# Equilibrium I NOTES #47

Ap Chemistry

## I. What is Equilibrium????

A. Most reactions are REVERSIBLE!!!!

B. There are two different types of equilibrium.

PHYSICAL EQUILIBRIUM:
ex:

CHEMICAL EQUILIBRIUM:
ex:

C. Characteristics of Equilibrium....

1.

2.

3.

**** *Equilibrium simulation demonstration.....*

D. Graphically, what does Eq look like?

1. $N_2O_4\,(g) \Leftrightarrow 2\,NO_2\,(g)$

Concentration vs Time

Rate vs Time

2. Take a look at some more data of this reaction starting out at varying $[N_2O_4]$ and $[NO_2]$ concentrations.....

**TABLE 14.1 The $NO_2$–$N_2O_4$ System at 25°C**

| INITIAL CONCENTRATIONS (M) | | EQUILIBRIUM CONCENTRATIONS (M) | | RATIO OF CONCENTRATIONS AT EQUILIBRIUM | |
|---|---|---|---|---|---|
| $[NO_2]$ | $[N_2O_4]$ | $[NO_2]$ | $[N_2O_4]$ | $\frac{[NO_2]}{[N_2O_4]}$ | $\frac{[NO_2]^2}{[N_2O_4]}$ |
| 0.000 | 0.670 | 0.0547 | 0.643 | 0.0851 | $4.65 \times 10^{-3}$ |
| 0.0500 | 0.446 | 0.0457 | 0.448 | 0.102 | $4.66 \times 10^{-3}$ |
| 0.0300 | 0.500 | 0.0475 | 0.491 | 0.0967 | $4.60 \times 10^{-3}$ |
| 0.0400 | 0.600 | 0.0523 | 0.594 | 0.0880 | $4.60 \times 10^{-3}$ |
| 0.200 | 0.000 | 0.0204 | 0.0898 | 0.227 | $4.63 \times 10^{-3}$ |

No matter what concentrations of $N_2O_4$ and $NO_2$ you start with, you will notice that the ratio of _____ is always a constant!

E. Writing Equilibrium Expressions

1. The Law of Mass Action:
   the ratio of the [products] / [reactants] at equilibrium and at a constant _____ is constant for a particular reaction.

2. $aA + bB \Leftrightarrow cC + dD$ $\quad K =$ [ ]

ex: a) *formation of ozone:*
$3\ O_2\ (g) \Leftrightarrow 2\ O_3\ (g)$

b) *dissociation of acetic acid:*

_____

3. Never include SOLIDS or PURE LIQUIDS (like _____) in your eq expression.

   ex: decomposition of chalk: _____ K' =

   Why? _____

*** So, what *do* you include in your Eq expression??? _____

4. $K_c$ vs $K_p$ - The concentrations of the reactants/products in an Eq expression can either be express in terms Molarity ($K_c$) or in terms of partial pressures ($K_p$).

   a. So, in the reaction, $N_2O_4\ (g) \Leftrightarrow 2\ NO_2\ (g)$, the Eq expression can be written two ways.

   b. Do you suspect $K_c$ and $K_p$ are equal? _____

   c. What is the relationship between $K_c$ and $K_p$? $\quad aA\ (g) \Leftrightarrow bB\ (g)$

   d. When would $K_c = K_p$??? _____

EX: For which reaction will $K_c = K_p$?

a. $H_2\ (g) + Br_2\ (g) \Leftrightarrow 2\ HBr\ (g)$ $\quad Dn =$

b. $2\ H_2\ (g) + O_2\ (g) \Leftrightarrow 2\ H_2O\ (g)$ $\quad Dn =$

c. $H_2O\ (l) \Leftrightarrow H_2O\ (g)$ $\quad Dn =$

# Equilibrium II NOTES #48

5. Writing Eq expressions for rxns with MULTIPLE EQUILIBRIA.

   a. This often happens with the ionization of acids with more than one acidic proton to donate (DIPROTIC ACIDS).

   rxn1: $H_2CO_3\,(aq) \Leftrightarrow H^+\,(aq) + HCO_3^-\,(aq)$ $\quad K_c' =$

   rxn2: $\quad K_c'' =$

   Overall: $\quad K_c =$

   * The Eq expression can be written from the products and reactants of the overall equation.
   * If a reaction can be expressed as the sum of two or more reactions, the eq constant is given by the product of the equilibrium constants of the individual reactions.

   **$K_c$ =**

6. K can vary depending on how the equation is written.
   a. What if the reaction is written in the opposite direction?

   Ex: $N_2O_4 \Leftrightarrow 2\,NO_2$ vs $2\,NO_2 \Leftrightarrow N_2O_4$

   $K_c =$ $\quad K_c' =$

   * $K_c'$ would be the _____ of $K_c$. **$K_c' =$**

   b. What if the reaction is balanced with different coefficients?

   Ex: $N_2O_4 \Leftrightarrow 2\,NO_2$ vs $1/2\,N_2O_4 \Leftrightarrow NO_2$

   $K_c =$ $\quad K_c =$

PRACTICE:

ex: If $K_c$ for the following reaction, $N_2\,(g) + 3\,H_2\,(g) \text{-----> } 2\,NH_3\,(g)$, is $2.6\times10^{-5}$ at 25°C, what is $K_c$ for the following:

- $3\,N_2\,(g) + 9\,H_2\,(g) \Leftrightarrow 6\,NH_3$ $\quad K_c =$ _____
- $NH_3\,(g) \Leftrightarrow 1/2\,N_2\,(g) + 3/2\,H_2$ $\quad K_c =$ _____
- What would $K_p$ be? $\quad K_p =$ _____

## II. What ever does K really tell us??

1. The magnitude of K tells us whether the forward reaction or the backward reaction is favored. $K = \frac{[\text{products}]}{[\text{reactants}]}$

- If K > 1 ..... The _____ rxn is favored; or the _____ are favored.

  ** If K is *really* big, we can say that the reaction goes to _____.

- If K < 1 ..... The _____ rxn is favored; or the _____ are favored.

  ** If K is *really* small, the reaction does not occur to any significant extent.

** It's important to realize that the size of K and the time required to reach equilibrium are not directly related. In other words, a large K does not necessarily mean that the reaction will reach equilibrium quickly.

- Time to achieve equilibrium is determined by the reaction rate which is determined by...

_____.

E

rxn progress

- K, on the other hand, is determined by _____, the relative stability of the products vs reactants. (Other similar driving forces will be discuss later....such as the tendency towards *disorder*.....)

## III. Predicting the direction of a reaction.

1. For reactions that are NOT in equilibrium, we can still calculate the ratio of products to reactions. This ratio obtained, however, would not be K so instead, we would call such a value, Q or the _____. Q is a valuable piece of info that will allows make predictions about the reaction.

EX: The $K_c$ for the following reaction is $6.5 \times 10^4$ at 35°C. $2\ NO\ (g) + Cl_2\ (g) \Leftrightarrow 2\ NOCl\ (g)$

In a certain experiment, $2.0 \times 10^{-2}$ mole of NO, $8.3 \times 10^{-3}$ mole of $Cl_2$ and 6.8 moles of NOCl are mixed in a 2.0 L flask. In which direction will the system proceed to reach equilibrium?

** Since $Q_c$ is _____ than $K_c$, the reaction will have to proceed to the _____ or towards the _____ in order to reach equilibrium.

2. $Q > K$ The ratio of [products] to [reactants] is too _____. Need to convert _____ back to _____. Eq shifts to the _____ to reach eq.

$Q = K$ The system is at Eq. (yeah!)

$Q < K$ The ratio of [products] to [reactants] is too _____. Need to convert _____ back to _____. Eq shifts to the _____ to reach eq.

*** *Just like our favoritest story,* _____.