Worksheet

1) A chemical company claims that they are able to produce a certain product through a thermodynamically unfavored process. Explain how this is possible.

2) For a certain reaction ΔG° was found to be +32 kJ. What can be said about the relative proportion of reactants and products when the system is at equilibrium?

3) For a certain reaction $\Delta H^\circ = -20$ kJ/mol and $\Delta S^\circ = -75$ kJ/mol.
   a. Without using your calculator, determine whether or not the process is thermodynamically favorable.
   b. Does the equilibrium lie to the left, the right, or close to the middle? Justify your answer.

4) For the reaction below, ΔH° = -305.3 kJ/mol and ΔS° = -155.2 J/molK.

$$Ni(s) + Cl_2(g) \rightleftharpoons NiCl_2(s)$$

   a. Calculate the equilibrium constant, K_{eq}, at 25.0°C.
   b. Does the system contain mostly reactants or mostly products at equilibrium? Explain using two proofs.
   c. What is the partial pressure of $Cl_2(g)$ at equilibrium?

5) For the reaction below, ΔH° = 178.1 kJ/mol and ΔS° = 160.5 J/molK.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

   a. Calculate the equilibrium constant, K_{eq}, at 25°C.
   b. Does the system contain mostly reactants or mostly products at equilibrium? Explain using two proofs.
   c. What is the partial pressure of $CO_2(g)$ at equilibrium?

6) For the reaction below, ΔH° = -537.2 kJ/mol and ΔS° = 13.7 J/molK.

$$H_2(g) + F_2(g) \rightleftharpoons 2\ HF(g)$$

   a. Without doing any calculations, determine whether or not this process is thermodynamically favored. Justify your answer.
   b. Calculate the equilibrium constant, K_{eq}, at 25°C.
   c. Does the system contain mostly reactants or mostly products at equilibrium? Explain using two proofs.

7) For the reaction below ΔH° = -106.7 kJ/mol and ΔS° = -142.2 J/molK.

$$C_{(graphite)} + 2\ Cl_2(g) \rightleftharpoons CCl_4(g)$$

   a. Calculate ΔG°.
   b. Does the system contain mostly reactants or mostly products at equilibrium? Explain.

8) For the reaction below ΔH° = -508.3 kJ/mol and ΔS° = -178 J/molK.

$$2\ PCl_3(g) + O_2(g) \rightleftharpoons 2\ POCl_3(g)$$

   a. Calculate ΔG°.
   b. Is this process thermodynamically favored? Explain.
   c. Find Q_p if the partial pressures are found to be: $(P_{PCl_3}) = 1.14$ atm, $(P_{O_2}) = 0.73$ atm, and $(P_{POCl_3}) = 0.54$ atm.
   d. Find K_{eq} for the reaction at 298 K.
   e. In which direction will the reaction proceed? Justify your answer.

9) For the reaction below, $\Delta H^\circ = 85$ kJ/mol and $\Delta S^\circ = 198$ J/molK.

$$N_2F_4(g) \rightleftharpoons 2\ NF_2(g)$$

a. Calculate ΔG°.
b. Find Q_p if the partial pressures are found to be:
$(P_{N_2F_4}) = 0.94$ atm, and $(P_{NF_2}) = 0.72$ atm.

10) Find ΔG°_{700K} for the reaction below. $K_p = 0.140$ at 700 K.

$$ClF_3(g) \rightleftharpoons ClF(g) + F_2(g)$$

11) For the reaction below $K_c = 2.5 \times 10^{-3}$ at 1127°C.

$$CH_4(g) + 2\ H_2S(g) \rightleftharpoons CS_2(g) + 4\ H_2(g)$$

a. Find K_p
b. Find ΔG°_{1400K} in kJ/mol.

12) For a certain reaction $K_p = 3.54$ at 325°C. Find ΔG°_{598K} in kJ/mol.

13) If $\Delta H^\circ = -246$ kJ and $\Delta S^\circ = +146$ J/K for a reaction, will K_{eq} be greater than 1, less than 1, or equal to 1? Provide justification for your answer without doing any calculation.

14) Find the equilibrium constant, K_p, for the following reaction at 298 K using the thermodynamic values from the appendix in your textbook.

$$N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$$

15) Consider the following processes that take place at 25.0°C.

I. $A\ (aq) + BC\ (aq) \rightleftharpoons AB\ (aq) + C\ (aq)$ $\quad K_c = 1.76 \times 10^{-5}$

II. $AB\ (aq) + D\ (aq) \rightleftharpoons AD\ (aq) + B\ (aq)$ $\quad K_c = 2.85 \times 10^{12}$

a. Is process I. thermodynamically favored? Justify your answer.
b. Is process II. thermodynamically favored? Justify your answer.
c. Find the equilibrium constant, K_c, for the following process at 25.0°C.
$$A\ (aq) + BC\ (aq) + D\ (aq) \rightleftharpoons C\ (aq) + AD\ (aq) + B\ (aq)$$
d. Is the process in part c. thermodynamically favored? Justify your answer.
e. Can non-thermodynamically favored processes become thermodynamically favored when they are coupled with other thermodynamically favored processes?