Chemistry 1310 I
Lecture Notes

W, October 27, 2004

Heat "flows" downhill.

Temperature is a measure of the heat content of an object.

We detect heat "flow" by changes in temperature.

Adapted from
OFB, Ch.p10, p. 474, # 14
Iron pellets weighing 17.0 g at a temperature of 92.0 °C are mixed in an insulated container with 17.0 g of water at a temperature of 20.0 °C. The specific heat capacity of water is 4.184 J/(K·g) and the specific heat of iron is 0.449 J/(K·g). Compute the final temperature of this mixture.
Bath full of boiling water
Bath at some t
Bigger one has
more heat
Heat = \text{Amount of substance} \times \text{Heat Capacity} \times \text{Temp. change}

q_g = \text{Mass} \times \left( \frac{\text{Specific heat}}{\text{Capacity}} \right) \Delta T

\frac{g}{K} = \text{chemical} \times \left( \frac{\text{Molar heat}}{\text{Capacity}} \right) \Delta T

\text{mol} \times \frac{J}{\text{molK}} = 110
System + surroundings = Universe

Heat Lost = -Heat Gained by water by iron

\[ \Delta T = T_f - T_i \]
Irm

\[
\frac{17.0 \text{ g Fe} \times (0.449 \text{ J/g K})}{8 \text{ K}} (t_f - 92.0^\circ \text{C})
= - 17.0 \text{ g H}_2\text{O} \left( \frac{4.184 \text{ J}}{9^\circ \text{C}} \right) (t_f - 20.0^\circ \text{C}) \quad \text{Water}
\]

\[t_f = 27.9^\circ \text{C}\]
Rule of Dulong and Petit

Molar heat capacity of a metal is 25 \( \frac{J}{\text{mol} \cdot K} \) = 3 \( \text{R} \)

\[ R = 0.08206 \text{ L atm} = 8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}} \]
\[
\text{Specific heat} \times \text{atomic mass} = \text{molar heat capacity}
\]

\[
\frac{0.449 \text{ J}}{9 \text{ K}} \times A = \frac{25 \text{ J}}{\text{mol K}}
\]

\[
A_{Fe} = 55.68 \frac{\text{g}}{\text{mol}}
\]

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This simple calculation has many approximations:

1) Assume no heat enters or leaves the container.

2) Assume iron is pure.

3) Assume the temperatures quoted are the temperatures at time of mixing.

4) Assume that no heat is absorbed by calorimeter walls and thermometer.

In constant pressure calorimeter, we are usually speaking only of the heat absorbed by walls and thermometer. In constant volume calorimeters (bomb calorimeters), the calorimeter constant refers to the heating of a fixed amount of water used to charge the calorimeter as well as the inner walls and thermometer.
\[ \Delta T = T_f - T_i \]
\[ \Delta P = P_f - P_i \]
\[ \Delta V = V_f - V_i \]

state function

Path dependent variable
An electric current is passed through a resistance coil in a bomb calorimeter and generates 5682 J of heat. The temperature rises by 2.31 °C. Subsequently, 0.2843 g of benzene (C₆H₆ (l)) is burned in oxygen in the calorimeter, causing the temperature to rise by 4.40 °C. Find the heat of combustion of benzene in units of J/g.

\[
\frac{5682 \text{ J}}{2.31 \degree \text{C}} \times 4.40 \degree \text{C} = 10,823 \text{ J}
\]

\[\text{q}_{\text{cal}} = 10.8 \text{ kcal}\]

System = combustion of benzene
\[\text{C}_6\text{H}_6 + \frac{15}{2}\text{O}_2 \rightarrow 6\text{CO}_2 + 3\text{H}_2\text{O}\]

\[\text{q}_{\text{sys}} = -10.8 \text{ kcal}\]

\[-10.823 \text{ kcal} \times \frac{0.28479}{g} = -38.1 \text{ kcal/g}\]
<table>
<thead>
<tr>
<th>Path</th>
<th>$Q_{\beta}$</th>
<th>$w$</th>
<th>$\Delta E$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path 1</td>
<td>400 J</td>
<td>0</td>
<td>400 J</td>
</tr>
<tr>
<td>Path 2</td>
<td>200 J</td>
<td>200 J</td>
<td>400 J</td>
</tr>
<tr>
<td>Path 3</td>
<td>0</td>
<td>400 J</td>
<td>400 J</td>
</tr>
<tr>
<td>Path 4</td>
<td>-150 J</td>
<td>550 J</td>
<td>400 J</td>
</tr>
</tbody>
</table>

$\Delta E = q_v \quad w = 0 \quad PdV = 0$

The heat associated with a constant volume path is equal to the change in internal energy.

$W = - \int F \cdot d \vec{r}$

$P = \frac{F}{A}$

$W = - (P \cdot dA \cdot d) = - \int PdV$ differential
Heat is a path dependent variable. The amount of heat associated with a process will vary with the nature of the process (constant volume, constant pressure, constant temperature, adiabatic, etc.).

In addition, the amount of heat associated with a chemical change will vary with sample size (generally reported as grams of reactant or grams of product).

Chemists usually want to have things reported in molar quantities. How do we go from J/g to a molar quantity that is not path dependent?

First Law of Thermodynamics

\[ \Delta E = q + w \]

\( q \) is positive if heat is absorbed and negative if heat is given off

\( w \) is positive if work is done on the system and negative if the system does work

The internal energy (change), \( \Delta E \), is a state function.

\[ \Delta E = E_f - E_i \]
\[ \Delta E = E_f - E_i \]

internal energy (change)

\[ \Delta H = H_f - H_i \]

enthalpy (change)