Experiment 30 –Fun with Heat

Phase changes and dissolving are physical processes that involve heat. In this experiment, you will explore heat exchange by boiling water in a paper cup, heating water in a beaker using snack food, decide if Joulies really work, and determine the heat of solution of two different ionic compounds.

Part 1: Flaming Cheetos

Heat can be difficult to measure directly. In this part of the lab, we will use food to heat water. Food contains energy and we can harness that energy to good use. We will measure the heat evolved from burning a Cheetos to raise the temperature of water. Using this information, we can calculate the Cal/g of Cheetos.

Part 2: Surviving in the cold with a paper cup and water.

In this part of the lab, you will use a small paper cup as a vessel to boil water using a Bunsen burner. Will the paper cup burn? That is the question!

Part 3: Do Joulies Really work?

Joulies are used to cool your boiling hot water to 140°F, the temperature that the company deems perfect for drink the bitter brew. Joulies have a special phase change material that melts at temperatures above 140°F, thus absorbing extra energy from your coffee. This process cools the coffee down faster, so you can enjoy your coffee (or tea) without 3rd degree burns. The energy stored in the Joulies is released back to the coffee, keeping it warm and delicious over a longer period. The phase change material goes back to the solid state. But does it really work?

The material in the Joulies is undergoing a phase change. The material is in the solid phase below 140°F. When warmed above this point the phase change material (PCM) absorbs energy and becomes a liquid. It melts! The process of melting is called fusion. The melting (fusion) of any solid substance is an endothermic process. A substance must absorb heat in order to be converted from the solid phase to the liquid phase. You won't be measuring the actual heat of fusion of the PCM in the Joulies, that would be harder than what we can do in the lab time, but you can determine if the PCM does cool boiling water down to 140°F (about 60°C) and how long it takes, and the energy released by the water to the Joulies.

When a substance is heated, the temperature rises because the heat energy is used to increase the kinetic energy of the molecules of the substance. Increasing kinetic energy means that the molecules of the substance are moving faster (since kinetic energy = $\frac{1}{2} mv^2$, with m = mass and v = velocity), and increased molecular velocity is observed and measured as increased temperature.

When a substance is at its melting point or boiling point, however, its temperature will not change as it is heated. Instead, it will undergo a **phase change** - it will either melt or boil - and phase changes are processes that occur at constant temperature. The heat energy is used in these cases to increase the potential energy of the molecules. In melting, energy is required to break apart the crystalline lattice of the solid state. In boiling, the molecules must be separated from each other in order to vaporize. Heat energy is used to overcome intermolecular forces holding the molecules together.

The amount of heat energy that is required to melt the PCM be measured by allowing the ice to melt in a known amount of liquid water. When the joulie is placed in water, an exchange of thermal energy takes place. The joulie absorbs energy from the water and melts the PCM (potential energy increases), while the water gets colder (the kinetic energy of the molecules decreases) as it loses thermal energy to the joulie.

If the process of the heat exchange occurs in an insulated container, no heat energy will enter the system from the outside. All of the energy gained by the joulie will come from the originally liquid water. In other words, the heat flow for the joulie Q_{joulie}, must be equal, but opposite in sign, to the heat flow for the originally liquid water, $Q_{H2O\ in\ cal.}$. This can be expressed by the equation:

$$Q_{joulie} + Q_{H2O\ in\ cal} = 0 \text{ and, therefore, } Q_{joulie} = -Q_{H2O\ in\ cal}$$

The amount of heat energy lost by the originally water in the calorimeter can be calculated by measuring its mass ($m_{cal\ H2O}$) and its temperature change ($\Delta T = T_f - T_{i\ cal}$). The definition of the calorie states that 1.00 calorie is required to heat one gram of water by 1 °C. Therefore, the total amount of heat energy gained or lost by a sample of water in changing temperature is as follows:

$$Q = 4.184 \frac{J}{g \cdot {}^{\circ}C} \times m \times \Delta T$$

When this equation is applied using the weight and the temperature change of the originally liquid water, then $Q_{H2O\ in\ cal}$ can be found. Changing the sign of this value gives Q_{joulie}, the energy needed to warm the joulie to the final temperature.

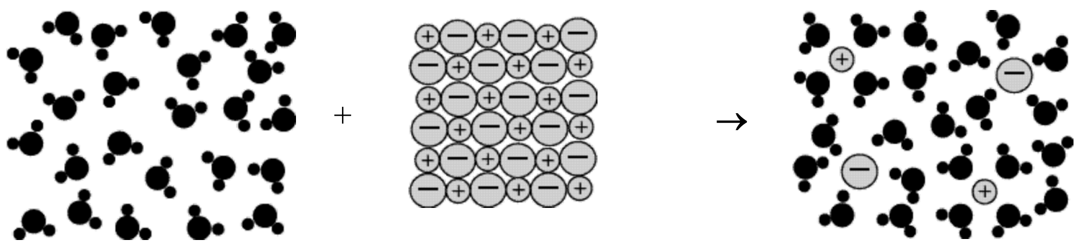
Our goal will be to determine the amount of energy per gram required to warm the joulie

Part 4: Heat of Solution of Two Solutes

When a solute dissolves in a solvent, energy can be absorbed or released. In this part of the experiment, you will be dissolving two different ionic solids in a known amount of water and determine the heat of solution of each substance. (The heat of solution is the energy involved in dissolving a specific amount of the substance in a particular solvent).

When water and an ionic compound are mixed to form a solution, the heat of solution ($\Delta H_{solution}$) depends not only on the attractions between water and the ions in the solution, but also on the water-water attractions in pure water, and on the ion-ion attractions when the pure crystal.

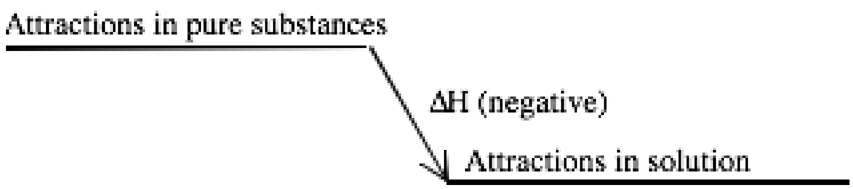
<u>Pure water</u> <u>Pure ionic compound</u> <u>Solution</u>



Water-water attractions Ion-ion attractions Ion-water attractions

For some substances, the heat of solution is endothermic, and for others the solution process is exothermic. The overall energy change depends on two main factors. Energy must be added to break the solid apart into separate ions, and energy is released when the water molecules hydrate the solute ions. When these two amounts of energy are added together, the result can be either positive or negative (endothermic or exothermic) overall. (See Section 13.1 in text)

If the attractions in the solution are stronger than the attractions in the pure substances, the dissolving process will be exothermic. By dissolving, the water and the ions will reach a more stable state (lower potential energy). The difference in potential energy will appear as heat (kinetic energy). The solution will be hotter than the pure substances were before mixing.



Safety Precautions:

- Wear your safety goggles.

Waste Disposal:

- The waste from this experiment may be safely disposed of in the sink with plenty of running water.

Procedure

Part 1: Flaming Cheetos

1. Assemble the apparatus as shown.
2. Weigh the empty small can
3. Weigh the empty watch glass and foil
4. Transfer about 100 mL of iced water provided into the small can into the small can, and weigh again.

5. Place 3-4 Cheetos on the watch glass and re-weigh
6. Take the initial temperature of the water in the beaker.
7. Light the Cheetos with a match.
8. Allow the Cheetos to combust completely.
9. Record the maximum temperature of the water in the beaker.

<u>Part 2-</u> **Surviving in the cold with a paper cup and water.**

1. Obtain obtain a small Dixie cup.
2. Obtain a ring stand and ring,
3. Place a wire gauze on the ring on the ring stand.
4. Fill a small Dixie cup to about 0.5 cm from the rim with water.
5. Put the cup on the wire gauze
6. Light the Bunsen burner under the cup
7. Observe what happens.
8. You will want to make detailed observations here, temperature, the appearance of the cup, what is happening to the water.
9. Let the water cool before you attempt to remove the cup from the ring stand.

Part 3: Do Joulies Really work?

1. Obtain 2 Styrofoam cups, and nest one in the other.
2. Add about 100 mL (4oz) of near boiling water to the mark on the cup

1. Sign out a Joulie
2. Carefully add 1 joulie.
3. Note the time
4. Record the temperature of the water until it reaches a steady value.
5. Note the time
6. Return your Joulie to the instructor (I need them to cool my coffee)

Part 4: Heat of Solution of Two Solutes

1. Obtain 2 Styrofoam cups, and nest one in the other. Weigh the cups.
2. Transfer about 100 mL of deionized water into the cup, and weigh again.
3. Carefully measure and record the temperature of the water in the cup to ± 0.1°C.
4. Dump vial 1 in the water, make sure you record the mass of the compound that is on the vial.
5. Vigorously stir the mixture with the thermometer until the entire sample of solid has dissolved. Watch the temperature reading, and record the reading that differs the most from the initial temperature.
6. Dump the solution down the sink, and rinse and dry the calorimeter.
7. Repeat steps 1-6, vial 2. The contents of vial 2 will not dissolve as easily as vial 1, so be sure to stir the solution vigorously. The compound must dissolve in less that 40 seconds, or your results will be inaccurate.

<u>Calculations</u>

Part 1: Flaming Cheetos

Show your work and organize the final data in the table on the report sheet

1. Calculate the mass of the water
2. Calculate the temperature change of the water
3. Calculate the mass of the Cheetos to be burned
4. Calculate the mass of the mass of the Cheetos that burned
5. Calculate the calories absorbed by the water
6. Calculate the calories released by the Cheetos
7. Calculate the kcal released by the Cheetos
8. Calculate the Cal/g Cheetos
9. Calculate the % error based on the value on the bag.

Part 3: Do Joulies Really work?

Answer the following questions on the report sheet. Use complete sentences

1. What was the final temperature of the water after adding the Joulie?
2. How long did it take for the Joulie to cool the water to the final temperature?
3. Do you think Joulies worked to cool the near boiling water to about 60°, a comfortable temperature?
4. In a similar experiment, blogger Jeff Ammons noted that rocs worked the same way. His experiment was more detailed then ours. What did he conclude and why do you think he got similar results? http://jeffammons.net/2012/01/a-swift-kick-in-the-joulies/

Part 4: Heat of Solution of Two Solutes

Note: Do these calculations separately for each trial.

1. Determine the mass of water and mass of solution in the cup.
2. From the mass of solution, the temperature change the solution underwent, and the heat capacity of the solution (assume the heat capacity of the solution is very close to the heat capacity of water), determine the amount of energy absorbed by/given off by the water/solution in the cup.
3. Determine the amount of energy absorbed by or given off by the dissolving solid dissolving in water.
4. Calculate the "heat of solution" of this compound (ΔH_{soln}) in units of kilojoules per gram of solute. Make sure to include the appropriate sign.