1. True or false statements.
   
a) The standard free energy of formation, $\Delta G^{\circ}$, of H$_2$O(l) is zero. [2 pts]  
   
   **FALSE**, $\Delta G^{\circ}$ is zero for an **element** in its standard state.

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

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

3. Which of the following has the **larger** standard entropy ($S^\circ$) at 25°C, Na(s) or I$_2$(s)? [2 pts]
   
   I$_2$(s). With both substances being solids, the larger one has greater complexity and hence a larger standard entropy.

4. Predict whether the entropy change is **positive** (more disorder) or **negative** (more order) for the following reactions. [3 pts]
   
a) C$_2$H$_5$OH (l) $\rightarrow$ C$_2$H$_5$OH (s)  
   **negative**

b) C$_6$H$_{12}$O$_6$ (s) $\rightarrow$ C$_6$H$_{12}$O$_6$ (aq)  
   **positive**

c) N$_2$ (g) (at 80°C) $\rightarrow$ N$_2$ (g) (at 20°C)  
   **negative**

5. 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 $\Delta S_{\text{rxn}}^{\circ}$ is $-134.0$ J K$^{-1}$. [3 pts]  

   **Homework Problem**

   \[
   \begin{array}{c|c|c}
   \text{species} & S^\circ \text{ (J K}^{-1} \text{ mol}^{-1}) & \\
   \hline
   \text{C}_2\text{H}_4(g) & 219 & \\
   \text{Cl}_2(g) & 223 & \\
   \hline
   \end{array}
   \]

   \[
   \Delta S_{\text{rxn}}^{\circ} = \Sigma n S^\circ \text{(products)} - \Sigma n S^\circ \text{(reactants)}
   \]

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

   \[
   S^\circ(\text{CH}_2\text{ClCH}_2\text{Cl}) = 308 \text{ J/K mol}
   \]
6. a) Calculate the $\Delta H^\circ_{\text{rxn}}$ for the following reaction:

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

$\Delta H^\circ_1 [\text{CaO (s)}] = -635.6 \text{ kJ/mol}$

$\Delta H^\circ_2 [\text{Ca}^{2+} (aq)] = -542.96 \text{ kJ/mol}$

**Homework Problem**

$$\Delta H^\circ_{\text{rxn}} = \Sigma n\Delta H^\circ_1 (\text{products}) - \Sigma n\Delta H^\circ_2 (\text{reactants})$$

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

$$\Delta H^\circ_{\text{rxn}} = -1271.2 \text{ kJ/mol}$$

b) How much heat is evolved when 5.5 moles of Ca(s) are reacted with excess oxygen. [3 pts]

**Homework Problem**

$$\frac{1271.2 \text{ kJ}}{2 \text{ mol Ca}} \times 5.5 \text{ mol Ca} = 3495.8 \text{ kJ}$$

7. What is the $\Delta G$ of a reaction at 81.0 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) $\Delta G = \Delta H - T\Delta S$

$$\Delta G = 250.0 \text{ kJ} - (81.0 \text{ K})(270.0 \text{ J/K}) \times \frac{1 \text{ kJ}}{1000 \text{ J}}$$

$$\Delta G = 228.1 \text{ kJ}$$

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 *nons spontaneous* 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 $\Delta G$, $\Delta H$, and $\Delta S$ for the following phase change at 120°C. [3 pts]

Na (s) $\rightarrow$ Na (l)  melting point = 97.6°C

$\Delta G = \Delta H + \Delta S$

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.