Chapter 10 Worksheet 2

1. For the process \( A \rightarrow B \), \( \Delta H^\circ = 171 \text{ kJ/mol} \) and \( \Delta S^\circ = 161 \text{ J/K-mol} \). Assuming that \( \Delta H^\circ \) and \( \Delta S^\circ \) do not change with temperature, at what temperature in °C does the reaction go from being nonspontaneous to spontaneous?

2. What is the standard free energy change, \( \Delta G^\circ \), in kJ, for the following reaction at 298K?

\[
\text{C}_2\text{H}_5\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(g)
\]

<table>
<thead>
<tr>
<th>Compound</th>
<th>( \Delta G^\circ ) (kJ mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{C}_2\text{H}_5\text{OH}(l) )</td>
<td>-175</td>
</tr>
<tr>
<td>( \text{CO}_2(g) )</td>
<td>-394</td>
</tr>
<tr>
<td>( \text{H}_2\text{O}(g) )</td>
<td>-229</td>
</tr>
<tr>
<td>( \text{O}_2(g) )</td>
<td>0</td>
</tr>
</tbody>
</table>

2. A reaction has a standard enthalpy change, \( \Delta H \), of +10.00 kJ mol\(^{-1}\) at 298 K. The standard entropy change, \( \Delta S \), for the same reaction is +10.00 J K\(^{-1}\) mol\(^{-1}\). What is the value of \( \Delta G \) for the reaction in kJ mol\(^{-1}\)?
3. The equation for the decomposition of calcium carbonate is given below.

\[ \text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g}) \]

At 500 K, \( \Delta H \) for this reaction is +177 kJ mol\(^{-1} \) and \( \Delta S \) is 161 J K\(^{-1} \) mol\(^{-1} \)

(a) Explain why \( \Delta H \) for the reaction above cannot be described as \( \Delta H^0 \)

(b) State the meaning of the term \( \Delta S \).

(c) Calculate the value of \( \Delta G \) at 500 K and determine, giving a reason, whether or not the reaction will be spontaneous.

4. Consider the following reaction:

\[ \text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad \Delta H = -92.4 \text{ kJ mol}^{-1} \]

(i) The absolute entropy values, \( S \), at 238 K for \( \text{N}_2(\text{g}) \), \( \text{H}_2(\text{g}) \) and \( \text{NH}_3(\text{g}) \) are 192, 131 and 193 J K\(^{-1} \) mol\(^{-1} \) respectively. Calculate \( \Delta S^0 \) for the reaction and explain the sign of \( \Delta S^0 \).

(ii) Calculate \( \Delta G^0 \) for the reaction at 238 K. State and explain whether the reaction is spontaneous.
5. Hex-1-ene gas, \( \text{C}_6\text{H}_{12} \), burns in oxygen to produce carbon dioxide and water vapour.

(a) Write an equation to represent this reaction.

(b) Use the data below to calculate the values of \( \Delta H_c^\theta \) and \( \Delta S^\theta \) for the combustion of hex-1-ene.

<table>
<thead>
<tr>
<th>Substance</th>
<th>( \text{O}_2\text{(g)} )</th>
<th>( \text{C}<em>6\text{H}</em>{12}\text{(g)} )</th>
<th>( \text{CO}_2\text{(g)} )</th>
<th>( \text{H}_2\text{O}\text{(l)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard enthalpy of formation, ( \Delta H_f^\theta ) (kJ mol(^{-1}))</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Entropy, ( S^\theta ) (J K(^{-1}) mol(^{-1}))</td>
<td>205</td>
<td>385</td>
<td>214</td>
<td>189</td>
</tr>
</tbody>
</table>

(i) Value of \( \Delta H_c^\theta \)

(ii) Value of \( \Delta S^\theta \)

(c) Calculate the standard free energy change for the combustion of hex-1-ene.

(d) State and explain whether or not the combustion of hex-1-ene is spontaneous at 25°C.