EQUILIBRIUM LAW - K_{eq}

A simple mathematical relationship defines each reaction at chemical equilibrium.

$$H_{2(g)} + I_{2(g)} <===> 2\ HI_{(g)}$$

EQUILIBRIUM LAW - K_{eq}

- can always be developed from the balanced chemical equation

- K_{eq} will always have a specific value at specific environmental conditions
  - if the conditions change, the K_{eq} will also change

- units for K_{eq} will never be used

EQUILIBRIUM LAW - K_{eq}

Example #1

a) $N_{2(g)} + 3\ H_{2(g)}$ <====> $2\ NH_{3(g)}$

b) $2\ H_{2(g)} + O_{2(g)}$ <====> $2\ H_2O_{(g)}$

c) 2 NO <====> N O

EQUILIBRIUM LAW - K_{eq}

How are the equilibrium laws of the following equations related?

i) $N_{2(g)} + 3\ H_{2(g)} <===> 2\ NH_{3(g)}$

ii) $2NH_{3(g)} <===> N_{2(g)} + 3\ H_{2(g)}$

EQUILIBRIUM LAW - K_{eq}

How are the equilibrium laws of the following equations related?

i) $PCl_{3(g)} + Cl_{2(g)} <====> PCl_{5(g)}$

ii) $2\ PCl_{3(g)} + 2\ Cl_{2(g)} <====> 2\ PCl_{5(g)}$

EQUILIBRIUM LAW - K_{eq}

What is the equilibrium law of the sum of the following reactions?

i) $2\ N_{2(g)} + O_{2(g)} \Leftarrow\Rightarrow 2\ N_2O_{(g)}$

ii) $2\ N_2O_{(g)} + 3\ O_{2(g)} \Leftarrow\Rightarrow 4\ NO_{2(g)}$

EQUILIBRIUM LAW - K_{eq}

When chemical equilibria are added together, the equilibrium constants are multiplied together.

$$K_{eq\ final\ rxn} = K_{eq\ rxn\ 1} \times K_{eq\ rxn\ 2}$$

EQUILIBRIUM LAW - K_{eq}

Example #2

At 25°C, $K_{eq} = 7.0 \times 10^{25}$ for:

$$2\ SO_{2(g)} + O_{2(g)} <====> 2\ SO_{3(g)}$$

What is the value of K_{eq} for:

$$SO_{3(g)} <====> SO_{2(g)} + \frac{1}{2}\ O_{2(g)}$$

K_{eq} = 7.0×10^{25} inversed, to the power of 0.5

$= 1.195 \times 10^{-13}$

$= 1.2 \times 10^{-13}$

EQUILIBRIUM LAW - K_{eq}

MAGNITUDE OF K_{eq}

The value of K_{eq} (large or small) can provide a hint to the ratio of reactants to products at equilibrium.

EQUILIBRIUM LAW - K_{eq}

MAGNITUDE OF K_{eq}

1. K_{eq} is very large ($K_{eq} > 1$)
   - [products] [reactants]

2. $K_{eq} \approx 1$
   - [products] [reactants]

3. K_{eq} is very small ($K_{eq} < 1$)
   - [products] [reactants]

EQUILIBRIUM LAW - K_{eq}

MAGNITUDE OF K_{eq}

Example #3

Which of the following reactions will tend to proceed farthest toward completion?

a) $H_{2(g)} + Br_{2(g)} <====> 2\ HBr_{(g)}$

$K_{eq} = 1.4 \times 10^{-21}$

b) $2\ NO_{(g)} <====> N_{2(g)} + O_{2(g)}$

$K_{eq} = 2.1 \times 10^{30}$

c) $2\ BrCl_{(g)} <====> Br_{2(g)} + Cl_{2(g)}$

$K_{eq} = 0.195$

EQUILIBRIUM LAW - K_{eq}

EQUILIBRIUM – SOLIDS AND LIQUIDS

What is the concentration of a solid or liquid? (i.e. H_2O)

Does the concentration of these pure compounds change?

ex. 1 mol $NaHCO_3$ occupies 38.9 cm^3

2 mol $NaHCO_3$ occupies 77.8 cm^3

Molar concentration remains the same. Solids and liquids are unaffected by concentration

EQUILIBRIUM LAW - K_{eq}

EQUILIBRIUM – SOLIDS AND LIQUIDS

In the equilibrium law, solids and liquids do not need to be included as it becomes part of the equilibrium constant.

$$NH_{3(aq)} + H_2O_{(l)} \Longleftrightarrow NH_4{}^{+}{}_{(aq)} + OH^{-}{}_{(aq)}$$

$$k_{eq} = \frac{[NH_4{}^{+}{}_{(aq)}][OH^{-}{}_{(aq)}]}{[NH_{3(aq)}]}$$

EQUILIBRIUM LAW - K_{eq}

EQUILIBRIUM – SOLIDS AND LIQUIDS

Example #4

Write the equilibrium law for the following reactions:

a) $CaCO_{3(s)}$ <====> $CaO_{(s)}$ + $CO_{2(g)}$

b) 2 $NaHCO_{3(s)}$ <====> $Na_2CO_{3(s)}$ + $H_2O_{(g)}$ + $CO_{2(g)}$

c) $CaO_{(s)}$ + $SO_{2(g)}$ <====> $CaSO_{3(s)}$

EQUILIBRIUM LAW - K_{eq}

EQUILIBRIUM – SOLIDS AND LIQUIDS

Example #4

d) $2\ Hg_{(l)} + Cl_{2(g)} <====> Hg_2Cl_{2(s)}$

e) $NH_{3(g)} + HCl_{(g)} <====> NH_4Cl_{(s)}$

EQUILIBRIUM LAW - K_{eq}

EQUILIBRIUM – TEMPERATURE

Will temperature change the value of K_{eq}? Why or why not?

Reactions are endothermic or exothermic and therefore will be affected by the addition or removal of heat.

EQUILIBRIUM LAW - K_{eq}

EQUILIBRIUM – TEMPERATURE

$$3\ H_{2(g)} + N_{2(g)} <===> 2\ NH_{3(g)} + \text{heat}$$

a) What is the equilibrium law?

b) Which way does equilibrium shift when temperature increases? How will K_{eq} change?

c) When temperature decreases?

EQUILIBRIUM LAW - K_{eq}

EQUILIBRIUM – TEMPERATURE

$$heat + PCl_{5(g)} \Longleftrightarrow PCl_{3(g)} + Cl_{2(g)}$$

a) What is the equilibrium law?

b) Which way does equilibrium shift when temperature increases? How will K_{eq} change?

c) When temperature decreases?