**Freeze Glass to Wood**

**Description:** Solid barium hydroxide (Ba(OH)$_2$) and ammonium thiocyanate (NH$_4$SCN) are mixed and generate an endothermic reaction cold enough to freeze a glass container to a wet piece of wood.

**Materials:**
- Ba(OH)$_2$•8H$_2$O
- NH$_4$SCN
- Water
- Erlenmeyer or beaker
- Wood
- Glass stirring rod

**Procedure:**
For large lecture halls, perform demonstration using a document camera.

Place a large drop of water on the wood (size of a quarter). Place the flask (or beaker) on the wood and add 32 g Ba(OH)$_2$•8H$_2$O and 16 g NH$_4$SCN. Mix the two solids together while keeping the container on the wood. Mixture will become wet and ammonia will be generated. After a couple of minutes, the mixture will be cold enough that the drop of water beneath the glass container will freeze. Alternatively, this reaction can be performed using 11 g NH$_4$Cl or 17 g NH$_4$NO$_3$.

**Discussion:** This experiment demonstrates a SPONTANEOUS endothermic reaction. According to the free energy equation, $\Delta G = \Delta H - T\Delta S$, a reaction with a positive $\Delta H$ will only be spontaneous if the positive $\Delta H$ is offset by a large positive $\Delta S$ value. This is achieved in this setup with the generation of H$_2$O (l) and NH$_3$ (g). The equation below describes the reaction from this demonstration:

$$\text{Ba(OH)}_2\text{•8H}_2\text{O} (s) + 2 \text{NH}_4\text{SCN} (s) \rightarrow \text{Ba(SCN)}_2 (aq) + 2 \text{NH}_3 (g) + 10 \text{H}_2\text{O} (l)$$

Although thermodynamic data is not available for the thiocyanate compounds in this reaction, a quantitative analysis can be performed using the nitrate or chloride derivatives as shown in the table below (Shakhshiri):

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$\Delta H^0$ (kJ)</th>
<th>$\Delta S^0$ (J/K)</th>
<th>$\Delta G^0$ (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH$_4$NO$_3$</td>
<td>+62.3</td>
<td>406</td>
<td>-60.2</td>
</tr>
<tr>
<td>NH$_4$Cl</td>
<td>+63.6</td>
<td>368</td>
<td>-47.7</td>
</tr>
</tbody>
</table>
Safety: Wear proper protective equipment including gloves and safety glasses when preparing and performing this demonstration. Avoid prolonged contact with the flask as temperatures can become as cold as -30 °C. Barium and ammonium salts are irritants to the skin. Barium salts are toxic if ingested.

Disposal: The contents should be disposed off in an appropriate waste container.

References:

Video:
http://genchem.chem.wisc.edu/demonstrations/Gen_Chem_Pages/06thermopage/thermochemistry.htm

http://www.youtube.com/watch?v=MyAzjSdc3Fc