EQUILIBRIUM CONTANTS

MEANING OF VALUES

$2H_2(g) + O_2(g) \Longleftrightarrow 2H_2O(g)$

$$K_c = \frac{[H_2O]^2}{[H_2]^2[O_2]} = \frac{9.1x10^{80}}{1}$$

Very little reactant relative to product.
Requires 200,000L of water vapor to locate 2 H_2 and 1 O_2 molecules.

$N_2(g) + O_2(g) \Longleftrightarrow 2NO(g)$

$$K_c = \frac{[NO]^2}{[N_2][O_2]} = 4.8x10^{-31} = \frac{4.8}{10^{31}}$$

Very little product relative to reactant.

In general for either K_c or K_p

K value very large	Reaction far toward completion
K value close to 1	Reactant and product concentrations nearly same
K value very small	Hardly any products formed

EQUILIBRIUM EXPRESSION

Equilibrium Expression for General Reaction

aA + bB <=> cC + dD $$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Also termed “mass action quotient” or “reaction quotient”

For reverse reaction cC + dD <=> aA + bB $$K_c^{-1} = \frac{[A]^a[B]^b}{[C]^c[D]^d}$$

If double reaction, all coefficients are twice original value so $(K_c)^2$
If ½ reaction, all coefficients are ½ original value so $(K_c)^{1/2}$

If add two reactions

$$2A \Leftrightarrow C \qquad K_1 = \frac{[C]}{[A]^2}$$

$$3B \Leftrightarrow 3D \qquad K_2 = \frac{[D]^3}{[B]}$$

$$2A + B \Leftrightarrow C + 3D$$

$$K = K_1 K_2 = \frac{[C]}{[A]^2} \times \frac{[D]^3}{[B]} = \frac{[C][D]^3}{[A]^2[B]}$$

EQUILIBRIUM EXPRESSIONS

Relationship of K_p and K_c

For a gaseous reaction the ratio of products to reactants in terms of pressure (atm) is K_p

$aA + bB \Leftrightarrow cC + dD$

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b} \quad \text{and} \quad K_p = \frac{P_C{}^c\, P_D{}^d}{P_A{}^a\, P_B{}^b}$$

PV = nRT so $P = \frac{n}{V}RT = MRT$

$$K_p = \frac{P_C{}^c\, P_D{}^d}{P_A{}^a\, P_B{}^b} = \frac{(M_C RT)^c\ (M_D RT)^d}{(M_A RT)^a\ (M_B RT)^b}$$

Factor out RT

$$K_p = (RT)^{\Delta n_{gas}} \left(\frac{M_C^c\, M_D^d}{M_A^a\, M_B^b} \right)$$

Therefore

$K_p = (RT)^{\Delta n_{gas}} K_c$ where $\Delta n_{gas} = (c+d) - (a+b)$

EQUILIBRIUM EXPRESSIONS

For the reaction: $2NO(g) + Cl_2(g) \Leftrightarrow 2ClNO(g)$, write the K_c and K_p equilibrium expressions.

$$K_C = \frac{[ClNO]^2}{[NO]^2[Cl_2]}$$

$$K_P = \frac{P_{ClNO}{}^2}{P_{NO}{}^2 P_{Cl2}}$$

At 500K, an equilibrium mixture contained 0.242 atm NO, 0.605 atm Cl_2, and 1.38 atm ClNO. Determine the K_p and K_c values.
To calculate K_c the relationship $K_p = K_c(RT)^{\Delta n}$ is used.

$$K_P = \frac{P_{ClNO}{}^2}{P_{NO}{}^2 P_{Cl2}} = \frac{(1.38atm)^2}{(0.242atm)^2(0.605atm)} = 53.7atm^{-1}$$

$$K_P = K_C(RT)^{\Delta n\ gas}$$

$$53.7atm^{-1} = K_C(0.08206\ L \bullet atm/mol \bullet K\ *\ 500K)^{-1}$$

$$K_C = 2.20 \times 10^3\ M^{-1}$$

HETEROGENEOUS EQUILIBRIA

Pure solids or pure liquids do not appear in equilibrium expression since their concentration is constant.

EXAMPLE: $CaCO_3(s) \Leftrightarrow CaO(s) + CO_2(g)$

density = 2.71g/cm^3 (CaCO$_3$); density = 3.25g/cm^3 (CaO)

$$[CaCO_3] = \left(\frac{2.71g}{cm^3}\right)\left(\frac{1mol}{100.1g}\right)\left(\frac{1000\ cm^3}{1L}\right) = 27.1\ mol/L$$

$$[CaO] = \left(\frac{3.25g}{cm^3}\right)\left(\frac{1mol}{56.1g}\right)\left(\frac{1000\ cm^3}{1L}\right) = 57.9\ mol/L$$

$$K = \frac{[CaO][CO_2]}{[CaCO_3]}$$

$$\frac{K * [CaCO_3]}{[CaO]} = [CO_2]$$

So $K_c = [CO_2]$ and $K_p = P_{CO2}$