SURREY SUPPLEMENT: THERMODYNAMICS

1) For oxygen difluoride, $OF_2(g)$, the Gibbs free energy of formation is +40.6 kJ/mol.
   a) Is the preparation of $OF_2(g)$ from its elements at 25°C a spontaneous process? **[No]**
   b) For ozone, $O_3(g)$, the Gibbs free energy of formation is +163.43 kJ/mol. Is it theoretically possible to prepare $OF_2(g)$ at 25°C by the reaction:

      $3F_2(g) + O_3(g) \longrightarrow 3OF_2(g)$
      [Yes]

2) The standard enthalpy of formation of $CS_2(l)$ is +87.9 kJ/mol. The absolute molar entropy of C(graphite) is 5.69 J/mol-K, of S(rhombic) is 31.9 J/mol-K, and of $CS_2(l)$ is 151.0 J/mol-K. Calculate the standard Gibbs free energy of formation of $CS_2(l)$. **[63.7 kJ/mol]**

3) Look up the necessary data in the appendices of your textbook or online to determine the $K_{p,298}$ value for the reaction:

   $SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$
   [1.45 x 10^6]

4) For the reaction:

   $NH_4CO_2NH_2(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$

   $\Delta G°_{298}$ = +31.00 kJ and $\Delta H°_{298}$ = +159.95 kJ

   a) Calculate the value of K_p at 298 K **[3.67 x 10^{-6}]**
   b) Calculate the pressure of NH_3 and CO_2 at equilibrium at 298 K **[P_{CO2} = 9.7 x 10^{-3} bar and P_{NH3} = 1.94 x 10^{-2} bar]**
   c) Calculate the value of K_p at 500 K **[7.8 x 10^{-5}]**
   d) Calculate the absolute molar entropy of NH_3 at 298 K given the following absolute molar entropies: $CO_2(g)$ = 213.60 J/mol·K and $NH_4CO_2NH_2(s)$ = 166.10 J/mol·K **[192.6 J/mol·K]**

5) Given the following standard electrode potentials and Gibbs free energies of formation at 298 K:

   $Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$ $\mathcal{E}°$ = +0.337 V
   $Cu^+(aq) + e^- \rightleftharpoons Cu(s)$ $\mathcal{E}°$ = +0.521 V
   $\Delta G°_{f,298}(Cu(OH)_2(s))$ = -356 kJ/mol

   a) Calculate $\mathcal{E}°$ for the reaction: $Cu^{2+}(aq) + e^- \rightleftharpoons Cu^+(aq)$ **[0.152 V]**
   b) Calculate $\Delta G°$ and K_c at 298 K for the reaction: $2Cu^+(aq) \rightleftharpoons Cu^{2+}(aq) + Cu(s)$ **[0.184 V]**
   c) Given the K_{sp} of $Cu(OH)_2$ = 1.6 x 10^{-19}, calculate $\Delta G°_{f,298}$ for $OH^-(aq)$. **[-156.9 kJ/mol]**
   d) Using the Gibbs free energies of formation at 298 K for the OH^- and H^+ ions along with the $\Delta G°_{f,298}$ for $H_2O(l)$ = -237 kJ/mol, calculate the K_w for water at 25°C. **[9.1 x 10^{-15}]**

6) For the reaction:

$$Ag^{+}(aq) + I^{-}(aq) \rightleftharpoons AgI(s)$$

$\mathcal{E}° = +0.951$ V at 25°C and $K_{328} = 1.88 \times 10^{14}$

a) Calculate ΔG° for the above reaction at 298 K **[-91.8 kJ]**
b) Calculate ΔH° and ΔS° for this reaction at 298 K. Assume that ΔH° and ΔS° are independent of temperature. **[ΔH° = -113.6 kJ and ΔS° = -73.3 J/K]**
c) Given that the Gibbs free energy of formation of $Ag^{+}(aq)$ at 298 K is +77.11 kJ/mol, calculate $\mathcal{E}°_{298}$ for the half reaction: $Ag(s) + I^{-}(aq) \rightleftharpoons AgI(s) + e^{-}$ **[0.152 V]**