1. Calculate the standard enthalpy change, \( \Delta H^\circ \), for the formation of 1 mol of strontium carbonate (the material that gives the red color in fireworks) from its elements. \((-1220 \text{ KJ})\)

\[
\text{Sr} (s) + \text{C(graphite)} + \frac{3}{2} \text{O}_2(g) \rightarrow \text{SrCO}_3(s)
\]

The information available is:

(1) \( \text{Sr} (s) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{SrO} (s) \) \( \Delta H^\circ = -592 \text{ kJ} \)

(2) \( \text{SrO} (s) + \text{CO}_2 (g) \rightarrow \text{SrCO}_3 (s) \) \( \Delta H^\circ = -234 \text{ kJ} \)

(3) \( \text{C(graphite)} + \text{O}_2 (g) \rightarrow \text{CO}_2 (g) \) \( \Delta H^\circ = -394 \text{ kJ} \)

2. The combination of coke and steam produces a mixture called coal gas, which can be used as a fuel or as a starting material for other reactions. If we assume coke can be represented by graphite, the equation for the production of coal gas is \((+15.3 \text{ kJ})\)

\[
2 \text{C} (s) + 2 \text{H}_2\text{O} (g) \rightarrow \text{CH}_4 (g) + \text{CO}_2(g)
\]

Determine the standard enthalpy change for this reaction from the following standard enthalpies of reaction:

(1) \( \text{C}(s) + \text{H}_2\text{O} (g) \rightarrow \text{CO} (g) + \text{H}_2 (g) \) \( \Delta H^\circ = 131.3 \text{ kJ} \)

(2) \( \text{CO} (g) + \text{H}_2\text{O} (g) \rightarrow \text{CO}_2 (g) + \text{H}_2 (g) \) \( \Delta H^\circ = -41.2 \text{ kJ} \)

(3) \( \text{CH}_4 (g) + \text{H}_2\text{O} (g) \rightarrow 3 \text{H}_2 (g) + \text{CO} (g) \) \( \Delta H^\circ = 206.1 \text{ kJ} \)

The next one is challenging!

3. One reaction involved in the conversion of iron ore to the metal is \((-11 \text{ kJ})\)

\[
\text{FeO} (s) + \text{CO} (g) \rightarrow \text{Fe} (s) + \text{CO}_2 (g)
\]

Calculate the standard enthalpy change for this reaction from these reactions of iron oxides with CO:

(1) \( 3\text{Fe}_2\text{O}_3 (s) + \text{CO} (g) \rightarrow 2 \text{Fe}_3\text{O}_4 (s) + \text{CO}_2 (g) \) \( \Delta H^\circ = -47 \text{ kJ} \)

(2) \( \text{Fe}_2\text{O}_3 (s) + 3 \text{CO} (g) \rightarrow 2 \text{Fe} (s) + 3 \text{CO}_2 (g) \) \( \Delta H^\circ = -25 \text{ kJ} \)

(3) \( \text{Fe}_3\text{O}_4 (s) + \text{CO} (g) \rightarrow 3 \text{FeO} (s) + \text{CO}_2 (g) \) \( \Delta H^\circ = 19 \text{ kJ} \)
[4] Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:

\[ \text{PCl}_5(g) \rightarrow \text{PCl}_3(g) + \text{O}_2(g) \]

\[ \text{P}_4(s) + 6\text{Cl}_2(g) \rightarrow 4\text{PCl}_3(g) \quad \Delta H = -2439 \text{ kJ} \]

\[ 4\text{PCl}_3(g) \rightarrow \text{P}_4(s) + 10\text{Cl}_2(g) \quad \Delta H = 3438 \text{ kJ} \]

Answer = 249.8 kJ

[5] Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:

\[ 2\text{CO}_2(g) + \text{H}_2\text{O}(g) \rightarrow \text{C}_2\text{H}_2(g) + \frac{5}{2}\text{O}_2(g) \]

\[ \text{C}_2\text{H}_2(g) + 2\text{H}_2(g) \rightarrow \text{C}_2\text{H}_6(g) \quad \Delta H = -94.5 \text{ kJ} \]

\[ \text{H}_2\text{O}(g) \rightarrow \text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \quad \Delta H = 71.2 \text{ kJ} \]

\[ \text{C}_2\text{H}_6(g) + \frac{7}{2}\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(g) \quad \Delta H = -283 \text{ kJ} \]

Answer = 235 kJ

[6] Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:

\[ \text{N}_2\text{H}_4(l) + \text{H}_2(g) \rightarrow 2\text{NH}_3(g) \]

\[ \text{N}_2\text{H}_4(l) + \text{CH}_4\text{O}(l) \rightarrow \text{CH}_2\text{O}(g) + \text{N}_2(g) + 3\text{H}_2(g) \quad \Delta H = -37 \text{ kJ} \]

\[ \text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g) \quad \Delta H = -46 \text{ kJ} \]

\[ \text{CH}_4\text{O}(l) \rightarrow \text{CH}_2\text{O}(g) + \text{H}_2(g) \quad \Delta H = -65 \text{ kJ} \]

Answer = -18 kJ

[7] Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:

\[ \text{H}_2\text{SO}_4(l) \rightarrow \text{SO}_3(g) + \text{H}_2\text{O}(g) \]

\[ \text{H}_2\text{S}(g) + 2\text{O}_2(g) \rightarrow \text{H}_2\text{SO}_4(l) \quad \Delta H = -235.5 \text{ kJ} \]

\[ \text{H}_2\text{S}(g) + 2\text{O}_2(g) \rightarrow \text{SO}_3(g) + \text{H}_2\text{O}(l) \quad \Delta H = -207 \text{ kJ} \]

\[ \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{O}(g) \quad \Delta H = 44 \text{ kJ} \]

Answer = 72 kJ

[8] Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:

\[ 2\text{C}_2\text{H}_6\text{O}(l) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{C}_2\text{H}_6\text{O}(l) + \text{O}_2(g) \]

\[ \text{C}_2\text{H}_6\text{O}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l) \quad \Delta H = -685.5 \text{ kJ} \]

\[ \text{C}_2\text{H}_6\text{O}(l) + \frac{5}{2}\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 2\text{H}_2\text{O}(l) \quad \Delta H = -583.5 \text{ kJ} \]

Answer = 204.0 kJ

[9] Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:

\[ \text{N}_2(g) + 2\text{O}_2(g) \rightarrow 2\text{NO}_2(g) \]

\[ \text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g) \quad \Delta H = -115 \text{ kJ} \]

\[ 2\text{NH}_3(g) + 4\text{H}_2\text{O}(l) \rightarrow 2\text{NO}_2(g) + 7\text{H}_2(g) \quad \Delta H = -142.5 \text{ kJ} \]

\[ \text{H}_2\text{O}(l) \rightarrow \text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \quad \Delta H = -43.7 \text{ kJ} \]

Answer = -83 kJ

[10] Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:

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

\[ \text{H}_2\text{O}(l) \rightarrow \text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \quad \Delta H = 643 \text{ kJ} \]

\[ \text{C}_2\text{H}_6(g) \rightarrow 2\text{C}(s) + 3\text{H}_2(g) \quad \Delta H = 190.6 \text{ kJ} \]

\[ 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l) \rightarrow \text{C}_2\text{H}_6(g) + \frac{7}{2}\text{O}_2(g) \quad \Delta H = 3511.1 \text{ kJ} \]

Answer = 886 kJ
These problems involve using heat of formation values that are found in the appendix of your textbook.

What is the enthalpy of the following reactions? Use equation from Equation Sheet – [Products minus reactants]

(a) \( \text{SiF}_4(g) \rightarrow \text{Si}(s) + 2\text{F}_2(g) \)
(b) \( \text{SiF}_4(g) \rightarrow \text{Si}(g) + 2\text{F}_2(g) \)
(c) \( \text{SO}_3(g) + \text{H}_2\text{O}(g) \rightarrow \text{H}_2\text{SO}_4(\text{aq}) \)
(d) \( 3\text{K}_2\text{O}_2(\text{s}) + 3\text{H}_2\text{O}(\text{l}) \rightarrow 6\text{KOH}(\text{aq}) + \text{O}_3(\text{g}) \)
(e) \( \text{Fe}_3\text{O}_4(\text{s}) + 8\text{HCl}(\text{g}) \rightarrow 2\text{FeCl}_3(\text{s}) + \text{FeCl}_2(\text{s}) + 4\text{H}_2\text{O}(\text{g}) \)

\( \text{SiF}_4 \) - \( \Delta H_f = -1615.0 \text{ KJ/mol} \)
\( \text{FeCl}_2 \) - \( \Delta H_f = -341.8 \text{ KJ/mol} \)
\( \text{FeCl}_3 \) - \( \Delta H_f = -399.5 \text{ KJ/mol} \)
\( \text{Fe}_3\text{O}_4 \) - \( \Delta H_f = -1118.4 \text{ KJ/mol} \)
\( \text{SO}_3 \) - \( \Delta H_f = -454.5 \text{ KJ/mol} \)
\( \text{Si}(g) \) - \( \Delta H_f = 450 \text{ KJ/mol} \)
Directions: use your textbooks appendix to calculate the standard enthalpy change for each of the following reactions using heats of formation. Must show all work to receive credit. These are from another textbook, $\Delta H_f$ values may be a bit different.

\[(5.71)\]

\[\text{[1]} \quad \text{SO}_2(g) + \text{O}_2(g) \rightarrow \text{SO}_3(g) \quad (\Delta H_f = -196.6 \text{ kJ})\]

\[\text{[2]} \quad \text{Mg(OH)}_2(s) \rightarrow \text{MgO}(s) + \text{H}_2\text{O}(l) \quad (\Delta H_f = 37.1 \text{ kJ})\]

\[\text{[3]} \quad \text{N}_2\text{O}_4(g) + \text{H}_2(g) \rightarrow \text{N}_2(g) + \text{H}_2\text{O}(g) \quad (\Delta H_f = -976.94 \text{ kJ})\]

\[\text{[4]} \quad \text{SiCl}_4(l) + \text{H}_2\text{O}(l) \rightarrow \text{SiO}_2(s) + \text{HCl}(g) \quad (\Delta H_f = -68.3 \text{ kJ})\]

\[\text{[5]} \quad \text{HBr}(g) + \text{O}_2(g) \rightarrow \text{H}_2\text{O}(l) + \text{Br}_2(l) \quad (\Delta H_f = -426.74 \text{ kJ})\]

\[\text{[6]} \quad \text{NaOH}(s) + \text{SO}_3(g) \rightarrow \text{Na}_2\text{SO}_4(s) + \text{H}_2\text{O}(g) \quad (\Delta H_f = -382.5 \text{ kJ})\]

\[\text{[7]} \quad \text{CH}_4(g) + \text{Cl}_2(g) \rightarrow \text{CCl}_4(l) + \text{HCl}(g) \quad (\Delta H_f = -433.7 \text{ kJ})\]

\[\text{[8]} \quad \text{Fe}_2\text{O}_3(s) + \text{HCl}(g) \rightarrow \text{FeCl}_3(s) + \text{H}_2\text{O}(g) \quad (\Delta H_f = -150 \text{ kJ})\]
1. a) Calculate the amount of heat transferred when 10.00 g of N₂O(g) is formed by the following reaction:  
\[ 2\text{N}_2(g) + \text{O}_2(g) \rightarrow 2\text{N}_2\text{O}(g) \quad \Delta H_{\text{rxn}} = +163.2 \text{ kJ} \]

b) Draw an energy diagram for this process.

2. Predict the value for \( \Delta H^\circ \) for the following scenarios: and explain why
   a) Br₂(g)
   b) Br₂(l)
   c) I₂(g)
   d) I₂(s)

3. Calculate the \( \Delta H_{\text{rxn}} \) for the following reaction:
   \[ \text{C}_2\text{H}_4(g) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 2\text{H}_2\text{O}(l) \]
   \[ \Delta H^\circ \text{C}_2\text{H}_4(g) = 226.6 \text{ kJ/mol} \]
   \[ \Delta H^\circ \text{CO}_2(g) = -393.5 \text{ kJ/mol} \]
   \[ \Delta H^\circ \text{H}_2\text{O}(l) = -285.8 \text{ kJ/mol} \]

4. A 5.00 g sample of liquid water at 25.0°C is heated by the addition of 84.0 J of energy. The final temperature of the water is \_________\°C. The specific heat capacity of the liquid is 4.18 J/g°C.  \[ \text{E, work must prove that} \]
   a) -21  b) 4.02  c) 25.2  d) 95.2  e) 29.0

5. This problem was taken directly from the 1995 AP chem. exam.
   Propane is a hydrocarbon that is commonly used as a fuel for cooking. Propane’s formula is \( \text{C}_3\text{H}_8 \).
   a) Write a balanced equation for the complete combustion of propane gas.
   b) Calculate the volume of air at 30°C and 1.00 atm that is needed to burn completely 10.0 g of propane. Assume that air is 21.0% O₂ by volume.  \[ 134 \text{ L of air} \]
   c) The heat of combustion (\( \Delta H^\circ_{\text{combustion}} \)) is -2,220.1 kJ/mol. Calculate the heat of formation, \( \Delta H^\circ_f \), of propane given that \( \Delta H_f \) of H₂O(l) is -285.3 kJ/mol and \( \Delta H^\circ_f \) of CO₂(g) is -393.5 kJ/mol.  \[ -101.6 \text{ kJ/mol} \]
   d) Assuming that all of the heat evolved burning 10.0 g propane is transferred to 8.00 kg of water (specific heat = 4.184 J/g°C), calculate the increase in temperature of the water.  \[ 15.0 \text{ C is change in } T \]
7. Answer the following questions that relate to the chemistry of nitrogen.

(a) Two nitrogen atoms combine to form a nitrogen molecule, as represented by the following equation.

\[ 2 \text{N(g)} \rightarrow \text{N}_2(g) \]

Using the table of average bond energies below, determine the enthalpy change, \( \Delta H \), for the reaction.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Average Bond Energy (kJ mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (=) N</td>
<td>160</td>
</tr>
<tr>
<td>N (=) N</td>
<td>420</td>
</tr>
<tr>
<td>N (=) N</td>
<td>950</td>
</tr>
</tbody>
</table>

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3. In another experiment, liquid heptane, \( \text{C}_7\text{H}_{16}(l) \), is completely combusted to produce \( \text{CO}_2(g) \) and \( \text{H}_2\text{O}(l) \), as represented by the following equation.

\[ \text{C}_7\text{H}_{16}(l) + 11 \text{O}_2(g) \rightarrow 7 \text{CO}_2(g) + 8 \text{H}_2\text{O}(l) \]

The heat of combustion, \( \Delta H_{\text{comb}}^\circ \), for one mole of \( \text{C}_7\text{H}_{16}(l) \) is \(-4.85 \times 10^3\) kJ.

(c) Using the information in the table below, calculate the value of \( \Delta H_f^\circ \) for \( \text{C}_7\text{H}_{16}(l) \) in kJ mol\(^{-1}\).

<table>
<thead>
<tr>
<th>Compound</th>
<th>( \Delta H_f^\circ ) (kJ mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{CO}_2(g) )</td>
<td>-393.5</td>
</tr>
<tr>
<td>( \text{H}_2\text{O}(l) )</td>
<td>-285.8</td>
</tr>
</tbody>
</table>

(d) A 0.0108 mol sample of \( \text{C}_7\text{H}_{16}(l) \) is combusted in a bomb calorimeter.

(i) Calculate the amount of heat released to the calorimeter.

(ii) Given that the total heat capacity of the calorimeter is 9.273 kJ °C\(^{-1}\), calculate the temperature change of the calorimeter.

\[ \text{CO(g)} + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CO}_2(g) \]

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2. The combustion of carbon monoxide is represented by the equation above.

(a) Determine the value of the standard enthalpy change, \( \Delta H_{\text{rxn}}^\circ \), for the combustion of \( \text{CO(g)} \) at 298 K using the following information.

\[ \text{C(s)} + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CO(g)} \quad \Delta H_{298}^\circ = -110.5 \text{ kJ mol}^{-1} \]

\[ \text{C(s)} + \text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H_{298}^\circ = -393.5 \text{ kJ mol}^{-1} \]
7. Answer the following questions about thermodynamics. **Skip part (d) for now.**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Combustion Reaction</th>
<th>Enthalpy of Combustion, $\Delta H_{\text{comb}}^\circ$, at 298 K (kJ mol$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$(g)</td>
<td>H$_2$(g) + $\frac{1}{2}$ O$_2$(g) $\rightarrow$ H$_2$O(l)</td>
<td>−290</td>
</tr>
<tr>
<td>C(s)</td>
<td>C(s) + O$_2$(g) $\rightarrow$ CO$_2$(g)</td>
<td>−390</td>
</tr>
<tr>
<td>CH$_3$OH(l)</td>
<td></td>
<td>−730</td>
</tr>
</tbody>
</table>

(a) In the empty box in the table above, write a balanced chemical equation for the complete combustion of one mole of CH$_3$OH(l). Assume products are in their standard states at 298 K. Coefficients do not need to be whole numbers.

(b) On the basis of your answer to part (a) and the information in the table, determine the enthalpy change for the reaction C(s) + H$_2$(g) + H$_2$O(l) $\rightarrow$ CH$_3$OH(l).

(c) Write the balanced chemical equation that shows the reaction that is used to determine the enthalpy of formation for one mole of CH$_3$OH(l).

(d) Predict the sign of $\Delta S^\circ$ for the combustion of H$_2$(g). Explain your reasoning.

(e) On the basis of bond energies, explain why the combustion of H$_2$(g) is exothermic.