Energy Content of Fuels

Energy content is an important property of fuels. This property helps scientists and engineers determine the usefulness of a fuel. Energy content is the amount of heat produced by the burning of 1 gram of a substance, and is measured in joules per gram (J/g).

You can determine energy content of a fuel by burning an amount of the fuel and capturing the heat released in a known mass of water in a calorimeter. If you measure the initial and final temperatures, the energy released can be calculated using the equation

\[ H = \Delta t \cdot m \cdot C_p \]

where \( H \) = heat energy absorbed (in J), \( \Delta t \) = change in temperature (in °C), \( m \) = mass (in g), and \( C_p \) = specific heat capacity (4.18 J/g°C for water). Dividing the resulting energy value by grams of food burned gives the energy content (in J/g).

OBJECTIVES

In this experiment, you will

- use a TI Graphing Calculator, a CBL System, and a temperature probe to measure temperature
- use a balance
- determine energy content
- compare the energy content of different fuels

MATERIALS

CBL System
TI Graphing Calculator
Vernier Temperature Probe
Vernier adapter cable
fuel sample (candle, oil, or alcohol)
ring stand and 4" ring
utility clamp

slit stopper
100-mL graduated cylinder
2 stirring rods
balance
small can
cold water
matches

Figure 1
PROCEDURE

1. Obtain and wear goggles.

2. Plug an adapter cable into Channel 1 of the CBL System, and then plug a temperature probe into the adapter cable. Connect the CBL System to the TI Graphing Calculator with the link cable using the port on the bottom edge of each unit. Firmly press in the cable ends.

3. Turn on the CBL unit and the calculator. Press PRGM and select PHYSCI. Press ENTER, then press ENTER again to go to the MAIN MENU.

4. Set up the calculator and CBL for one temperature probe and a temperature calibration.
   - Select SET UP PROBES from the MAIN MENU.
   - Enter “1” as the number of probes.
   - Select TEMPERATURE from the SELECT PROBE menu.
   - Enter “1” as the channel number.
   - Select USE STORED from the CALIBRATION menu.

5. Set up the calculator and CBL for data collection.
   - Select COLLECT DATA from the MAIN MENU.
   - Select TIME GRAPH from the DATA COLLECTION menu.
   - Enter “5” as the time between samples, in seconds.
   - Enter “96” as the number of samples (the CBL will collect data for a total of 8 minutes).
   - Press ENTER, then select USE TIME SETUP to continue. Note: If you want to change the sample time or sample number you entered, select MODIFY SETUP.
   - Enter “0” as the minimum temperature (Ymin).
   - Enter “50” as the maximum temperature (Ymax).
   - Enter “10” as the temperature increment (Yscl).

6. Find and record the initial mass of the lamp with fuel sample or candle assigned to you. Make sure no more than 0.5 cm of wick sticks out of a lamp.

7. Set up the apparatus shown in Figure 1.
   - Determine and record the mass of the empty can.
   - Place cold water from the teacher into the can. Use 100 mL for candles and 200 mL for alcohol and oil.
   - Determine and record the mass of the can plus water.
   - Use a 4" ring and stirring rod to suspend the can about 5 cm above the candle or lamp.
   - Use a utility clamp and slit stopper to suspend the temperature probe in the water. The probe should not touch the bottom of the can.

8. Press ENTER on the calculator to begin data collection. Remember: The temperature probe must be in the water for at least 45 seconds before you begin! Monitor the temperature on the CBL screen for a few seconds, then record the initial temperature (round to the nearest 0.1°C). Light the lamp or candle. Heat the water until its temperature reaches 40°C and then extinguish the flame. CAUTION: Keep hair and clothing away from open flames.

9. Stir the water until the temperature stops rising. Record this final temperature (round to the nearest 0.1°C). After 8 minutes, data collection is completed (“DONE” appears on the CBL screen).
10. Determine the final mass of the lamp and fuel or candle.

11. Press [ENTER] to display a graph of temperature vs. time. Confirm the initial and maximum values you recorded earlier by using ► to examine the data points along the curve. As you move the cursor right or left, the time (X) and temperature (Y) values of each data point are displayed below the graph.

12. Press [ENTER], then choose YES to repeat the procedure using a different fuel. Start with cold water again.

**DATA**

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel used</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>Mass of lamp and fuel or candle (initial)</td>
<td>_____ g</td>
<td>_____ g</td>
</tr>
<tr>
<td>Mass of lamp and fuel or candle (final)</td>
<td>____ g</td>
<td>____ g</td>
</tr>
<tr>
<td>Mass of empty can</td>
<td>______ g</td>
<td>______ g</td>
</tr>
<tr>
<td>Mass of can plus water</td>
<td>______ g</td>
<td>______ g</td>
</tr>
<tr>
<td>Initial water temperature</td>
<td>______ °C</td>
<td>______ °C</td>
</tr>
<tr>
<td>Final water temperature</td>
<td>______ °C</td>
<td>______ °C</td>
</tr>
</tbody>
</table>

**PROCESSING THE DATA**

1. Calculate the change in water temperature, Δt, for each sample by subtracting the initial temperature from the final temperature (Δt = t_f - t_i).

2. Calculate the mass (in g) of the water heated for each sample. Subtract the mass of the empty can from the mass of the can plus water.

3. Use the results of Steps 1 and 2 to determine the heat energy gained by the water (in J). Use the equation

   \[
   H = \Delta t \cdot m \cdot C_p
   \]

   where \( H \) = heat absorbed (in J), \( \Delta t \) = change in temperature (in °C), \( m \) = mass of the water heated (in g), and \( C_p \) = specific heat capacity (4.18 J/g°C for water).
4. Calculate the mass (in g) of fuel burned. Subtract the final mass from the initial mass.

5. Use the results of Steps 3 and 4 to calculate the energy content (in J/g) of the fuel samples.

6. Record your results and the results of other groups in the Class Results Table below.

<table>
<thead>
<tr>
<th>Fuel Type</th>
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</thead>
<tbody>
<tr>
<td>_______ J/g</td>
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</tr>
<tr>
<td>Avg. _______ J/g</td>
<td>_______ J/g</td>
<td>_______ J/g</td>
<td>_______ J/g</td>
</tr>
</tbody>
</table>

7. Which of the fuels has the greatest energy content?

EXTENSIONS

1. Make a bar graph comparing the fuels tested in your class.

2. Design an experiment to compare heat content of different alcohols or oils.
Energy Content of Fuels

1. Experiment 7, “Mixing Warm and Cold Water,” introduces heat calculations and should be the first experiment done in the series of heat experiments in this manual.

2. Alcohol burners, available from science supply companies, work well with either alcohol or lamp oil. Because alcohol evaporates rapidly, the mass of the alcohol and burner should be determined immediately before and after use.

3. Small soup cans work well. After removing the paper and top, place two holes, large enough to fit a stirring rod, near the top. Be sure to remove all sharp edges. Many teachers prefer to use aluminum beverage cans.

4. Have ice water available and make sure all ice is removed from the water to be used. Water initially at 4–5°C gives best results, because starting 17–19°C below and finishing 17–19°C above room temperature tends to equalize heat exchange with the room.

5. Have the candles mounted on small pieces of cardboard. The cardboard bases will catch candle drippings.

SAMPLE RESULTS

<table>
<thead>
<tr>
<th>Fuel used</th>
<th>candle</th>
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<tbody>
<tr>
<td>Initial candle mass (g)</td>
<td>24.82</td>
</tr>
<tr>
<td>Final candle mass (g)</td>
<td>24.18</td>
</tr>
<tr>
<td>Mass of empty can (g)</td>
<td>40.44</td>
</tr>
<tr>
<td>Mass of can plus water (g)</td>
<td>139.96</td>
</tr>
<tr>
<td>Initial water temperature (°C)</td>
<td>5.6</td>
</tr>
<tr>
<td>Final water temperature (°C)</td>
<td>41.2</td>
</tr>
</tbody>
</table>

PROCESSING THE DATA RESULTS

1. \( \Delta t = 41.2 - 5.6 = 35.6°C \)

2. \( 139.96 - 40.44 = 99.52 \text{ g water heated} \)

3. \( H = 35.6°C \times 99.52 \text{ g} \times 4.18 \text{ J/g°C} = 14,810 \text{ J gained} \)

4. \( 24.82 - 24.18 = 0.64 \text{ g candle burned} \)

5. \( 14,810 \text{ J} / 0.64 \text{ g} = 23,140 \text{ J/g} \)
6. Typical class averages are:

- candle (paraffin wax) 23,000–25,000 J/g
- lamp oil 16,000–18,000 J/g
- ethyl alcohol 12,000–14,000 J/g

Actual values are about 42.0 kJ/g and 26.8 kJ/g for paraffin wax and ethyl alcohol, respectively. You may want to discuss factors causing the values obtained in this experiment to be lower than the actual values.

7. Measured in J/g, candle wax has the greatest energy content.