Learning Objectives

- understand the concept of heat and joules.
- perform heat-gain and heat-loss calculations.

Procedure Overview

- hot and cold water are mixed. The water masses and temperature changes are used to calculate the heat lost and heat gained.
- ice is melted in water and the heat of fusion is calculated.
- candle is burned under a metal cup containing a known mass of water, and the heat of combustion of the candle is calculated.
**INTRODUCTION TO CALORIMETRY**

**Report Sheet**

**Heat loss and heat gain**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of cold water + cup</td>
<td>_____ g</td>
</tr>
<tr>
<td>Mass of cup</td>
<td>_____ g</td>
</tr>
<tr>
<td>Mass of cold water</td>
<td>_____ g</td>
</tr>
<tr>
<td>Mass of hot water</td>
<td>_____ g</td>
</tr>
<tr>
<td>Temperature of cold water</td>
<td>_____ °C</td>
</tr>
<tr>
<td>Temperature of hot water</td>
<td>_____ °C</td>
</tr>
<tr>
<td>Final mixture temperature</td>
<td>_____ °C</td>
</tr>
<tr>
<td>ΔT (hot water)</td>
<td>_____ °C</td>
</tr>
<tr>
<td>ΔT (cold water)</td>
<td>_____ °C</td>
</tr>
</tbody>
</table>
INTRODUCTION TO CALORIMETRY

Report Sheet (page 2)

Heat associated with a physical change

Mass of cup and water  
Mass of dry cup  
Mass of cup, ice + water  
Mass of water  
Mass of ice  
Initial water temperature  
Final water temperature (after the ice melts)  
$\Delta T$  

Heat associated with chemical change

Mass of water + metal cup  
Mass of metal cup  
Mass of water  
Mass of candle before burning  
Mass of candle after burning  
Mass of candle burned  
Initial water temperature  
Final water temperature  
$\Delta T$  
INTRODUCTION TO CALORIMETRY

Calculations

Heat loss and heat gain

1. Calculate the heat gained by the cold water.

2. Calculate the heat lost by the hot water.

3. Compare the results of (1) and (2). What conclusions can you draw?

Heat associated with a physical change

1. Calculate the heat lost by the water. See the example in the experiment description. Remember, this is also the heat gained by the ice.

2. Calculate the heat required to melt one gram of ice. See the example in the experiment description.
Heat associated with a chemical change
1. Calculate the heat absorbed by the water.

2. Calculate the heat released per gram of candle burned.
Questions/Problems

1. Distinguish between heat and temperature.

2. Describe what is meant by the specific heat of a substance.

3. In this experiment, you measured the heat associated with a burning candle. Does this represent a physical change and/or a chemical change? Describe the change(s) occurring.
1. Distinguish between heat and temperature.

*Heat is a form of energy, manifested by the transfer of energy between two bodies of different temperatures. It is an extensive property, depending on the amount of matter examined.*

*Temperature is an intensive property which depends on the intensity of energy present and not on the amount and type of material being measured.*

2. Describe what is meant by the **specific heat** of a substance.

*Specific heat is the amount of heat required to raise one gram of a substance by one °C.*

3. In this experiment, you measured the heat associated with a burning candle. Does this represent a physical change and/or a chemical change? Describe the change(s) occurring.

*The experiment represents a chemical change. During the combustion of the candle, the candle wax is being converted into carbon dioxide and water with small amounts of other chemicals. The chemical reaction is also generating heat. The incidental melting of wax which accompanies the combustion is a physical change.*
INTRODUCTION TO CALORIMETRY

Tips and Traps

1. It is easy for students to forget to measure some of the masses. Please remind them to read the instructions carefully!

2. Before the lab starts, show your students what approximately 10 grams of ice looks like so no one actually tries to measure it directly on the balance! Remember, the mass of the ice will be measured indirectly by measuring the mass of the water and melted ice at the end.

3. The ice can be "dried" by dabbing it with a paper towel.

4. It is important to remind the students to wipe the carbon black off of the bottom of the metal cup after each use! The soot is very messy!

SAMPLE HEATING CURVE

![Sample Heating Curve: Temp°C / Data Source 3 vs. Time 1](image)

SAMPLE COOLING CURVE

![Sample Cooling Curve: Temp°C / Data Source 3 vs. Time 1](image)
INTRODUCTION TO CALORIMETRY

Sample Data

Heat loss and heat gain

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of cold water + cup</td>
<td>39.72 g</td>
</tr>
<tr>
<td>Mass of cup</td>
<td>1.83 g</td>
</tr>
<tr>
<td>Mass of cold water</td>
<td>37.89 g</td>
</tr>
<tr>
<td>Mass of hot water</td>
<td>29.82 g</td>
</tr>
<tr>
<td>Temperature of cold water</td>
<td>9.72 °C</td>
</tr>
<tr>
<td>Temperature of hot water</td>
<td>45.12 °C</td>
</tr>
<tr>
<td>Final mixture temperature</td>
<td>23.68 °C</td>
</tr>
<tr>
<td>ΔT (hot water)</td>
<td>-21.44 °C</td>
</tr>
<tr>
<td>ΔT (cold water)</td>
<td>13.96 °C</td>
</tr>
</tbody>
</table>

Heat associated with a physical change

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of cup and water</td>
<td>102.39 g</td>
</tr>
<tr>
<td>Mass of dry cup</td>
<td>1.79 g</td>
</tr>
<tr>
<td>Mass of cup, ice + water</td>
<td>113.06 g</td>
</tr>
<tr>
<td>Mass of water</td>
<td>100.60 g</td>
</tr>
<tr>
<td>Mass of ice</td>
<td>10.67 g</td>
</tr>
<tr>
<td>Initial water temperature</td>
<td>19.21 °C</td>
</tr>
<tr>
<td>Final water temperature (after the ice melts)</td>
<td>11.10 °C</td>
</tr>
<tr>
<td>ΔT</td>
<td>8.11 °C</td>
</tr>
</tbody>
</table>

Heat associated with chemical change

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of water + metal cup</td>
<td>53.76 g</td>
</tr>
<tr>
<td>Mass of metal cup</td>
<td>1.91 g</td>
</tr>
<tr>
<td>Mass of water</td>
<td>51.85 g</td>
</tr>
<tr>
<td>Mass of candle before burning</td>
<td>17.35 g</td>
</tr>
<tr>
<td>Mass of candle after burning</td>
<td>17.13 g</td>
</tr>
<tr>
<td>Mass of candle burned</td>
<td>0.22 g</td>
</tr>
<tr>
<td>Initial water temperature</td>
<td>18.51 °C</td>
</tr>
<tr>
<td>Final water temperature</td>
<td>37.95 °C</td>
</tr>
<tr>
<td>ΔT</td>
<td>19.44 °C</td>
</tr>
</tbody>
</table>
Calculations

Heat loss and heat gain

1. Calculate the heat gained by the cold water.

\[(4.184 \text{ J/g } ^\circ\text{C}) (37.89 \text{ g}) (13.96 ^\circ\text{C}) = 2213 \text{ J}\]

2. Calculate the heat lost by the hot water.

\[(4.184 \text{ J/g } ^\circ\text{C}) (29.82 \text{ g}) (21.44 ^\circ\text{C}) = 2675 \text{ J}\]

3. Compare the results of (1) and (2). What conclusions can you draw?

*The ratio of the heat gained to heat lost is 2213 J/2675 J, or 0.827. This value should theoretically be "1"; however, we should certainly expect some error. There seems to be an unaccounted for heat loss in the transfer of heat from the hot water to the cold water.*

Heat associated with a physical change

1. Calculate the heat lost by the water. See the example in the experiment description. Remember, this is also the heat gained by the ice.

\[(4.184 \text{ J/g } ^\circ\text{C}) (100.60 \text{ g}) (8.11 ^\circ\text{C}) = 3.41 \times 10^3 \text{ J}\]

2. Calculate the heat required to melt one gram of ice. See the example in the experiment description.

\[\text{heat loss} = \text{heat gained}\]

\[3.41 \times 10^3 \text{ J} = (10.67 \text{ g}) (\Delta H_{\text{fusion}}) + (4.184 \text{ J/g } ^\circ\text{C}) (10.67 \text{ g}) (11.10 ^\circ\text{C})\]

\[\Delta H_{\text{fusion}} = 273 \text{ J/g}\]

Heat associated with a chemical change

1. Calculate the heat absorbed by the water.

\[(4.184 \text{ J/g } ^\circ\text{C}) (51.85 \text{ g}) (19.44 ^\circ\text{C}) = 4217 \text{ J}\]

2. Calculate the heat released per gram of candle burned.

\[4217 \text{ J/0.22 g} = 1.9 \times 10^4 \text{ J/g}\]
INTRODUCTION TO CALORIMETRY

Laboratory Preparation (per student station)

Equipment
- MicroLAB interface and temperature probe
- ring stand, iron ring
- utility clamp
- two foam cups
- cover for foam cup
- clay triangle
- small metal cup (like a Vienna sausage can)
- 100 mL graduated cylinder

Supplies
- candle
- paper towel
- matches

Chemicals
- water
- ice

Safety and Disposal
There are no disposal problems in this experiment. All waste can go in the trash can or down the drain.