CHAPTER 5: ANSWERS TO ASSIGNED PROBLEMS
Hauser- General Chemistry I
revised 10/14/08

CAUTION: Many different units are used in thermochemistry. Report the units! Also report the sign when appropriate!

5.41 Consider the following reaction:

\[ 2 \text{Mg (s)} + \text{O}_2 (g) \rightarrow 2 \text{MgO (s)} \quad \Delta H = -1204 \text{kJ} \]

(a) Is this reaction exothermic or endothermic?

EXOTHERMIC (negative $\Delta H$)

(b) Calculate the amount of heat transferred when 2.4 g of Mg (s) reacts at constant pressure.

\[ 2.4 \text{ g Mg (1 mol Mg / 24.31 g)} \cdot (-1204 \text{ kJ / 2 mol Mg}) = -59 \text{ kJ (2 SF)} \]

COEFFICIENTS MATTER! Note the 2 for Mg.

5.43 When solutions containing silver ions and chloride ions are mixed, silver chloride precipitates:

\[ \text{Ag}^+ (aq) + \text{Cl}^- (aq) \rightarrow \text{AgCl (s)} \quad \Delta H = -65.5 \text{kJ} \]

(a) Calculate $\Delta H$ for production of 0.200 mol of AgCl by this reaction.

0.200 mol AgCl (-65.5 kJ / 1 mol AgCl) = -13.1 kJ

(b) Calculate $\Delta H$ for the production of 2.50 g of AgCl.

\[
\begin{align*}
\text{Ag} &\quad 1 \times 107.87 \\
\text{Cl} &\quad 1 \times 35.45 \\
\text{sum} &\quad 143.32
\end{align*}
\]

\[ 2.50 \text{ g AgCl (1 mole AgCl / 143.32 g)} \cdot (-65.5 \text{ kJ / 1 mole AgCl}) = -1.14 \text{ kJ} \]
5.51 The specific heat of iron metal is 0.450 J/g-K. How many J of heat are necessary to raise the temperature of a 1.05-kg block of iron from 25.0 °C to 88.5 °C?

\[ q = C \cdot m \cdot \Delta T \]

get \( C \) from table or from problem (0.450 J / g-K)

Since \( C \) and \( K \) have the same "size," the \( \Delta T \) does not require conversion to K.

\[ \Delta T = T_f - T_i \]

Note: \((88.5 - 25.0 = 63.5)\) gives 1 dp and 3 SF for these #s

\[ m = 1.05 \text{ kg (1000 g / 1 kg)} = 1050 \text{ g} \]

\[ q = (0.45 \text{ J / g-C}) \cdot (1050 \text{ g}) \cdot (88.5 \text{ °C} - 25.0 \text{ °C}) = 30003.75 \text{ J} = 3.00 \times 10^4 \text{ J (3 SF)} \]

Answer must show size and SF. Note: Question asked for HOW MANY, so a positive answer is appropriate.

5.59 What is the connection between Hess’s law and the fact that \( H \) is a state function?

\( \Delta H \) is path-independent so any # of steps will give the true \( \Delta H \) for the overall process.

5.61 Calculate the enthalpy change for the reaction

\[ \text{P}_4\text{O}_6 (s) + 2 \text{O}_2 (g) \rightarrow \text{P}_4\text{O}_{10} (s) \]

given the following enthalpies of reaction:

\[ \text{EQ 1} \quad \text{P}_4 (s) + 3 \text{O}_2 (g) \rightarrow \text{P}_4\text{O}_6 (s) \quad \Delta H = -1640.1 \text{ kJ} \]

\[ \text{EQ 2} \quad \text{P}_4 (s) + 5 \text{O}_2 (g) \rightarrow \text{P}_4\text{O}_{10} (s) \quad \Delta H = -2940.1 \text{ kJ} \]

Use Hess's Law. Identify a substance unique to only one DATA equation. Focus on handling that substance in each case.

REVERSE EQ 1 to get \( \text{P}_4\text{O}_6 \) on left side; reverse sign

EQ 2 stays same to keep \( \text{P}_4\text{O}_{10} \) on right side.

\[ \text{P}_4\text{O}_6 (s) \rightarrow \text{P}_4 (s) + 3 \text{O}_2 (g) \quad \Delta H = +1640.1 \text{ kJ} \]

\[ \text{P}_4 (s) + 5 \text{O}_2 (g) \rightarrow \text{P}_4\text{O}_{10} (s) \quad \Delta H = -2940.1 \text{ kJ} \]

create "grand" equation and subtract common items

\[ \text{P}_4\text{O}_6 + \text{P}_4 + 5 \text{O}_2 \rightarrow \text{P}_4 + 3 \text{O}_2 + \text{P}_4\text{O}_{10} \]

both \( \text{P}_4 \)'s leave and, after subtracting 3 \( \text{O}_2 \), get 2 \( \text{O}_2 \)'s on left side.

\[ \text{P}_4\text{O}_6 (s) + 2 \text{O}_2 (g) \rightarrow \text{P}_4\text{O}_{10} (s) \]

sum the \( \Delta H \)'s: \(+1640.1 \text{ kJ} -2940.1 \text{ kJ}\) dp rule

ANSWER: \( \Delta H = -1300.0 \text{ kJ} \)
5.63 From the enthalpies of reaction

EQ 1 \[ \text{H}_2 (\text{g}) + \text{F}_2 (\text{g}) \rightarrow 2 \text{HF} (\text{g}) \quad \Delta H = -537 \text{ kJ} \]

EQ 2 \[ \text{C} (\text{s}) + 2 \text{F}_2 (\text{g}) \rightarrow \text{CF}_4 (\text{g}) \quad \Delta H = -680 \text{ kJ} \]

EQ 3 \[ 2 \text{C} (\text{s}) + 2 \text{H}_2 (\text{g}) \rightarrow \text{C}_2\text{H}_4 (\text{g}) \quad \Delta H = +52.3 \text{ kJ} \]

calculate \( \Delta H \) for the reaction of ethylene with \( \text{F}_2 \)

\[ \text{C}_2\text{H}_4 (\text{g}) + 6 \text{F}_2 (\text{g}) \rightarrow 2 \text{CF}_4 (\text{g}) + 4 \text{HF} (\text{g}) \]

Identify a substance unique to only one DATA equation. Focus on handling that substance in each case.

DOUBLE EQ 1 to get 4HF (double \( \Delta H \))
DOUBLE EQ 2 to get 2 CF\(_4\) (double \( \Delta H \))
REVERSE EQ 3 to get \( \text{C}_2\text{H}_4 \) on left side. (reverse sign \( \Delta H \))

\[
\begin{align*}
2\text{H}_2 (\text{g}) + 2\text{F}_2 (\text{g}) & \rightarrow 4 \text{HF} (\text{g}) \quad 2 \Delta H = 2 (-537 \text{ kJ}) = -1074 \text{ kJ} \\
2\text{C} (\text{s}) + 4 \text{F}_2 (\text{g}) & \rightarrow 2\text{CF}_4 (\text{g}) \quad 2 \Delta H = 2 (-680 \text{ kJ}) = -1360 \text{ kJ} \\
\text{C}_2\text{H}_4 (\text{g}) & \rightarrow 2 \text{C} (\text{s}) + 2 \text{H}_2 (\text{g}) \quad - \Delta H = - (+52.3 \text{ kJ}) = -52.3 \text{ kJ}
\end{align*}
\]

sum equations

\[
2\text{H}_2 + 2\text{F}_2 + 2\text{C} + 4 \text{F}_2 + \text{C}_2\text{H}_4 \rightarrow 2\text{CF}_4 + 4 \text{HF} + 2\text{C} + 2\text{H}_2
\]

combine \( \text{F}_2 \)

\[
\text{C}_2\text{H}_4 + 6 \text{F}_2 \rightarrow 2\text{CF}_4 + 4 \text{HF}
\]

sum the adjusted \( \Delta H \) values:

\[
-1074 \text{ kJ} \\
-1360 \text{ kJ} \\
-52.3 \text{ kJ}
\]

sum = - 2486 kJ

(Prof H. says to use dp rules since we multiply by counting #s then add: so no dp for this value here)
The following is known as the thermite reaction

\[
2 \text{Al (s)} + \text{Fe}_2\text{O}_3 \text{(s)} \rightarrow \text{Al}_2\text{O}_3 \text{(s)} + 2 \text{Fe (s)}
\]

This highly exothermic reaction is used for welding massive units, such as propellers for large ships. Using standard enthalpies of formation in Appendix C, calculate \( \Delta H^\circ \) for this reaction.

Use Enthalpy of Formation data and equation:
Note the standard state symbol and "f". DO NOT USE HESS'S LAW!

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

\[
[\Delta H^\circ_f \text{Al}_2\text{O}_3 \text{(s)} + 2 \Delta H^\circ_f \text{Fe (s)}] - [2 \Delta H^\circ_f \text{Al (s)} + \Delta H^\circ_f \text{Fe}_2\text{O}_3 \text{(s)}]
\]

\[
[-1669.8 \text{kJ} + 2 (0)] - [2 (0) + -822.16 \text{kJ}]
\]

\[-1669.8 \text{kJ} - [-822.16 \text{kJ}]\]

\[
\Delta H^\circ_{\text{rxn}} = -847.64 \text{ reported to 1 dp based on data } = -847.6 \text{ kJ}
\]

Using values from Appendix C, calculate the standard enthalpy change for the following reaction:

\( \text{(c) } \text{N}_2\text{O}_4 \text{(g)} + 4 \text{H}_2 \text{(g)} \rightarrow \text{N}_2 \text{(g)} + 4 \text{H}_2\text{O (g)} \) WATCH PHASES!

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

\[
[\Delta H^\circ_f \text{N}_2 \text{(g)} + 4 \Delta H^\circ_f \text{H}_2\text{O (g)}] - [\Delta H^\circ_f \text{N}_2\text{O}_4 \text{(g)} + 4 \Delta H^\circ_f \text{H}_2 \text{(g)}]
\]

\[
[0 + 4 (-241.82 \text{kJ})] - [9.66 \text{kJ} + 4 (0)] \quad \text{DO NOT PRE-ROUND!}
\]

\[-967.28 \text{kJ} - [9.66 \text{kJ}]\]

\[
\Delta H^\circ_{\text{rxn}} = -976.94 \text{ kJ (2 dp based on data)}
\]