

CHM 130LL: Heat and Energy

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 and 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 banana chip 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, $\text{NaC}_2\text{H}_3\text{O}_2$

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 (50°C).
2. Check out a 10 mL Erlenmeyer flask from the instructor. Use your scoopula to add sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$, to the 5-mL mark on the 10-mL Erlenmeyer flask. Use your deionized (DI) water bottle to add water also 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 black paper on the lab bench. Once all the solid has dissolved, carefully put the Erlenmeyer flask on the black 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 while sitting on the black paper.) 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, $\text{NaC}_2\text{H}_3\text{O}_2$, 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, $\text{NaC}_2\text{H}_3\text{O}_2$, recrystallizes. Indicate if the recrystallization of sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$, is exothermic or endothermic.

Waste disposal: Add water to the $\text{NaC}_2\text{H}_3\text{O}_2$ 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. If needed, heat briefly to dissolve the solid. Return the clean flask to your instructor.

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.

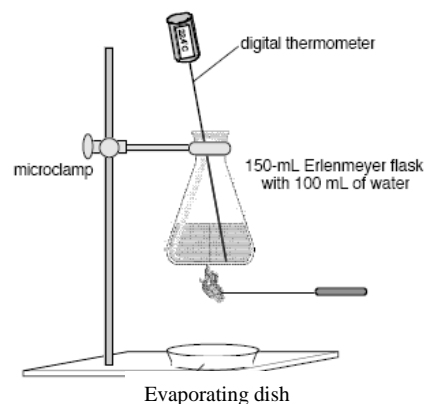
E. Evaporation of isopropyl (rubbing) alcohol, C₃H₈O

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. 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!

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 ring stand 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.” Remember to write down all the numbers. 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. Now hold the Bugle directly under 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 of the water for at least five minutes. Stir the water, 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. Now weigh the evaporating dish with the burned Bugle, and record the mass under Mass with Evaporating Dish after burning. 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.
9. Obtain a banana chip from the instructor cart. Clean your evaporating dish, and weigh the dish and banana chip. Record the mass of both as “Evaporating Dish with banana chip before burning.” Afterwards, place the evaporating dish directly under the Erlenmeyer flask as shown above.
10. 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 and clean the flask.** Refill the flask to the 100 mL mark with deionized water. Again, measure the temperature of the water using the digital thermometer, and record it as “initial temperature of water before burning” for the banana chip (in °C).
11. Set the banana chip on the holder, and then hold the banana chip over a Bunsen burner flame to light the banana chip until it remains on fire. Now hold the banana chip just under the Erlenmeyer flask with the water (as shown in the picture above) until the flame goes out. If the flame goes out before 4 minutes have passed, light the banana chip again using the Bunsen burner. Be sure to hold the banana chip over the evaporating dish so any liquids dripping from the banana chip will fall into the evaporating dish. The banana chip typically takes 3-4 minutes to burn completely.
12. When the banana chip is completely black and totally burned, 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 banana chip burning. Record the change in temperature (in °C).
13. Weigh the evaporating dish with the burned banana chip, and record the mass under Mass with Evaporating Dish after burning. 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 banana chip.
14. Calculate the number of calories (or caloric content) for the Bugle and the banana chip as indicated in your data table.

WASTE: Dispose of the burned Bugles and banana chips 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 tap water to remove the soot deposited on both. Take a wet paper towel to wipe off any soot remaining on the flask and ringstand apparatus. Wash then dry all of your equipment and your entire lab area. Wash your hands well.

CHM 130LL:

Heat and Energy

Name: _____

Partner: _____

Section Number: _____

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. Answer in complete sentences with proper grammar.

2. Fill in the blanks. Be specific do not answer hot and cold.

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

_____ loses heat and _____ gains heat.

Heat transfers from _____ to _____.

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

_____ loses heat and _____ gains heat.

Heat transfers from _____ to _____.

c. Why an ice cube melts in your hand.

_____ loses heat and _____ gains heat.

Heat transfers from _____ to _____.

B. A supersaturated solution of sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$

1. What do you observe AND feel when you drop a crystal of sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$, into the supersaturated solution?

2. When you drop a crystal of sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$, 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, $\text{HCl}(\text{aq})$, is mixed with sodium hydroxide, $\text{NaOH}(\text{aq})$,

the temperature _____. (Circle one) increases decreases

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

E. Evaporation of isopropyl (rubbing) alcohol, $\text{C}_3\text{H}_8\text{O}$

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. Name the **physical change** the alcohol undergoes, and explain 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			
Banana chip			

Food	Initial temperature of water before burning	Final temperature of water after burning	Temperature change for water
Bugle			
Banana chip			

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

$$\begin{array}{l} \text{heat of} \\ \text{combustion} \\ \text{for a chip} \end{array} = 0.100 \frac{\text{Cal}}{\cancel{\text{°C}}} \times (\underline{8.4} \cancel{\text{°C}}) = \underline{0.84} \text{ Cal}$$

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 of the previous page), then calculate the heat of combustion for the Bugle sample below. Do the same for the banana chip.

$$\text{Bugle: } \begin{array}{l} \text{heat of} \\ \text{combustion} \\ \text{for the Bugle} \end{array} = 0.100 \frac{\text{Cal}}{\text{°C}} \times (\underline{\hspace{2cm}} \text{°C}) = \underline{\hspace{2cm}} \text{ Cal}$$

$$\text{Banana chip: } \begin{array}{l} \text{heat of} \\ \text{combustion} \\ \text{for the chip} \end{array} = 0.100 \frac{\text{Cal}}{\text{°C}} \times (\underline{\hspace{2cm}} \text{°C}) = \underline{\hspace{2cm}} \text{ Cal}$$

- 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 of the previous page) 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 banana chip.

$$\text{Bugle: } \begin{array}{l} \text{heat of} \\ \text{combustion} \\ \text{per gram for} \\ \text{the Bugle} \end{array} = \frac{\begin{array}{l} \text{heat of combustion} \\ \text{for the Bugle} \end{array}}{\begin{array}{l} \text{mass of Bugle sample} \\ \text{that burned} \end{array}} = \frac{\text{Cal}}{\text{g}} = \underline{\hspace{2cm}} \text{ Cal/g}$$

$$\text{Banana chip: } \begin{array}{l} \text{heat of} \\ \text{combustion} \\ \text{per gram for} \\ \text{the chip} \end{array} = \frac{\begin{array}{l} \text{heat of combustion} \\ \text{for the chip} \end{array}}{\begin{array}{l} \text{mass of chip sample} \\ \text{that burned} \end{array}} = \frac{\text{Cal}}{\text{g}} = \underline{\hspace{2cm}} \text{ Cal/g}$$

2. Which food has the higher heat of combustion per gram? Bugle Banana chip
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 banana chip. Which food would you consume to provide you with energy for a longer period of time? Explain why.