mostly solid with just a little water for the most dramatic result. There should just be enough water to cover the surface of the sodium acetate.***
3. Swirl to mix the solution, then place the Erlenmeyer flask on the hot plate. Heat the resulting slush until the solid has dissolved completely. Do not allow the solution to boil! (If the solution boils, use a paper towel to protect your hand from the hot glass or solution when you transfer the flask in the next step.)
4. Place the piece of colored paper on the lab bench. Once all the solid has dissolved, carefully transfer the Erlenmeyer flask onto the piece of colored paper to cool for at least 20 minutes. (Note: The flask may be a little warm to the touch but not too hot to handle. Be careful not to place the flask directly on the lab bench, which may be cold enough to cause it to recrystallize. Also, do not disturb the flask.) Turn off the hotplate. Work on part C while the solution cools.
5. Make sure the Erlenmeyer flask is completely cool, but the sample has not turned into a solid. If it has turned into a solid, reheat it to dissolve the sample, and allow it to cool again. (Note: The results will not be as dramatic if the solution is still warm, and you may have to start over.) Use your scoopula to get one or two small crystals of sodium acetate, $NaC_2H_3O_2$, out of the reagent container. Without disturbing the flask, drop the crystals into the center of the solution. You should observe a dramatic change when the crystal is added. Record your observations on your Report Sheet.
6. Place the Erlenmeyer flask in the palm of your hand to feel the temperature change. Record if the temperature increases or decreases when a supersaturated solution of sodium acetate, $NaC_2H_3O_2$, recrystallizes. Indicate if the recrystallization of sodium acetate, $NaC_2H_3O_2$, is exothermic or endothermic.

   **Waste disposal: Add water to the $NaC_2H_3O_2$ solid in the flask and use your stirring rod to make it into a slurry (or slush), then dispose of it in the waste container in the hood.**

**C. The dissolution of ammonium chloride, $NH_4Cl$**

1. Use your water bottle to add deionized water to a clean test tube until it is 1/3rd full. Feel the test tube to get a sense of the initial temperature of the test tube and water.
2. Use your scoopula to add a scoop of solid ammonium chloride, $NH_4Cl$, to the test tube, and shake the test tube to dissolve the solid.
3. Wrap your hand around the test tube to feel the temperature change. If you do not sense any change in temperature, use a glass stirring rod to dissolve more ammonium chloride, $NH_4Cl$, in the test tube until you feel a change in temperature. Record if the temperature increases or decreases when ammonium chloride, $NH_4Cl$, dissolves. Indicate if the dissolution of ammonium chloride, $NH_4Cl$, is exothermic or endothermic.

**Waste disposal: Dispose of the solution in the waste container in the hood.**

## D. The heat of reaction for an acid-base neutralization reaction

**CAUTION: Sodium hydroxide, NaOH (aq), and hydrochloric acid, HCl (aq), are both toxic and corrosive. NaOH (aq) can quickly damage eyes, and both can cause chemical burns and damage clothing. Any HCl (aq) or NaOH (aq) spilled on your skin must be washed immediately with water for at least 15 minutes. Any HCl (aq) or NaOH (aq) spilled on the lab benches must be neutralized, then washed with water and wiped clean. Inform your instructor of any HCl (aq) or NaOH SPILLS.**

**CHECK that your goggles fit snugly around your face. Wash and rinse hands completely before touching any part of your face after handling any HCl (aq) or NaOH (aq) containers.**

1. Add 10 drops of hydrochloric acid, HCl (aq), to a clean test tube. Add 10 drops of sodium hydroxide, NaOH (aq), to the same test tube.
2. Wrap your hand around the test tube to feel the temperature change. If you do not sense any change in temperature, use a stirring rod to mix the solutions until you feel a change in temperature. Record if the temperature increases or decreases when the acid and base react. Indicate if the acid-base reaction is exothermic or endothermic.

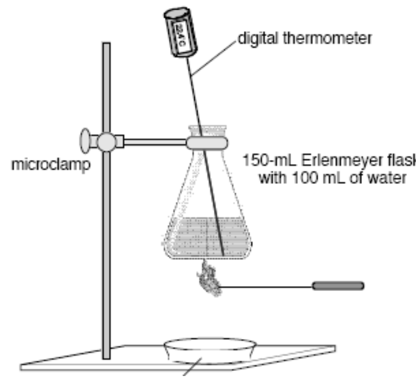
**Waste disposal: Dispose of the solution in the waste container in the hood.**

## E. Evaporation of isopropyl (rubbing) alcohol, $C_3H_8O$

1. Place a drop of isopropyl (or rubbing) alcohol on the back of your hand. Use a cotton swab to spread the liquid gently over you hand.
2. Record any sensation of heat or cold.
3. Answer the questions based on your observations.

## F. Heat of Combustion and the Calories in Food

**CAUTION: The fumes given off by the air-freshener plug-ins are flammable. Keep flames away from the plug-ins to avoid causing a fire!**



Evaporating dish

1. Use the markings on a 125-mL Erlenmeyer flask to measure out 100 mL of deionized water.
2. Carefully attach the Erlenmeyer flask to the ringstand using a micro-clamp. Turn on the digital thermometer, and place it into the Erlenmeyer flask as shown at the right.
3. Obtain a Bugle, and place it in a clean evaporating dish. Weigh the Bugle and evaporating dish together, and record the mass of both as "Evaporating Dish with Bugle before burning" (to 4 decimal places). Afterwards, place the evaporating dish directly under the Erlenmeyer flask as shown above.
4. Use the digital thermometer to measure the initial temperature of the water. Record the initial temperature in ˚C.
5. Gently place the Bugle on the holder—do not pierce it or it will crumble! Hold the Bugle over a Bunsen burner flame to light the snack until it remains on fire. Hold the Bugle directly below the Erlenmeyer flask until the flame goes out. If the flame goes out almost immediately after lighting it, light the bugle again using the Bunsen burner. Also, be sure to hold the snack above the evaporating dish so any liquids dripping from the snack will fall into the evaporating dish.
6. Drop any remnants of the snack into the evaporating dish, and set aside so it can cool to room temperature before weighing.
7. When the Bugle finishes burning, note the temperature for the water for at least five minutes. Stir the solution, and record the highest temperature reached as the Final temperature of water after burning (in ˚C). Subtract the "Initial temperature of water before burning" from the "Final temperature of water after burning" to get the "Temperature change for water" for the Bugle burning. Record the change in temperature (in ˚C).
8. Obtain a nut that is between 1-2 grams in mass. Get another clean evaporating dish, and weigh the dish and nut. Record the mass of both as "Evaporating Dish with nut before burning" (to 4 decimal places). Afterwards, place the evaporating dish directly under the Erlenmeyer flask as shown above.
9. Put on a pair of latex gloves to minimize the soot that gets on your hands, then pour the water in the flask from the Bugle burning down the drain. Refill the flask to the 100 mL mark with deionized water. Measure the temperature of the water using the digital thermometer, and record it as "initial temperature of water before burning" for the nut (in ˚C).
10. Set the nut in the holder, then hold the nut over a Bunsen burner flame to light

the nut until it remains on fire. Hold the nut below the Erlenmeyer flask with the water (as shown in the picture above) until the flame goes out. If the flame goes out almost immediately after lighting it, light the nut again using the Bunsen burner.  Be sure to hold the nut above the evaporating dish so any liquids dripping from the nut will fall into the evaporating dish.

11. When the nut finishes burning, note the temperature for the water for at least five minutes, and record the highest temperature reached as the Final temperature of water after burning (in ˚C). Subtract the "initial temperature of water before burning" from the "final temperature of water after burning" to get the "Temperature change for water" for the nut burning. Record the change in temperature (in ˚C).
12. Weigh the evaporating dish with the burned Bugle, and record the mass under Mass with Evaporating Dish after burning (to 4 decimal places). Subtract the Mass with Evaporating Dish after burning from the Mass with Evaporating Dish before burning to get the Mass of sample that burned for the Bugle.
13. Weigh the evaporating dish with the burned nut, and record the mass under Mass with Evaporating Dish after burning (to 4 decimal places). Subtract the Mass with Evaporating Dish after burning from the Mass with Evaporating Dish before burning to get the Mass of sample that burned for the nut.
14. Calculate the number of calories (or caloric content) for the Bugle and the nut as indicated in your data table.

**WASTE:  Dispose of the used Bugles and nuts in the waste containers in the hood. Carefully remove the digital thermometer, and dry it. Wait for the microclamp, Erlenmeyer flask, and the ringstand to cool before touching any of them. Put on a pair of latex gloves before handling the microclamp and the Erlenmeyer flask, which will be covered with soot. Wash both in the sink with soap and water to remove the soot deposited on both. Take a wet paper towel to wipe off any soot remaining on the ringstand apparatus.**

**Wash then dry all of your equipment and your entire lab area.**

*LAB REPORT*

# *CHM 130LL: Heat and Energy*

Name: ______________________

Partner: ______________________

Section Number: _______________

**DATA**

**A. Heat transfer**

1. Explain why the faster red particles in the video slow down and the slower blue particles speed up when they come into contact with each other.

2. Explain each of the following in terms of heat transfer (i.e. what loses heat and what gains heat):

   a. Why the concrete feels hot against your bare feet in the summer.

   b. Why the stone countertop in the lab feels cool when you place your hand on it.

   c. Why an ice cube melts in your hand.

**B. A supersaturated solution of sodium acetate, $NaC_2H_3O_2$**

1. What do you observe when you drop a crystal of sodium acetate, $NaC_2H_3O_2$, into the supersaturated solution?

2. When you drop a crystal of sodium acetate, $NaC_2H_3O_2$, into the supersaturated solution, the temperature __________. (Circle one) increases decreases

   Thus, this process is __________. (Circle one) exothermic endothermic

**C. The dissolution of ammonium chloride, $NH_4Cl$**

When ammonium chloride, $NH_4Cl$, dissolves,

the temperature __________. (Circle one) increases decreases

Thus, this process is __________. (Circle one) exothermic endothermic

**D. The heat of reaction for an acid-base neutralization reaction**

When hydrochloric acid, HCl(aq), is mixed with sodium hydroxide, NaOH(aq),

the temperature __________. (Circle one) increases decreases

Thus, acid-base reactions are _______. (Circle one) exothermic endothermic

**E. Evaporation of isopropyl (rubbing) alcohol, $C_3H_8O$**

1. When you wipe rubbing alcohol onto your hand, your skin feels ____________. (Circle one) hot cold
2. Thus, this process is __________. (Circle one) exothermic endothermic
3. Explain what **physical change** the alcohol undergoes and what you feel in terms of heat transfer.

## F. Heat of Combustion and the Caloric Content of Food

| Food | Mass with Evaporating Dish before burning | Mass with Evaporating Dish after burning | Mass of sample that burned |
|---|---|---|---|
| Bugle | | | |
| Nut | | | |

| Food | Initial temperature of water before burning | Final temperature of water after burning | Temperature change for water |
|---|---|---|---|
| Bugle | | | |
| Nut | | | |

1 a. Consider the sample calculation for the heat of combustion for a potato chip:

$$\text{heat of combustion for a chip} = 0.100\ \frac{\text{Cal}}{^{\circ}\text{C}} \times (\underline{\ \ 8.4\ \ }\ ^{\circ}\text{C}) = \underline{\ \ 0.84\ \ }\ \text{Cal}$$

Note that ˚C units cancel, so the final units are only Calories (abbreviated "Cal").

Enter your temperature change for water when the Bugle burned (from the bottom table at the bottom of p. 7), then calculate the heat of combustion for the Bugle sample below. Do the same for the nut.

**Bugle:** $$\text{heat of combustion for the Bugle} = 0.100\ \frac{\text{Cal}}{^{\circ}\text{C}} \times (\underline{\qquad\qquad}\ ^{\circ}\text{C}) = \underline{\qquad\qquad}\ \text{Cal}$$

**Nut:** $$\text{heat of combustion for the Nut} = 0.100\ \frac{\text{Cal}}{^{\circ}\text{C}} \times (\underline{\qquad\qquad}\ ^{\circ}\text{C}) = \underline{\qquad\qquad}\ \text{Cal}$$

b. Write down the heat of combustion for the Bugle in the numerator, then write down the mass of the Bugle sample that burned (from the first table at the bottom of p. 7) in the denominator. Divide the two values to calculate the heat of combustion per gram of Bugle (in Cal/g) below. Do the same for the nut.

**Bugle:** $$\text{heat of combustion per gram for the Bugle} = \frac{\text{heat of combustion for the Bugle}}{\text{mass of Bugle sample that burned}} = \frac{\qquad\qquad\ \text{Cal}}{\text{g}} = \underline{\qquad\qquad}\ \text{Cal/g}$$

**Nut:** $$\text{heat of combustion per gram for the Nut} = \frac{\text{heat of combustion for the Nut}}{\text{mass of Nut sample that burned}} = \frac{\qquad\qquad\ \text{Cal}}{\text{g}} = \underline{\qquad\qquad}\ \text{Cal/g}$$

2. Which food has the higher heat of combustion per gram? Bugle nut

3. Which food would you consume to get more energy per gram of food eaten? Explain why.

4. Consider how quickly the Bugle burned compared to the nut. Which food would you consume to provide you with energy for a longer period of time? Explain why.