FOCUS

Applications of enthalpy:
– Enthalpies of formation
– Enthalpy of reaction
– Determination of product or reactant-favored reactions

Standard Enthalpy Values

Most $\Delta H$ values are labeled $\Delta H^\circ$ (standard enthalpy change)

$\Delta H^\circ$ is measured under standard conditions
- $P = 1$ bar (1 atmosphere)
- Concentration = 1 mol/L
- $T = \text{usually } 25 ^\circ C$
- with all species in standard states

Standard state of an element or compound is its most stable state under standard conditions (e.g., C = graphite and O$_2$ = gas)

Standard Molar Enthalpy of Formation, $\Delta H^\circ_f$

This is the enthalpy change when 1 mol of compound is formed directly from its elements under standard conditions.

Examples:

See Table 6.2 (page 231) and Table (Appendix L, pg A31) for some $\Delta H^\circ_f$ values
Standard Molar Enthalpy Values

Can the enthalpy change for the following reaction be considered standard molar enthalpy changes?

$$\text{CaO}(s) + \text{CO}_2(g) \rightarrow \text{CaCO}_3(s) \quad \Delta H = -178 \text{kJ}$$

Can the enthalpy change for the following reaction be considered standard molar enthalpy changes?

$$\text{P}_4(s) + 6 \text{Cl}_2(g) \rightarrow 4 \text{PCl}_3 \quad \Delta H = -1278.8 \text{kJ}$$

Standard Molar Enthalpy of Formation

$\Delta H^\circ_f$ of Elements

By definition, $\Delta H^\circ_f = 0$ for elements in their standard states.
Standard Molar Enthalpy of Formation

$\Delta H_f^\circ$ of Compounds in Solution

Values of $\Delta H_f^\circ$, for substances in solution refers to the enthalpy change for the formation of a 1M solution of the compound from its elements (under standard conditions) plus the enthalpy change for its dissolution.

For example:

- **Standard Molar Enthalpy of Formation**

  Using $\Delta H_f^\circ$ for Compounds Relative Stability Comparisons

  The more the heat evolved in the formation of a compound, the more stable is the compound.

  In the following table, HF is the most stable since its heat of formation is the most negative of the series.

<table>
<thead>
<tr>
<th>Compound</th>
<th>$\Delta H_f^\circ$ (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF(g)</td>
<td>-273.3</td>
</tr>
<tr>
<td>HCl(g)</td>
<td>-92.3</td>
</tr>
<tr>
<td>HBr(g)</td>
<td>-56.3</td>
</tr>
<tr>
<td>HI(g)</td>
<td>-26.5</td>
</tr>
</tbody>
</table>

- **Using Standard Molar Enthalpy Values**

  Calculating Enthalpy of Reaction, $\Delta H_f^{\text{rxn}}$

  Calculate $\Delta H$ of reaction?

  In general, when ALL standard molar enthalpies of formation for both reactants and products are known:
Using Standard Molar Enthalpy Values

Problem:
Given that the standard heat of formation, $\Delta H_f^\circ$, of $\text{H}_2\text{O}$ and CO are -242 kJ/mol and -111 kJ/mol respectively calculate enthalpy change for the reaction:
$\text{H}_2\text{O}(g) + \text{C( graphite)} \rightarrow \text{H}_2(g) + \text{CO(g)}$
(product is called “water gas”)

Using Standard Molar Enthalpy Values

Solution:
Do we need to know the $\Delta H_f^\circ$ for C and $\text{H}_2$? Why or Why not? Explain your answer

Using Standard Molar Enthalpy Values

The net reaction that we are trying to calculate its $\Delta H_{\text{rxn}}^\circ$ is:
$\text{H}_2\text{O}(g) + \text{C( graphite)} \rightarrow \text{H}_2(g) + \text{CO(g)}$
Using Standard Molar Enthalpy Values

Solution Cont’d

\[ \Delta H^o_{\text{rxn}} = \Sigma \Delta H^o_f (\text{products}) - \Sigma \Delta H^o_f (\text{reactants}) \]

\[ \text{H}_2\text{O}(g) + \text{C}(\text{graphite}) \rightarrow \text{H}_2(g) + \text{CO}(g) \]

Using Standard Enthalpy Values

Calculate the heat of combustion of methanol, i.e., \( \Delta H^o_{\text{rxn}} \) for

\[ \text{CH}_3\text{OH}(g) + \frac{3}{2} \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(g) \]

\[ \Delta H^o_{\text{rxn}} = \Sigma \Delta H^o_f (\text{prod}) - \Sigma \Delta H^o_f (\text{react}) \]

See table 6.2 page 231 for the necessary information you need (Note: \( \Delta H^o_f \) for CH\(_3\)OH(g) = 201.5 kJ/mol)

Using Standard Enthalpy Values

\[ \text{CH}_3\text{OH}(g) + \frac{3}{2} \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(g) \]

\[ \Delta H^o_{\text{rxn}} = \Sigma \Delta H^o_f (\text{prod}) - \Sigma \Delta H^o_f (\text{react}) \]
Predicting Product- Or Reactant-Favored Reactions

In most cases, product favored reactions have negative $\Delta H^\circ_{\text{rxn}}$ while reactant-favored reactions have positive $\Delta H^\circ_{\text{rxn}}$.

Examples: