Period 6: Specific Heat, Latent Heat and Heat Capacity

6.1 The Specific Heat of Materials

Your instructor will discuss the specific heat ($s_{\text{heat}}$) of materials.

1) Measuring the Specific Heat of Water

a) Empty the water from the hot pot on your table into a beaker. Measure 500 ml of water in a beaker and pour this water into the hot pot. Measure the temperature of the water before you turn on the pot. Record your measurement on the first line (0 seconds elapsed) of the table below.

b) Plug in the hot pot and set the timer for 8 minutes. Measure the temperature of the water every 30 seconds. Record your data in the table and make a graph.

<table>
<thead>
<tr>
<th>Time Elapsed (seconds)</th>
<th>Temperature (°C)</th>
<th>Time Elapsed (seconds)</th>
<th>Temperature (°C)</th>
<th>Time Elapsed (seconds)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>150</td>
<td>30</td>
<td>180</td>
<td>60</td>
<td>210</td>
</tr>
<tr>
<td>30</td>
<td>180</td>
<td>60</td>
<td>210</td>
<td>90</td>
<td>240</td>
</tr>
<tr>
<td>60</td>
<td>210</td>
<td>90</td>
<td>240</td>
<td>120</td>
<td>270</td>
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<tr>
<td>90</td>
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<td>120</td>
<td>270</td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>120</td>
<td>270</td>
<td></td>
<td>330</td>
<td></td>
<td>360</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>390</td>
<td></td>
<td>420</td>
</tr>
</tbody>
</table>

0 30 60 90 120 150 180 210 240 270 300 330 360 390 420

0 10 20 30 40 50 60 70 80 90 100 110
b) Group Discussion Question: Would this graph have a different appearance if you had added the same amount of heat to a larger volume of water? In what ways would the graph change?

2) Calculating the Specific Heat of Water

Next, we calculate the specific heat of water using data from your experiment.

a) How many seconds did it take the water to reach its maximum temperature? 

b) The hot pots are rated at 600 watts (600 J/sec). How many joules of heat $Q$ were added to the water? 

c) What is the mass $M$ of the water in grams? (One ml of water has a mass of 1 gram.)


d) What was the change in temperature of the water, $\Delta T$, in Celsius degrees?


e) Calculate the specific heat of water $s_{\text{heat}}$ by organizing the equation $Q = s_{\text{heat}} \times M \times \Delta T$ as $s_{\text{heat}} = \frac{Q}{M \Delta T}$

f) Group Discussion Question: Your instructor will give you a value for the specific heat of water. How well does your calculated value agree with the accepted value of specific heat of water? What sources of error may be present in your experiment?
3) Latent Heat

Your instructor will discuss the latent heat \( (L_{heat}) \) of a material during phase changes.

a) To find how many calories of heat are required to convert 700 grams of water at a temperature of 40 °C into steam at 100 °C, follow the three steps below.

Step 1: Find the heat required to raise the temperature of the water at 40 °C to water to 100 °C. The specific heat of liquid water is 1.00 calories/gram °C. Hint: use the equation \[ Q = s_{heat} \times M \times \Delta T \]

Step 2: Find the heat required for the phase change of 700 grams of water at 100 °C into steam at 100 °C. The latent heat of evaporation of water is 540 calories/gram. Hint: use the equation \[ Q = L_{heat} \times M \]

Step 3: Find the total heat required to heat the water to 100 °C and the heat required to convert the liquid water into steam.

4) Heat Capacity

Your instructor will discuss the heat capacity \( (H_{cap}) \) of objects.

a) Place 200 mL of water into a 600 mL beaker. Place a 200 gram metal mass into another 600 mL beaker. Measure the temperature of the water and metal with the infrared thermometer. Record their temperatures in the table below.

b) Your instructor will pour 100 mL of liquid nitrogen into each beaker. Caution: liquid nitrogen can cause injury if it comes in contact with your skin.

After the liquid nitrogen has stopped boiling, measure the temperature of the water and the metal and record the temperatures below.

<table>
<thead>
<tr>
<th>Water</th>
<th>Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Temperature</td>
<td></td>
</tr>
<tr>
<td>Final Temperature</td>
<td></td>
</tr>
<tr>
<td>Change in Temperature</td>
<td></td>
</tr>
</tbody>
</table>

c) Which substance has a larger heat capacity? ____________

How do you know?
d) This experiment compared equal masses of water and metal. Which of these substances has a larger specific heat? ________________ How do you know?

e) Group Discussion Question: When comparing two objects, will the object with the higher specific heat always have a greater heat capacity? __________
Explain why or why not.

5) **Boiling Liquid Freon**
   
a) Can you make the freon in the dippy duck boil by heating it in the palm of your hand? ____ (Warning: putting the dippy duck in hot water will break it.)

b) Measure the temperature of the boiling freon in the dippy duck with the infrared thermometer. At what temperature does the freon boil? ________

c) Group Discussion Question: Why is the low boiling temperature of freon important to making the dippy duck work well?

6) **Boiling Liquid Nitrogen**

Your instructor will pour liquid nitrogen into an empty styrofoam cup on your table. **Caution:** liquid nitrogen can cause injury if it comes in contact with your skin. The temperature of liquid nitrogen is 77 Kelvin, −190°C, or −360°F.

a) What is the source of thermal energy that causes the liquid nitrogen to boil?

b) What happens to the temperature of the liquid nitrogen as it boils? ________

c) Measure the temperature of a water balloon with the infrared thermometer. ________

d) Carefully place the water balloon into the cup of liquid nitrogen. After 30 seconds, carefully remove the balloon. Measure the balloon’s temperature. ________

c) What happened to the water in the balloon? Why?

d) What happened to the rate of boiling of the liquid nitrogen when you added the water balloon to the cup? ________________

e) Group Discussion Question: Measure the temperature of the water balloon again after it has been out of the liquid nitrogen for a few minutes. Has the temperature changed substantially? Why or why not?
Period 6 Exercises: Specific Heat, Latent Heat, and Heat Capacity

1. Finding heat capacity
   a) It takes 528 calories to raise the temperature of a block of aluminum from 23 °C to 35°C. What is the heat capacity of this block of aluminum?

2. Finding specific heat
   a) The block of aluminum described in question 1 has a mass of 200 grams. From this information, calculate the specific heat of aluminum.

   b) Explain the difference between the heat capacity and specific heat of an object such as the block of aluminum.

3. Finding latent heat
   Find how many calories of heat are required to melt a 15 gram ice cube at -20°C (minus 20 degrees Celsius) into liquid water at 25°C. The specific heat of water is 1 calorie/gram °C. The heat of fusion (heat of freezing) of water is 80 calories/gram.
   a) How many calories are required to raise the temperature of 15 grams of ice from -20°C to 0°C?

   b) How many calories are required to melt the 15 grams of ice at 0°C into liquid water at 0°C?

   c) How many calories are required to raise the temperature of the 15 grams of liquid water from 0°C to 25°C?

   d) What is the total heat required?