Intro to Chapter 13: Equilibrium and K

1) The Law of Mass Action

a) Many reactions go to completion (only go forwards, not backwards)
Ex: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

b) Many reactions do not react completely but reach an equilibrium:
forward rate = reverse rate

Ex: $4NH_3(g) + 7O_2(g) \rightleftharpoons 4NO_2(g) + 6H_2O(g)$

Note: $\rightleftharpoons$ means it's an equilibrium reaction

If I place certain concentrations of $NH_3 + O_2$ in a flask, after a while all 4 compounds will be present and remain at constant concentrations. This is regardless of limiting reactants.

How can we find out what those final concentrations will be?
By experiment we have found an equilibrium constant, "K", for each reaction. It will be the same no matter how much of each reactant or even product we start with as long as the temperature and the pressure are the same.

It is calculated as follows:

$$K = \frac{[NO_2]^4[H_2O]^6}{[NH_3]^4[O_2]^7}$$

Where K = the equilibrium constant and [ ] = concentration in moles per liter at equilibrium.

This is called "The Law Of Mass Action" and is officially the expression of equilibrium. Its general form is given as:

For the chemical reaction $aA + bB \rightleftharpoons cC + dD$, $K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$

Important note: K is empirical (found only by experiment).

c) Example: Let's say two experiments at the same temperature and pressure are performed with this reaction:
$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$

	Expt 1	Expt 2
[NO]	1.09 M	.764 M
$[Br_2($]	1.15 M	.826 M
[NOBr]	2.85 M	*x*

What would be the concentration of NOBr in the second experiment?

Since they're at the same temperature and pressure, K will be the same for each.

$$K = \frac{[NOBr]^2}{[NO]^2[Br_2]}$$

$$K_1 = \frac{[2.85\ M]^2}{[1.09\ M]^2[1.15\ M]} = 5.94$$ (Note: K has no units. Sorry.)

$$K_1 = K_2 = 5.94 = \frac{[x]^2}{[.764\ M]^2[.826\ M]}$$

Solving for x, $x^2 = 2.86387$
So x = 1.69 M

2) Manipulating The Reaction and K

a) Try this reaction: $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$

$$K = \frac{[N_2][H_2]^3}{[NH_3]^2}$$

i) What if you reverse it? $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

$$K_{rev} = \frac{[NH_3]^2}{[N_2][H_2]^3} \quad \text{so} \quad K_{rev} = \frac{1}{K}$$

ii) What if you then divide all the coefficients in half?

$$NH_3(g) \rightleftharpoons 1/2\ N_2(g) + 3/2\ H_2(g)$$

$$K_{1/2} = \frac{[N_2]^{1/2}[H_2]^{3/2}}{[NH_3]} = \left[\frac{[N_2][H_2]^3}{[NH_3]^2}\right]^{1/2} \quad \text{so } K_{1/2} = K^{1/2}$$

iii)Finally, if you tripled all the coefficients,

$$6NH_3(g) \rightleftharpoons 3\ N_2(g) + 9\ H_2(g)$$

$$K_{x\,3} = \frac{[N_2]^3[H_2]^9}{[NH_3]^6} = \left[\frac{[N_2][H_2]^3}{[NH_3]^2}\right]^3 \quad \text{so } K_{x\,3} = K^3$$

That's enough for now. Keep working on those Chapter 13 problems!