Work Session 20: Entropy and Free Energy

1. Explain what is meant by ΔS_{sys}, ΔS_{surr}, and ΔS_{univ}. What relationship among these terms is required for a spontaneous reaction. What law is this? State the law in formal terms.

2. Predict the sign of $\Delta S°$ for the following. Give a brief explanation:
   $CO_2(s) \rightarrow CO_2(g)$

   $2K(s) + F_2(g) \rightarrow 2K_2F(s)$

   $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$

3. Predict which of each of the following pairs has more entropy. Give a brief explanation.
   $O_2(g)$ or $O_3(g)$

   Na(s) or K(s)

   $C_3H_7OH(l)$ or C_2H_5OH (l)

4. Use values in the appendix of the textbook to calculate the $\Delta S°$ for the reaction:
   $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

5. Explain why a reaction with $\Delta H°<0$ and $\Delta S°>0$ is spontaneous at all temperatures.

   Explain why a reaction with $\Delta H°>0$ and $\Delta S°<0$ is not spontaneous at any temperature.

   Explain why a reaction with $\Delta H°>0$ and $\Delta S°>0$ becomes spontaneous at high temperatures.

   Explain why a reaction with $\Delta H°<0$ and $\Delta S°<0$ is spontaneous only at low temperatures.

6 For the reaction: $2\ Fe_2O_3(s) + 3\ C(graphite) \rightarrow 4\ Fe(s) + 3\ CO_2(g)$
   Calculate $\Delta H°$ and $\Delta S°$ using appendix B.

   Use these values to calculate $\Delta G°$ at 298K and at 1000K.

   What does the algebraic sign on $\Delta G°$ at each temperature say about the spontaneity of the reaction? What causes the change?

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7. For the reaction in question 6, at what T would the $\Delta G°$ become zero?

   This temperature is called the crossover temperature. Explain why.

8. For the reaction in question 6, explain what the algebraic sign on the terms $\Delta H°$ and $\Delta S°$ says about the tendency of the reaction to go to the right or to the left as influenced by that term.

9. What is the value for K_{eq} at 298K for the reaction in question 6?

10. K_{eq} for a reaction is 5.6×10^8 at 25°C. What is $\Delta G°$ at that temperature?

11. For this question, use the equation: $\Delta G = \Delta H° - T\Delta S° + RT \ln Q$, where $R = 8.31 J \cdot mol^{-1} \cdot K^{-1}$.

    For the reaction in question 6, show the mass action setup for Q

    At T = 800K, what would the value of ΔG be if the P of CO_2 = 0.1 atm? If the P of CO_2 = 10 atm? (Note that $Q = P^3$ of CO_2)

12. If a gas is produced in a reaction, there is a larger entropy change if the pressure is low than if the pressure is high. Why is that?