ENERGY CONTENT OF FUELS

Description

Fuels are substances that react with oxygen in air and give off a relatively large amount of heat. Reacting with oxygen in air, combustion, is a very commonly observed type of reaction that is very useful, due to the large quantities of heat energy liberated. How much heat is generated depends on what type of fuel is burned and how much of the fuel is burned.

A particular class of compounds containing only carbon and hydrogen, the hydrocarbons, are widely used as fuels. This class of compounds includes such common fuels as methane (CH₄, natural gas), propane (C₃H₈, LPG), butane (C₄H₁₀), and octane (C₈H₁₈). Some fuels, such as ethyl alcohol (C₂H₅OH, ethanol), contain carbon, hydrogen, and oxygen. Kerosene is a common fuel, with an approximate composition of C₁₀H₂₂. Fuels such as ethyl alcohol that contain oxygen are described as partially oxidized; fuels with no oxygen (such as butane and kerosene) are not oxidized.

Energy is commonly measured in units of Joules (J) or calories (cal), or kilocalories (kcal). The calorie is defined as the amount of energy required to raise the temperature of one gram of water by one degree Celsius. The total heat absorbed by the water is then equal to:

\[ \text{Heat absorbed by water} = \text{grams (water)} \times \text{temperature change (} \Delta T \text{)} \times 1 \text{ cal/g}^\circ \text{C} \]

This relationship can be used to determine the amount of heat liberated by a known amount of a particular fuel by measuring the increase in the water temperature due to energy provided by the fuel.

Outline

1. Assemble apparatus
2. Add a known volume of water to the can or beaker.
3. Determine the temperature of the water.
4. Obtain a burner with a known fuel.
5. Weigh the burner.
6. Use the burner to heat the water about 20°C above the initial temperature.
7. Measure accurately the highest temperature of the water.
8. Determine the amount of heat absorbed by the water.
9. Weigh the burner (be sure to use the same balance each time).
10. Determine: (a) the amount of fuel burned. and (b) the amount of heat liberated per gram of fuel burned.

Chemicals

alcohol lamps containing:
  absolute ethanol,
  butanol, or
  kerosene.

Equipment

1 beaker. 250ml or 1 soda can without a top
1 thermometer
1 wire gauze
1 ring
1 ring stand
1 glass rod

Procedure
Determining the Energy Content of Fuel.

1. Obtain a clean, dry beaker, 250 ml size or a soda can without a top.
2. Weigh the beaker or can to the nearest 0.1 g.
3. Add approximately 100 ml of water to the can or beaker.
4. Weigh the beaker (or can) and the water to determine the mass of the water in the beaker (can) to the nearest 0.1 g.
5. Attach an iron ring to a ring stand (if using the beaker, place the gauze on the iron ring).
6. Place the beaker of water on the gauze OR If using the can, place the glass rod through the holes in the soda can and then suspend the can on the ring which is attached on the ring stand.
7. Place a thermometer in the beaker (can) and measure the temperature of the water to the nearest 0.1 °C. Allow several minutes for the thermometer reading to stabilize.
8. Weigh a fuel burner and determine its mass to the nearest 0.01 gram, or, if possible, to the nearest 0.001 gram.
9. Place the weighed fuel burner under the beaker (can) of water. Adjust the ring so that the bottom of the beaker (can) is about 2 cm from the top of the wick of the burner.
10. Light the burner.
11. Check the flame height. If necessary, cautiously adjust the height of the beaker (can) so that the top of the flame is just below the bottom of the beaker (can).
12. Heat the water until the temperature has increased about 20°C, then extinguish the flame with a wet paper towel.
13. Reweigh the burner. Determine the mass of fuel consumed by subtracting the final mass from the original mass of the burner.
14. Repeat the whole procedure (number 1-13) with each available fuel.
15. Enter your results for each fuel beside your group name or number on the board at the front of the room.

To determine the amount of heat energy liberated by burning fuel, you must obtain the following information from your experiment: the mass of water that heated, the change in temperature of the water, and the mass of fuel burned. You will also need the specific heat of water, a quantity defined as the amount of energy (1 calorie) required to raise the temperature of one gram of water by 1°C, usually expressed as:

1 cal/g°C OR 4.184 J/g°C since 1 cal = 4.184 Joules.

Total heat energy liberated = degrees heated (ΔT) x grams of water heated x 1 cal/g°C

Calculate:
1. Total heat energy liberated for each separate fuel your group examined,
2. Calculate the heat liberated for 1 gram of each fuel.
3. Compare the data for different groups in the class, and calculate an average value for heat per gram for each fuel.
Data Sheet

<table>
<thead>
<tr>
<th>FUEL</th>
<th>Ethyl alcohol</th>
<th>Butyl alcohol</th>
<th>Kerosene</th>
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<tbody>
<tr>
<td>Mass of can + water</td>
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<td></td>
<td></td>
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<tr>
<td>Mass empty can</td>
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<td>Mass water</td>
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<tr>
<td>Final Temp (water)</td>
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<td></td>
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<tr>
<td>Initial Temp (water)</td>
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<tr>
<td>Change in Temp</td>
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<tr>
<td>Initial mass of burner</td>
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<td></td>
</tr>
<tr>
<td>Final mass of burner</td>
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<td></td>
</tr>
<tr>
<td>Mass of fuel burned</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total heat energy liberated</td>
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<tr>
<td>Heat energy per gram of fuel</td>
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Discussion Questions

1. What is the relationship between the heat liberated from each fuel, and the percentage of oxygen in the fuel? Use the chart to organize your data, then describe the relationship in words.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Heat liberated per gram of fuel</th>
<th>Percent oxygen in fuel</th>
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2. Predict the approximate amount of heat liberated by burning a gram of candle wax and a gram of propyl alcohol (Note: candle wax is a mixture of saturated carbon compounds with 20 or more carbons in each molecule and no oxygen. Propyl alcohol has the formula C₃H₇OH.) If time permits, perform an experiment to check your prediction.

3. Suppose a mixture that was 95% alcohol and 5% water was used instead of pure alcohol. How do you suppose the results would be affected?

4. There has been some interest on the part of midwestern grain farmers to promote ethyl alcohol as a fuel alternative to gasoline. Based on this experiment, what sort of problems and/or benefits may result from this substitution?

5. Your results may be different from the accepted values for heat liberated by the fuels you examined. The accepted value for a hydrocarbon is about 11.5 kilocalories/gram of fuel. There are many sources of error in this experiment. List them, and indicate whether they will contribute to a large, medium, or small amount of error. Also indicate for each source of error if it will cause your result to be too large or too small when compared to the accepted value.