Lecture 8
Quick Announcements

HW#3 is posted Due Oct 9\textsuperscript{th}

I will miss 3 days of class

- Oct 11\textsuperscript{th} – I’m getting an award and I have to go to a luncheon
  - TBL with Dr Burks
- Oct 16\textsuperscript{th} and Oct 18\textsuperscript{th} – BMES!
  - I will pre-record lectures and have problem sets for you to work on with Edward and Dr Burks
Warm up for today

Autoclaves are used to clean medical equipment,. The autoclave starts by flowing in cool water at $T=16\,^\circ\text{C}$ and $P = 1\,\text{atm}$. The system then heats at constant pressure to $100\,^\circ\text{C}$. Then the autoclave super heats the water to $132\,^\circ\text{C}$ at $1\,\text{atm}$ for a 5 minutes. The last step involves increasing the pressure, to $2\,\text{atm}$, while holding the temperature constant for 15 minutes to complete sterilization.

Diagram this process and write a formula for $\Delta H$ for this process.
Initial
16°C, 1 atm
water (l)

ΔT \rightarrow ΔH_1

Final
132°C, 2 atm
water (g)

ΔH_4 \uparrow ΔP

132°C, 1 atm
water (g)

ΔT \rightarrow ΔH_2

ΔH = \sum ΔH_i

ΔH_1 \leftrightarrow ΔH_3 = \int_{T_1}^{T_2} Cp(T) dT = MC_d \Delta T

fH = U + PV

\Delta H_4 \approx 0
Review of enthalpy and heat from last time

- Recall that enthalpy is a state function, so changes in pressure, volume, temperature and phase will all generate enthalpy at each step
- For a reaction: \( \Delta H = \sum (n \times H)_{\text{products}} - \sum (n \times H)_{\text{reactants}} \)
- For a vessel: \( \Delta H = \sum (n \times H)_{\text{input}} + \sum (n \times H)_{\text{output}} \)
- For heat of reaction at non-standard T&P
  \[
  \Delta H_{\text{rxn}} = \sum (\sigma \times H_{\text{formation}})_{\text{products}} - \sum (\sigma \times H_{\text{formation}})_{\text{reactants}}
  \]

You can find heat of formation in tables E.7 - E.9 in the textbook, there is no hear of formation for substance in their elemental for (C(s), H\(_2\)(g), N\(_2\)(g), etc.

Calculate heat of reaction given standard heat of reaction \( \Delta H_r = \frac{n_s f_s}{|\sigma_s|} \Delta H_r^o \)
Last time we inhaled and focused on the air. We noticed that when we warmed the air, we lost some body heat, let’s look at the body now during respiration.

We want to estimate the heat loss during respiration. Assume that a person inspired 6 L/min of dry air at 20°C. Expired air is saturated with water and leaves at body temp, 37°C.

Helpful information:
- MW air 28.84 g/mol
- Density of air: 0.0012 g/cm³
- Humidified air is a ratio of \( \frac{0.041 \text{ g water}}{1 \text{ g dry air}} \).
- \( \Delta H_{vap} = 2414.17 \text{ J/g} \) and \( \Delta H_{\text{warm}} = 494 \text{ J/mol} \).
8360 J/min  5980 J/min  -8360 J/min

1. Air
   64 L/min
   20°C

2. Water

3. Humid air
   37°C

\[ \sum m_i - \sum m_j = \frac{d\text{msys}}{dt} \]

\[ \sum m_i \frac{dA_i}{dt} - \sum m_j \frac{dA_j}{dt} + \sum Q + \frac{dW}{dt} = 0 \]

\[ - \Delta H + Q = 0 \]

no rxn.

\[ \dot{m}_1 = \left( \frac{L}{\text{min}} \right) \left( 0.0012 \frac{g}{\text{cm}^3} \right) \left( 1000 \frac{\text{cm}^3}{\text{m}^3} \right) = 7.29 \frac{g}{\text{min}} \]

\[ 7.2 \frac{g}{\text{min}} / 29.84 \approx 0.25 \text{ mol/ min} \]
\[ \dot{m}_{3 H_2O} = \left(0.04 (g \frac{H_2O}{g \text{air}}) \right)(7.2 \text{g air}) \]

\[ \dot{m} = 0.295 \text{ g H}_2\text{O} \text{ per min} \]

\[ \Delta H = \Delta H_{\text{warming air}} + \Delta H_{\text{water vapor}} \dot{m}_{3 H_2O} \]

\[ = 494 J (0.25 \text{ mol}) = 124 J \text{ per mol} \text{ per min} \]

\[ + 2414.17 J \left( \frac{J}{g} \right) (0.295 \text{ g}) = 714 \text{ J per min} \]

\[ \Delta H = 836 J \text{ per min} = Q \text{ energy needed to warm humidity} \]

\[ Q = -836 \text{ J per min from body} \]
Now let’s look at cellular respiration with a reaction and analyze the enthalpy of the body

The following reaction described respiration

\[ \text{C}_6\text{H}_{12}\text{O}_6(s) + 6\text{O}_2(g) \rightarrow 6\text{CO}_2(g) + 6\text{H}_2\text{O}(l) \]

Assume 1 mol glucose and 6 mol oxygen are available and the reaction goes to completion.

Start by drawing the path for each substance

Calculate the enthalpy of each step and overall heat of reaction

*Given \( \Delta H_r^\circ(\text{Glucose at } 25\degree C) = -2805 \frac{kJ}{mol} \)

<table>
<thead>
<tr>
<th>Compound</th>
<th>( C_p \left( \frac{J}{\text{mol} \cdot \degree C} \right) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose, C(<em>6)H(</em>{12})O(_6)(s)</td>
<td>225.9</td>
</tr>
<tr>
<td>Oxygen, O(_2)(g)</td>
<td>29.3</td>
</tr>
<tr>
<td>Carbon dioxide, CO(_2)(g)</td>
<td>36.47</td>
</tr>
<tr>
<td>Water, H(_2)O(\ell)</td>
<td>75.4</td>
</tr>
</tbody>
</table>
The path is critical since enthalpy is a state specific variable.
\[ \Delta H = \sum \int_{T_1}^{T_2} C_p(T) \, dT = \sum n_s C_p(T_2 - T_1) \]

Step 1 - Cooling

\[ \Delta H_1 = \left( \text{mol glucose} \right) \left( 225.9 \right) (25-37) + \text{le mol O}_2 \left( 29.3 \right) (25-37) \]

\[ \Delta H_1 = -4820 \, J \]

Step 3 - Warming

\[ \Delta H_3 = \text{le mol CO}_2 \left( 36.47 \right) (37-25) + \text{le mol H}_20 \left( 75.4 \right) (37-25) \]

\[ \Delta H_3 = 8050 \, J \]
\[ \Delta H_r(37) = \Delta H_1 + \Delta H^\text{adj}_r + \Delta H_3 \]

\[ \Delta H^\circ_r = \frac{n_S}{[Os]} \Delta H^\circ_{2s} = 1 \text{ mol} \times (-2805) \]

\[ = -2805 \text{ KJ} \]

\[ \Delta H_r(37) = -4.82 \text{ KJ} - 2805 \text{ KJ} + 8.05 \text{ KJ} \]

\[ = -2800 \text{ KJ} \]

again non main source of enthalpy
Now what if the reaction doesn’t go to completion? If we provide 1 mol of glucose and 9 mol of oxygen such that 0.2 mol of glucose is left over after the reaction completes

\[ \text{Recall } \Delta H_r = \frac{n_s f_s}{|\sigma_s|} \Delta H_r^\circ \]