Experiment #12 – Determination of the Enthalpy of Fusion of Water

Laboratory Overview

CHEM 1361

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Gary S. Buckley, Ph.D.
Department of Physical Sciences
Cameron University
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Thermochemistry Background

• Thermochemistry – the study of the relationship between chemical transformation and energy changes that involve heat

• Of most importance to this experiment – the determination of the heat evolved or absorbed when ice melts

• Key mathematical relationship:

\[ q = C_s \times m \times \Delta T \]

where:
- \( q \) = the heat absorbed or evolved in a process (usually J or cal)
- \( C_s \) = the specific heat capacity of a substance (usually J/g-K or cal/g-K)
- \( m \) = mass of substance
- \( \Delta T \) = change in temperature of substance
First Law of Thermodynamics

The First Law of Thermodynamics simply states that energy of the universe is conserved in any ordinary process. This is often stated as energy can be neither created nor destroyed.

The First Law of Thermodynamics provides the basis for our determination of the enthalpy of fusion of water. We allow ice to melt in contact with a device whose energy change we can calculate and, as a result, we can determine how much energy the ice absorbed while melting since it must match the energy lost by the device.
Experimental Aspects

We will use a device referred to as a calorimeter to determine the amount of heat absorbed when ice melts. As a calorimeter we will use a styrofoam coffee cup since it is a good insulator — very little heat will be transferred outside of the cup.

The concept behind the experiment is fairly straightforward. If we know how much the temperature rises in our calorimeter for a given amount of heat put into or taken out of it, we can use that information to find out how much heat is transferred in a process by measuring the temperature change in the calorimeter during that process.

The Vernier LabQuest2 will be used to monitor temperature. Further information about its use may be found at this link. Hit the Play button in the lower-left corner of the screen that opens. If you can’t hear the audio, go to Tools/Audio Wizard. Pick out the speakers that you have and check the audio level.
To determine the temperature rise in the calorimeter for a given amount of heat, you will conduct a calibration of the calorimeter. This involves measuring the temperature change in the calorimeter when known amounts of hot and cold water are mixed in it. By the First Law of Thermodynamics, the heat evolved by the hot water as it cools must match the heat absorbed by the colder water and the calorimeter as they warm up.

\[ \text{heat evolved by hot water} + \text{heat absorbed by cooler water} + \text{heat absorbed by calorimeter} = 0 \]

This is simply a statement of the First Law of Thermodynamics. The terms could be replaced by their mathematical expressions as given on the Thermochemistry Background slide. Then:

\[ C_{s,\text{hot}} \times m_{\text{hot}} \times \Delta T_{\text{hot}} + C_{s,\text{RT}} \times m_{\text{RT}} \times \Delta T_{\text{RT}} + C_{\text{calorimeter}} \times \Delta T_{\text{calorimeter}} = 0 \]

where RT refers to the room temperature water (which is cooler than the heated) and the specific heat and mass of the calorimeter have been rolled into one term which represents its heat capacity. Also note that the temperature changes will have different signs – they are always final temperature minus the initial temperature.
Experimental Aspects (continued)

The table in the lab book (example below) step you through the calculational process. The first three lines result in the mass of both the hot and RT water, the next three give the \( \Delta T \) for both the hot and RT water – note you need to pay attention to algebraic signs. From this information you arrive at the heat transfer for both the hot and RT water and can thus determine the \( C_{\text{calorimeter}} \).

<table>
<thead>
<tr>
<th>Calibration Data</th>
<th>Heat Evolved by Hot Water:</th>
<th>Heat Absorbed by Room Temperature (RT) Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final mass of calorimeter and mixed water (g)</td>
<td>Initial mass of calorimeter with room temperature (RT) water (g)</td>
<td></td>
</tr>
<tr>
<td>Initial mass of calorimeter with room temperature water (g)</td>
<td>Initial mass of empty dry calorimeter (g)</td>
<td></td>
</tr>
<tr>
<td>Mass of hot water (g)</td>
<td>Mass of RT water (g)</td>
<td></td>
</tr>
<tr>
<td>( T_f ) hot water (°C)</td>
<td>( T_f ) of RT water (°C)</td>
<td></td>
</tr>
<tr>
<td>( T_i ) hot water (°C)</td>
<td>( T_i ) of RT water (°C)</td>
<td></td>
</tr>
<tr>
<td>( T_f - T_i ) hot water (°C) (include algebraic sign)</td>
<td>( T_f - T_i ) RT water (°C) (include algebraic sign)</td>
<td></td>
</tr>
<tr>
<td>( q_{\text{hot}} ) (J)</td>
<td>( q_{\text{RT}} ) (J)</td>
<td></td>
</tr>
<tr>
<td>( =4.184 \text{ J/g\textdegree°C} \times m_{\text{hot}} \times (T_f - T_i) )</td>
<td>( =4.184 \text{ J/g\textdegree°C} \times m_{\text{RT}} \times (T_f - T_i) )</td>
<td></td>
</tr>
<tr>
<td>Sum of ( q_{\text{hot}} ) and ( q_{\text{RT}} ) (pay attention to algebraic signs) (J):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( q_{\text{calorimeter}} ) (same as previous line with opposite sign) (J)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( C_{\text{calorimeter}} ) (calorimeter constant, ( q_{\text{calorimeter}} ) divided by its temperature change which is the same as ( T_f - T_i ) for the RT water) (J/°C):</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Experimental Aspects (continued)

Once the $C_{\text{calorimeter}}$ is known, the enthalpy of fusion of water is determined by measuring the temperature change when ice is melted in a known mass of water.
End of Slides