1. Which of the following has the larger standard entropy ($S^\circ$) at 25°C, Ca(s) or Pb(s)? [2 pts]

Pb(s). With both substances being solids, the larger one has greater complexity and hence a larger standard entropy.

2. Predict whether the entropy change is positive (more disorder) or negative (more order) for the following reactions. [3 pts]

   a) $\text{C}_6\text{H}_12\text{O}_6 (s) \xrightarrow{\text{H}_2\text{O}} \text{C}_6\text{H}_12\text{O}_6 (aq)$  positive

   b) $\text{N}_2 (g)$ (at 80°C) $\rightarrow$ $\text{N}_2 (g)$ (at 20°C)  negative

   c) $\text{C}_2\text{H}_5\text{OH} (l) \rightarrow \text{C}_2\text{H}_5\text{OH} (s)$  negative

3. True or false statements.

   a) In an exothermic reaction heat is transferred from the system to the surroundings. [2 pts]

   TRUE

   b) The standard free energy of formation, $\Delta G^o_f$, of H$_2$O(l) is zero. [2 pts]

   FALSE, $\Delta G^o_f$ is zero for an element in its standard state.

4. A $-$ sign for $\Delta G$ indicates a spontaneous process, and a $+$ sign for $\Delta S_{uni}$ indicates a spontaneous process. [2 pts]

5. a) Calculate the $\Delta H^o_{\text{rxn}}$ for the following reaction: [3 pts]

\[
2 \text{Ca (s)} + \text{O}_2 (g) \rightarrow 2 \text{CaO (s)}
\]

$\Delta H^o_f [\text{CaO(s)}] = -635.6 \text{ kJ/mol}$  $\Delta H^o_f [\text{Ca}^{2+} (aq)] = -542.96 \text{ kJ/mol}$

Homework Problem

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

\[
\Delta H^o_{\text{rxn}} = (2)(-635.6 \text{ kJ/mol}) - [0 + 0]
\]

\[
\Delta H^o_{\text{rxn}} = -1271.2 \text{ kJ/mol}
\]
b) How much heat is evolved when 8.5 moles of Ca(s) are reacted with excess oxygen. [3 pts]

Homework Problem

\[
\frac{1271.2 \text{ kJ}}{2 \text{ mol Ca}} \times 8.5 \text{ mol Ca} = 5402.6 \text{ kJ}
\]

6. Hydrocarbons containing halogens are very useful molecules in synthetic chemistry. Calculate \( S^\circ \) for the reaction product (CH\(_2\)ClCH\(_2\)Cl) in the equation shown below if \( \Delta S^\circ_{\text{rxn}} \) is \(-134.0 \text{ J K}^{-1}\). [3 pts]

Homework Problem

\[
\text{C}_2\text{H}_4(g) + \text{Cl}_2(g) \rightarrow \text{CH}_2\text{ClCH}_2\text{Cl}(g)
\]

<table>
<thead>
<tr>
<th>( S^\circ \text{ (J K}^{-1} \text{ mol}^{-1}) )</th>
<th>( S^\circ \text{ (J K}^{-1} \text{ mol}^{-1}) )</th>
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<tbody>
<tr>
<td>( \text{C}_2\text{H}_4(g) )</td>
<td>219</td>
</tr>
<tr>
<td>( \text{Cl}_2(g) )</td>
<td>223</td>
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\( \Delta S^\circ_{\text{rxn}} = \Sigma nS^\circ \text{(products)} - \Sigma nS^\circ \text{(reactants)} \)

\( -134.0 \text{ J/K} = S^\circ \text{(CH}_2\text{ClCH}_2\text{Cl)} - [(1)(219 \text{ J/K mol}) + (1)(223 \text{ J/K mol})] \)

\( S^\circ \text{(CH}_2\text{ClCH}_2\text{Cl)} = 308 \text{ J/K mol} \)

7. What is the \( \Delta G \) of a reaction at 101.0 K with a \( \Delta H \) of 250.0 kJ and a \( \Delta S \) of 270.0 J/K? Input your answer in units of kJ. [4 pts] Homework Problem

a)  

\[
\Delta G = \Delta H - T\Delta S
\]

\[
\Delta G = 250.0 \text{ kJ} - (101.0 \text{ K})(270.0 \text{ J/K}) \times \frac{1 \text{ kJ}}{1000 \text{ J}}
\]

\( \Delta G = 222.7 \text{ kJ} \)

b) Is the reaction spontaneous? Yes or No? [2 pts]

No, positive \( \Delta G \) indicates that the reaction is nonspontaneous in the forward direction.

8. Which of the following always corresponds to a nonspontaneous reaction in the forward direction? [3 pts]

a) \( \Delta H > 0, \Delta S > 0 \)  

b) \( \Delta H < 0, \Delta S > 0 \)  

c) \( \Delta H < 0, \Delta S < 0 \)  

d) \( \Delta H > 0, \Delta S < 0 \)  

e) none of these

9. Predict the signs of \( \Delta H \), \( \Delta S \), and \( \Delta G \) for the following phase change at 120°C. [3 pts]

Na (s) \( \rightarrow \) Na (l)  

melting point = 97.6°C

\( \Delta H \)  

\( \Delta S \)  

\( \Delta G \)  

We are above the melting point for sodium, so the reaction is spontaneous (\( \Delta G \) is negative). To melt a solid, heat must be supplied, so \( \Delta H \) is positive. A liquid is more disordered than a solid, so \( \Delta S \) is positive.