# N44

# Equilibrium Constant & Quotient

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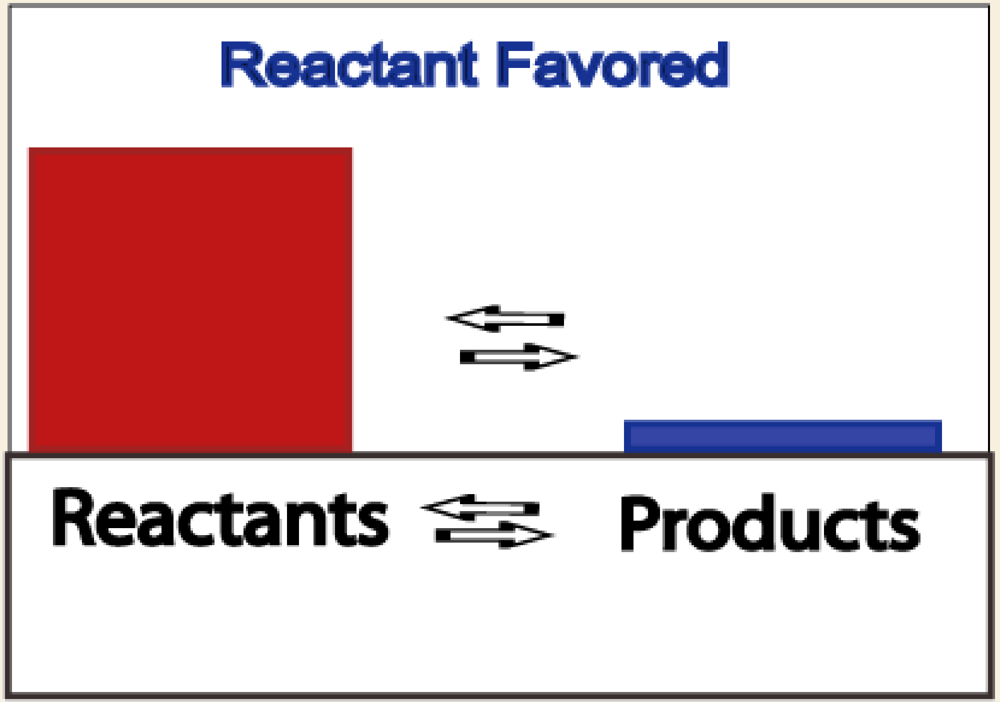
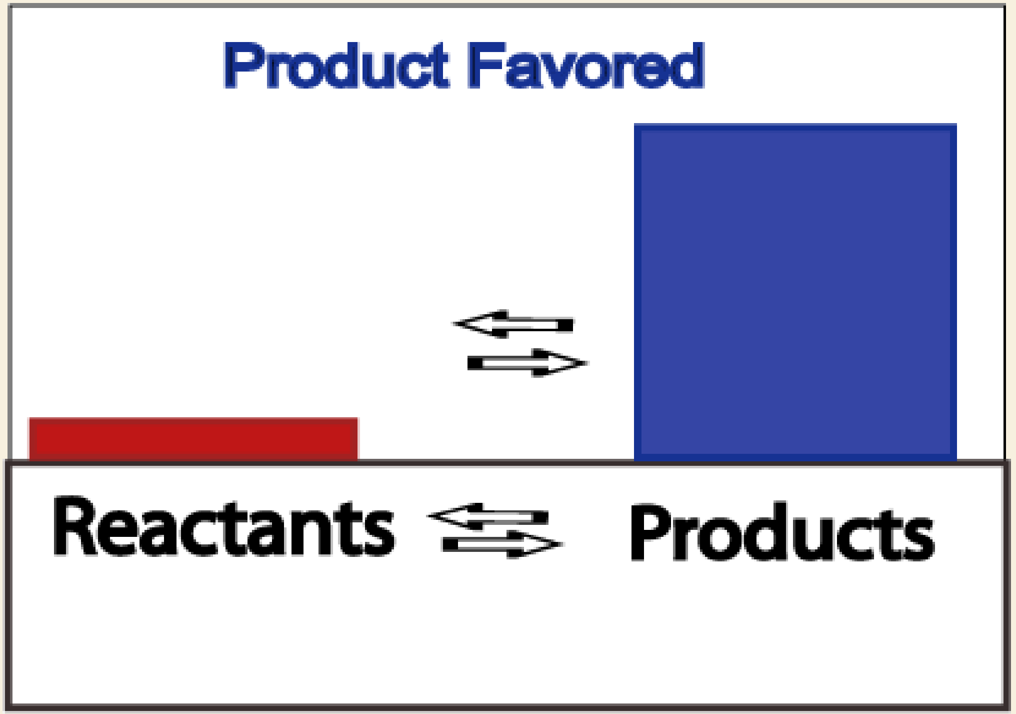
**Target: I can mathematically determine if a reaction is at equilibrium or not.**

**Link to YouTube Presentation:** https://youtu.be/stWybrjoM3w

# PRODUCT OR REACTANT FAVORED?

Once equilibrium is reached, you may have more products present, or you may have more reactants present.



# PRODUCT FAVORED OR REACTANT FAVORED?

$K_{eq}$ is a value (with no units) that allows us to determine if more products or reactants are being made. It is a ratio of products to reactants.

SIMPLIFIED VERSION FIRST: $K_{eq} = \frac{[Products]}{[Reactants]}$

- **K > 1 then more products!**
- **K < 1 then more reactants!**

# CALCULATING $K_{eq}$

- The "**Law of Mass Action**" will allow us to calculate $K_{eq}$ – **Ratio of Products over Reactants**

$$aA + bB \leftrightarrow cC + dD$$

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

*Still simplified, there is an additional part that we wont use that helps "fix" the units so Keq can have no units. Don't worry about it!*

* **Remember** how solids and liquids don't factor into equilibrium? They don't have true concentrations so there is nowhere to plug them into this equation is there!

# PRACTICE PROBLEM:

- Write the equilibrium expression for the reaction:

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

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

$$K_{eq} = \frac{[NO]^2[O_2]^1}{[NO_2]^2}$$

*Equilibrium expression is the same thing as the Law of Mass Action!* ☺

# ASSUME FORWARD REACTION…BUT WHAT IF ASKED FOR BACKWARDS RXN?

- Just flip it! Write K as K' for backwards reaction.

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

$$K'_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]^1}$$

$$K'_{eq} = \frac{1}{K_{eq}}$$

*Don't even bother writing the equation flipped!*
*Just flip your Law of Mass Action!*

# WHAT IF I HAVE PRESSURES NOT [ ] ?

- Just use partial pressures the same way you use concentrations!

$$aA + bB \leftrightarrow cC + dD$$

$$K_{eq} = \frac{(PC)^c (PD)^d}{(PA)^a (PB)^b}$$

# HOW CAN YOU TELL IF IT IS AT EQUILIBRIUM OR NOT?

- Calculate the values you have, and compare them to the $K_{eq}$ value
  - **Reaction Quotient** is what it is called if it isn't at equilibrium

$$aA + bB \leftrightarrow cC + dD$$

$$Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

# SO WHAT DOES Q TELL YOU?

- **$K = Q$ then you are at equilibrium!**
- **$K < Q$ you have too many products!**
  - SHIFT LEFT until you make enough reactants to get back to equilibrium
  - Reverse reaction will proceed faster until at equilibrium!
- **$K > Q$ you have too many reactants!**
  - SHIFT RIGHT until you make enough product to get back to equilibrium
  - Forward reaction will proceed faster until at equilibrium!

# WHY DO WE CARE ABOUT $K_{eq}$ ?

**Knowing $K_{eq}$ allows you to solve for:**

- –Which combos of [ ]s would reach an equilibrium position
- –Whether or not your given [ ]s are at an equilibrium point by comparing to Q
  - If you can compare K and Q then you can predict which way it needs to shift to reach equilibrium

# PRACTICE PROBLEM

Given the equation X(*g*) ↔ *Y*(*g*) + 2 *Z*(*g*). *At a particular temperature*, K = 1.4 x $10^3$. If you mixed 1.2 mol Y, 0.070 mol Z, and 0.003 mol X in a 1-L container, in which direction would the reaction initially proceed?

$$Q = \frac{[Y]^1[Z]^2}{[X]^1} \qquad Q = \frac{[1.2]^1[0.070]^2}{[0.003]^1} = 1.96$$

$$K = 1.4\ x\ 103 > \ Q = 1.96$$

**Q is too small - Not enough products!**

**Shift to the RIGHT!**

# THINGS THAT CHANGE $K_{EQ}$

**These things DON'T CHANGE $K_{eq}$**

- Changing Concentrations
- Changing Pressures
- Adding Solids or Liquids
- Adding Catalysts

**These things DO CHANGE $K_{eq}$**

- Temperature

# EQUILIBRIUM CONSTANT VERSUS "EQUILIBRIUM POINT"

- **The constant, Keq, is the actual NUMBER you get from your Law of Mass Action.**
  - **ONE Keq PER TEMPERATURE!**

- **The "Equilibrium Point" is the combination of SPECIFIC CONCENTRATIONS you plug in that get you the Keq number for that temperature.**
  - **LOTS of combinations that can get you Keq per temperature**

# EQUILIBRIUM CONSTANT VERSUS "EQUILIBRIUM POINT"

$$\frac{2}{1} = 2$$

K = 2

$$\frac{4}{2} = 2$$

Lots of different "equilibrium points" will get you that same number!

$$\frac{100}{50} = 2$$

# CAN IT CHANGE ANYTHING?

| **Factor** | Rate of Reaction | Rate Constant k | Equilibrium Point | Equilibrium Constant Keq |
|---|---|---|---|---|
| Δ [ ] | ✓ | ✗ | ✓ | ✗ |
| Δ Pressure | ✓ | ✗ | ✓ | ✗ |
| Δ Surface Area | ✓ | ✗ | ✗ | ✗ |
| Δ Amount of s/l | ✗ | ✗ | ✗ | ✗ |
| Inert Gas | ✗ | ✗ | ✗ | ✗ |
| Catalyst | ✓ | ✓ | ✗ | ✗ |
| Temperature | ✓ | ✓ | ✓ | ✓ |

# YOUTUBE LINK TO PRESENTATION

- https://youtu.be/stWybrjoM3w