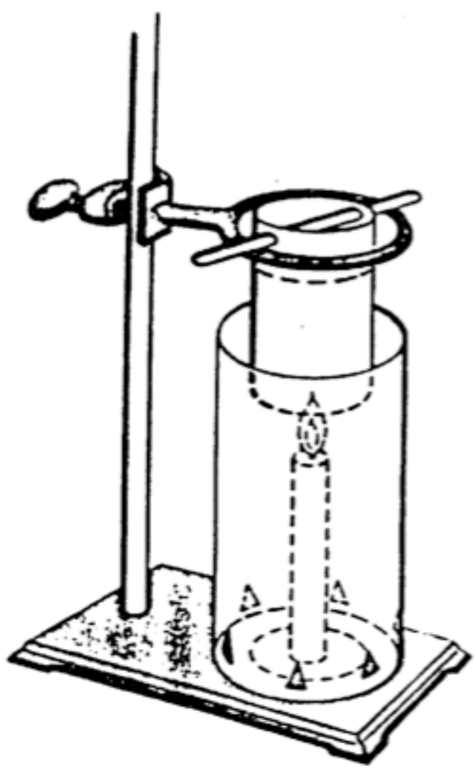
Experiment 6 - The Heat of Combustion and the Heat of a Phase Change

Part 1 – The Heat of a Combustion Reaction

Combustible fuels, such as coal, petroleum, and natural gas, are useful because of the heat energy they generate. Wax, in the form of a candle, is usually burned for the light energy it produces. However, as you know, a considerable amount of heat energy is also produced by a burning candle. In this experiment we will determine the actual amount of heat produced by a burning wax candle, and we will compare this to the amount of heat produced by other combustible fuels.

Safety Precautions:
- Wear your safety goggles.

Waste Disposal:
- Waste candle wax, if any, can go in one of the regular garbage cans.



Experimental Set-up for Part 1

Procedure – Part 1

1. Attach a candle to a tin can lid (unless this has already been done for you).
2. Set up the apparatus for this experiment. (This is illustrated on the previous page.) First, without the large can in place, adjust the height of the small can so that the bottom of it is about 2 inches above the tip of the candle wick. The tip of the flame should almost but not quite reach the bottom of the can.
3. Weigh the candle and lid to the nearest 0.01 gram (2 decimal places). Record this weight in the data table. Use the same balance for all subsequent weighings.
4. Place the candle and lid in position inside the large can which protects the candle from drafts.
5. Fill the small can about 2/3 full of tap water, then pour the water into a small beaker and add enough ice to it to cool it to about 10 °C.
6. Transfer the water to the small can, without transferring any of the ice with it. You may want to use a strainer.
7. Read the temperature of the cooled water, estimating to the nearest 0.1 °C. Record the temperature, and quickly go on to the next step.
8. Light the candle and quickly place the can of water in position. Heat the water, stirring it gently with the thermometer, and continue this process until the temperature reaches about 30 °C. Carefully blow out the candle.
9. Continue to stir the water (after the candle has been blown out) until the highest temperature is reached. Record this highest temperature to the nearest 0.1 °C.
10. Weigh the candle and lid on the same balance that you used before. Make sure that any drippings from the candle are weighed with it. Record the mass.
11. Very carefully pour the water in the small can into a graduated cylinder. Measure and record the volume of the water.

<u>Calculations – Part 1</u>

1. Did the candle weigh more or less after it was burned? Why? (Answer in specific chemical terms. Remember that wax is composed of hydrocarbons or hydrocarbon-like substances.)
2. Calculate the weight of candle wax burned. This can be done by subtracting the weight after burning from the weight before burning.
3. As the candle burned, the combustion reaction caused heat energy to be released. This heat was absorbed by the water in the can and was used to raise the temperature of the water. Therefore, all we have to do is to calculate the amount of heat absorbed by the water and we will know how much heat was released by the burning candle.
   First we have to calculate the temperature change of the water. This is the difference between the final and the initial temperatures.
4. It takes 1.00 calorie of heat energy to raise the temperature of 1.0 mL of water by 1.0 °C. How many milliliters of water did you heat with the energy from the burning candle wax? How many calories of heat energy would it take to raise the temperature of this much water by 1.0 °C? How many calories would it take to raise the temperature of this much water by 2.0 °C? How many calories would it take to raise the temperature of this much water by the number of degrees you observed?
   A simple formula to use is $q = s \bullet m \bullet \Delta T$, where q is the amount of heat in calories, s is the heat capacity of water (1.00 calories/g•°C), m is the mass of water, and ΔT is the temperature change.
5. The amount of heat absorbed by the water is the same as the amount of heat given off by the burning candle. (We are assuming that all of the energy given off by the candle was absorbed by the water, and that no heat was lost to the surrounding air.)

6. To find the heat of combustion of the wax, you need to determine the heat given off per gram of candle wax burned. To calculate this, divide the amount of heat your candle gave off by the weight of candle wax you burned. This gives you the amount of energy per gram of wax.

Questions – Part 1

1. 11,000 calories of heat energy are released when 1 gram of gasoline burns in a car engine; about 13,000 calories are released when 1 gram of methane gas burns. How does your candle wax compare with gasoline and methane as a fuel?
2. Suppose the energy that could by obtained by burning one gram of candle was were listed in a food calorie table. How many "Calories" would be shown?
3. Write and balance the equation for the combustion of the following compounds:
   a. C_6H_{12}
   b. C_6H_{14}

Part 2 – The Heat of a Phase Change

Freezing is an example of a phase change, or change of state, in which a liquid changes to a solid. Candle wax that is melted and then allowed to solidify (freeze) is undergoing two phase changes: first it melts, then it freezes. In this experiment, you will measure the amount of heat released when a sample of melted wax freezes.

Procedure – Part 2

1. Obtain an ordinary test tube containing solid wax. If the weight of wax is marked on the tube, record and use that number. If the weight is not marked, weigh a similar test tube and subtract to get the weight of wax.
2. Set up a ring stand with an iron ring and a piece of wire screen supporting a beaker of water. Heat the water with a Bunsen burner, and put the tube of wax in the water to melt the wax.
3. While you are waiting for the wax to melt, weigh an empty Styrofoam cup to serve as a calorimeter.
4. Make some cold water by making a water/ice mixture and letting it sit for 5-10 minutes. Strain out the ice. Pour about 150 mL of this cold water into the calorimeter.
5. Weigh the calorimeter with the cold water in it. Subtract to get the mass of the water.
6. Using a test tube holder, remove the melted wax sample from the hot water bath and hold it in the air until you see the beginning of solidification. This will be a slight cloudiness, probably in the bottom of the tube.
7. At this point (when you see the cloudiness), read and record the temperature in the cold water in the calorimeter.
8. Place the tube of wax in the calorimeter, and stir the tube around a bit in the bath.
9. Stir the water in the calorimeter with the thermometer, and read and record the highest temperature reached (within 2 or 3 minutes).
10. When it has solidified, return the tube of wax to its box in the fume hood.

Calculations – Part 2

1. From the temperature change, the mass of water, and the heat capacity of water, calculate the amount of energy (in calories and in joules) that was used to warm the water in the calorimeter ($q = s \cdot m \cdot \Delta T$). This energy came from the freezing process.
2. To get the heat of freezing in terms of the amount of heat per gram of substance, divide the amount of heat released by the number of grams of wax used. Express the heat of freezing in cal/g and in J/g.

Questions – Part 2

1. Compare the value of the heat of combustion for wax with the value of the heat of freezing for wax. Which is bigger? Is it much bigger?
2. Freezing always releases heat. Why does it release heat? Explain at the molecular level.