Spontaneity, Entropy, and Free Energy
Part II

1) If the conditions are STANDARD CONDITIONS, this means 1 atm of pressure (or an equivalent), 298 K for temperature, and 1 M concentration.

2) If the system is at standard state use the equation:

$$\Delta G^o = -RT \ln K$$

"K" can be ANY K we have used.

3) If the system is not at standard state. We must look at "Q," not "K."

$$\Delta G = \Delta G^o + RT \ln Q$$

Regardless of the equation used, "K" and "Q" represent product concentration over reactant concentration. We can also apply Le Châtelier's Principle here by comparing "K" and "Q."

1) If $K < Q$, then reaction must shift left. $\Delta G > 0$.

2) If $K > Q$, then the reaction must shift right. $\Delta G < 0$

3) If $K = Q$, then the system is at equilibrium and $\Delta G = 0$.

Notice that the free energy used above is the nonstandard conditions free energy. You must recognize the difference between ΔG^o and ΔG!

1. The equilibrium constant for the reaction

$$2Fe^{3+}(aq) + Hg_2^{2+}(aq) \rightleftharpoons 2Fe^{2+}(aq) + 2Hg^{2+}(aq)$$

is $K_c = 9.1 \times 10^{-6}$ at 298 K.

(a) What is ΔG^o at this temperature?

(b) If standard-state conditions of reactants and products were mixed, in which direction would the reaction proceed? Justify your answer.

(c) Calculate ΔG at 298 K when $[Fe^{3+}] = 0.20$ M, $[Hg_2^{2+}] = 0.010$ M, $[Fe^{2+}] = 0.010$ M, and $[Hg^{2+}] = 0.025$ M. In which direction will the reaction proceed to achieve equilibrium?

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Part II

2. The formation constant for the reaction

$$Ni^{2+}(aq) + 6NH_3(aq) \rightleftharpoons Ni(NH_3)_6^{2+}(aq)$$

is $K_f = 5.6 \times 10^8$ at 25 °C.

(a) What is ΔG^o at this temperature?
(b) If standard-state conditions of the reactants and products were mixed, in which direction would the reaction proceed?
(c) Determine ΔG when $[Ni(NH_3)_6^{2+}] = 0.010$ M, $[Ni^{2+}] = 0.0010$ M, and $[NH_3] = 0.0050$ M. In which direction will the reaction proceed to achieve equilibrium?

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3. The excessive production of ozone (O_3) gas in the lower atmosphere causes rubber to deteriorate, green plants to brown, and persons with respiratory disease to have difficult breathing.

	ΔH^o_f kJ/mol	ΔG^o_f kJ/mol	S^o J/mol
O_2	0	0	205
O_3	143	163	239

(a) Is the formation of O_3 from O_2 favored at all temperatures, no temperatures, high temperatures or low temperatures (HINT: determine ΔH^o_{rxn} and ΔS^o to determine the sign of ΔG^o.

(b) Calculate the value of ΔG^o.

(c) Calculate ΔG at 298 K for this reaction in urban smog where $[O_2] = 0.21$ M and $[O_3] = 5.0 \times 10^{-7}$ M.