CH302 Worksheet 4: Chemical Equilibria

Part 1: Some general equilibrium problems usually found on exams.

1. LeChatelier and pressure: If the pressure is decreased in a vessel containing the following equilibrium mixtures, which way will the reaction shift?

(a) $H_{2(g)} + O_{2(g)} \leftrightarrow H_2O_{(g)}$

(b) $N_{2(g)} + O_{2(g)} \leftrightarrow 2NO_{(g)}$

2. LeChatelier and temperature: How would increasing the temperature affect the following equilibria?

(a) $2H_2O_{(g)} \leftrightarrow 2H_{2(g)} + O_{2(g)}$ $\Delta H = 484$ kJ

(b) $C_3H_{8(g)} + 5O_{2(g)} \leftrightarrow 3CO_{2(g)} + 4H_2O_{(g)}$ $\Delta H = -2043$ kJ

(c) $CH_{4(g)} + 2\ O_{2(g)} \leftrightarrow CO_{2(g)} + 2\ H_2O_{(l)}$ $\Delta H = -890.4$ kJ

3. LeChatelier and concentration:

(a) What happens to C_2H_6 when HCl gas is added? $C_2H_6(g) + Cl_2(g) \leftrightarrow C_2H_5Cl(s) + HCl(g)$

(b) What happens to NH_3 when H_2 gas is added? $N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}$

4. Relating Chapter 7 to Chapter 9: What is K_c at room temperature for the reaction:

$K^+_{(aq)} + OH^-_{(aq)} \leftrightarrow KOH_{(aq)}$ $\Delta G_f^\circ = -439.6$ kJ/mol

Part 2: General Approach to Solving Chemical Equilibria Problems

The general form of a chemical reaction is aA + bB = cC +dD

Where A and B are reactants in the forward direction and C and D are products in the forward direction. The lower case letters are the stoichiometric coefficients for the balanced equation. The general form of the equilibrium constant equation is then

$$K_{eq} = [C]^c[D]^d/[A]^a[B]^b$$

Problems involving chemical equilibria can be placed into a matrix format with two kinds of concentrations identified: the initial or non-equilibrium concentration $\mathbf{C_x}$ and the equilibrium concentration **[X]**. (Note the bracket versus the Capital C. It is the equilibrium concentrations, **[**X], that are used to calculate K_{eq}.

reaction	A	B	C	D
initial	C_A	C_B	C_C	C_D
change	C_A-[A]	C_B-[B]	[C]- C_C	[D] - C_D
equilibrium	[A]	[B]	[C]	[D]

There are a variety of equilibrium problems that can be solved using the construction above. In some cases the problems are solved directly, with one unknown per equation. Others problems require significant algebraic manipulation. All of them are easy if you can identify the type of information used and place it in the matrix. The four three most common problem types are below:

Model chemical equilibrium for the following four calculations: $2NH_3 \rightarrow 3H_2 + N_2$ $K_{eq} = 3.8$

Eqilibrium Problem Type 1. Calculating K_{eq} from equilibrium concentrations.

In these problems it is necessary to determine all the bottom row equilibrium concentrations (the ones in [X]) and with the stoichiometric coefficients, K_{eq} is determined.

Calculation 1. For the ammonia equilibrium above, equilibrium concentrations are $[N_2]$ = .10 M, $[H_2]$ = .50 M, $[NH_3]$ =.057 M. What is K_{eq}? This is the easiest of problems because you are told what all the bottom row equilibria are.

	NH_3	H_2	N_2
initial			
change			
equilibrium	.057	.50	.10

Solve: K_{eq} =

Eqilibrium Problem Type 2. Using stoichiometry to complete the array.
A complex problem provides some of the initial and some of the equilibria concentrations and you are asked to solve for the rest of the concentrations in the array.

These problems are accomplished using stoichiometry and simple substitutions for unknowns.

Calculation 2. Given K_{eq} = 3.8, [N_2] = 0.3 M, [H_2] = 0.2 M and C_{NH3} = 0.04 M. What is the initial concentration of C_{N2}?

Fill in all empty boxes below.

	2NH3	3H2	N2
initial	.04		?
change			
final		.2	.3

Solve: C_{N2} =

Eqilibrium Problem Type 3. Problem solving using K_{eq} and initial concentrations.

The most realistic kind of equilibrium problem, the one you will use most often in Chapter 18 through 20, involves knowing the initial concentration of materials in the reaction, and the K_{eq}, obtained from a table. The equilibrium concentrations are then found through a series of algebraic substitutions. Note this problem represents what happens in real life. We can measure what we add to a reaction container, and we know K_{eq}

	A	B	C	D
initial	known	known	known	known
change				
final	unknown	unknown	unknown	unknown

This problem type is about the only kind you will work after Chapter 17. it is the most challenging and often requires solution of higher order polynomial equations.

Calculation 3. A quartic (which you would never be asked to solve on a test.)

Your initial concentration of C_{NH3} is 0.1M. What is the equilibrium concentration of [N_2]? (Remember that K_{eq} = 3.8).

	$2NH_3$	$3H_2$	N_2
initial	.1	0	0
change			
final			x

To solve this problem you need to generate an algebraic solution for the equilibrium values all in terms of a single variable. So let x = the amount of [N_2] at equilibrium. Then solve for the other unknowns using the stoichiometric relationship between the concentrations. Don't bother solving the equation unless you have a calculator that does it. Simply set up the expression for [N2]

Solve: [N_2] =

Calculation 4. A quadratic (which you will need to be able to solve on an exam.)
[H+] of a weak monoprotic acid. What is the [H^+] concentration for a 0.3M solution of acetic acid (K_a=1.8 x 10^{-5}).

$$HC_2H_30_2 \rightarrow H^+ + C_2H_3O_2^-$$

	$HC_2H_30_2$	H^+	$C_2H_3O_2^-$
initial	**.3**	**0**	**0**
change			
final		**x**	

Solve this problem the same way as Calculation 3. But the solution is easier and as a quadratic can be solved using the quadratic equation solution.

Solve: [H^+] =