Problem Set #6 – Chemistry 102 – Spring 2008
Due Wednesday, March 26th at the beginning of class.

Problems from Whitten, Ch. 17: #21, 33, 49, 55, 85

1. Consider the following reaction

$2\ SO_{2(g)} + O_{2(g)} \Leftrightarrow 2\ SO_{3(g)}$ $K_c = 900\ M^{-1}$ at 400 °C

a. What is the equilibrium constant for the reverse reaction?

Which way will the reaction run (forwards or backwards) under the following conditions?

b. $[SO_2] = [O_2] = 0.10$ M, $[SO_3] = 0$ M

c. $[SO_2] = [O_2] = 0.10$ M, $[SO_3] = 1.0$ M

d. $[SO_2] = [SO_3] = 0.10$ M, $[O_2] = 0.0010$ M

2. The lactose repressor (LacR) binds to a specific stretch of DNA in *E. coli* called the *lac* operator (lacO) very tightly, and dissociates from it with following equilibrium constant:

LacR•lacO ⇆ LacR + lacO $K = 1.0 \times 10^{-11}$ M

There are 10 molecules of LacR in each *E. coli* cell and one lacO segment per cell, which has a volume of 1.0×10^{-16} L. Assume a starting condition in which you have 9 free molecules of LacR and one molecule of LacR bound to lacO (LacR•lacO).

a. What concentration of lacO will be free at equilibrium?

b. What fraction of the total operator sequences in a population of E. coli cells will be free?

c. What if you started with only one molecule of LacR•lacO and no free LacR or lacO in the cell – what fraction of lacO would be free at equilibrium?

3. Consider the following reactions at equilibrium. Predict the response of the system to the specified disturbances. (In which direction will the equilibrium shift?)

a. $CO_{(g)} + 2\ H_{2\,(g)} \Leftrightarrow CH_3OH_{(g)}$ $\Delta H° = -18$ kJ

i. increase pressure
ii. increase temperature
iii. add more CO

b. $2\ NO_{(g)} + Cl_{2\,(g)} \Leftrightarrow 2\ NOCl_{(g)}$ $\Delta H° = -77$ kJ

i. remove NO
ii. increase volume
iii. add catalyst

c. $2\ C_{(s)} + O_{2\,(g)} \Leftrightarrow 2\ CO_{(g)}$ $\Delta H° = -220$ kJ

i. add more O_2
ii. add more C
iii. increase pressure

(continued on reverse)

4. Consider the following reaction:

$N_{2(g)} + 3\ H_{2(g)} \Leftrightarrow 2\ NH_{3(g)}$ $K_P = 0.0011\ atm^{-2}$ at 450 °C

a. Starting with 1.00 atm of N_2 and 1.00 atm of H_2 at 450 °C, how much NH_3 will be produced at equilibrium? How much N_2 and H_2 remain?

b. What is the theoretical yield in part "a" and what is the percent yield?

c. Let's say the equilibrium mixture you calculate in part "a" is compressed by 100-fold in volume. What is Q? What will ΔG for the reaction be?

d. Calculate $\Delta H°_{rxn}$ for this process using heats of formation available in Appendix K of Whitten. What is the equilibrium constant for this reaction at 25 °C?

e. The industrial synthesis of ammonia uses high pressures. Why?

f. The industrial process also takes place at high temperatures. Is that favorable from an equilibrium point of view? Explain. How about from a kinetic point of view?

5. For each of the following reactions, (i) calculate $\Delta G°_{rxn}$ using free energies of formation from Appendix K in the textbook, (ii) use those values to determine an equilibrium constant for the reaction, then (iii) state explicitly whether the reaction is product or reactant favored.

a. $2\ NO_{2(g)} \Leftrightarrow N_2O_{4(g)}$ - to finally see how good your lab result was…

b. $C_{graphite} + 2\ H_2O_{(g)} \Leftrightarrow CO_{2(g)} + 2\ H_{2(g)}$ – an idea for generating H_2 gas?

c. $2\ HI_{(g)} \rightarrow H_{2(g)} + I_{2(s)}$ – yet another idea…