Today's Topics

- Overview of Chapter 16
- Le Chatelier's Principle

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THE EQUILIBRIUM CONSTANT

$$a\,A + b\,B \leftrightarrows c\,C + d\,D$$

(at a given T)

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

conc. of products

conc. of reactants

equilibrium constant

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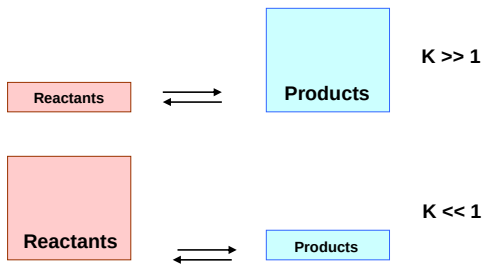
Product or Reactant Favored Reactions



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The Reaction Quotient, Q

REACTION QUOTIENT, Q.

$$a\,A + b\,B \leftrightarrows c\,C + d\,D$$

Under Any Reaction Conditions

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

Product concentrations

Reactant concentrations

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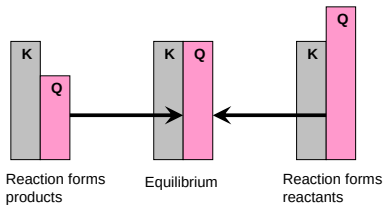
$$a\,A + b\,B \rightleftharpoons c\,C + d\,D$$



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Writing and Manipulating K Expressions

1. Adding equations

$S(s) + O_2(g) \leftrightarrows SO_2(g)$ $\quad K_1$

$+\ SO_2(g) + 1/2\ O_2(g) \leftrightarrows SO_3(g)$ $\quad K_2$

Net equation:

$S(s) + 3/2\ O_2(g) \leftrightarrows SO_3(g)$ $\quad K_{net}$

$$K_{net} = K_1 \cdot K_2$$

Adding two balanced equations **multiplies** their Ks

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Writing and Manipulating K Expressions

2. Changing coefficients

$S(s) + 3/2\ O_2(g) \leftrightarrows SO_3(g)$ K_{old}

$\times 2$

$2\ S(s) + 3\ O_2(g) \leftrightarrows 2\ SO_3(g)$ K_{new}

$$K_{new} = \frac{[SO_3]^2}{[O_2]^3} = (K_{old})^2$$

Doubling the balanced equation **squares** the K

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Writing and Manipulating K Expressions

3. Changing direction

$S(s) + O_2(g) \leftrightarrows SO_2(g)$ K_{old}

$SO_2(g) \leftrightarrows S(s) + O_2(g)$ K_{new}

$$K_{new} = \frac{[O_2]}{[SO_2]} = \frac{1}{K_{old}}$$

Reversing the balanced equation **inverts** the K

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Le Chatelier's Principle

- **Change T**
  - Changes the value of K
  - This causes a change in equilibrium concentrations
- **Add or take away reactant or product:**
  - K does not change
  - Reaction adjusts to new equilibrium "position"
- **Use a catalyst:**
  - K does not change. A catalyst does not affect equilibrium.
  - Modify the kinetics of the reaction. (Chapter 15)

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EQUILIBRIUM AND EXTERNAL EFFECTS

- **Concentration changes:**
  - **no change in K**
  - **only the equilibrium composition changes.**

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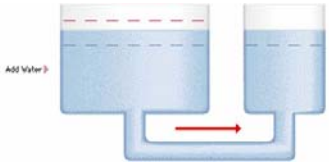
Le Chatelier's Principle

"reactant" "product"



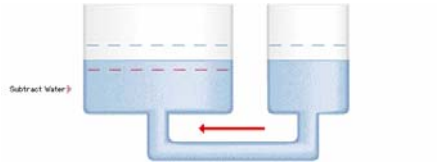
Adding a "reactant" to a chemical system.

reactants ⇆ products

Blue line= initial state
Red line = new state
Water level= eq. state

Le Chatelier's Principle

"reactant" "product"



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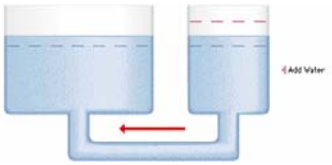
Le Chatelier's Principle

"reactant" "product"



Adding a "product" to a chemical system.

reactants ⇆ products

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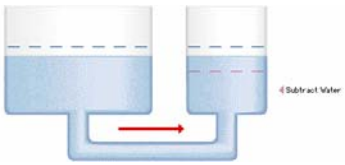
Le Chatelier's Principle

"reactant" "product"



Removing a "product" from a chemical system.

reactants ⇆ products

Blue line= initial state
Red line = new state
Water level= eq. state

CATALYSIS

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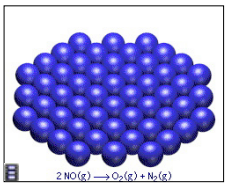
In auto exhaust systems — Pt, NiO

$2\,CO + O_2 \text{ ---> } 2\,CO_2$
$2\,NO \text{ ---> } N_2 + O_2$



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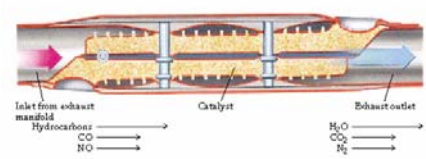
EQUILIBRIUM AND EXTERNAL EFFECTS

16



Catalytic exhaust system

- **Add catalyst ---> no change in K**
- **A catalyst only affects the RATE of approach to equilibrium.**

Rate = M sec⁻¹ ≡ M/sec

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Haber-Bosch Ammonia Synthesis

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Fritz Haber
1868-1934
Nobel Prize, 1918

Carl Bosch
1874-1940
Nobel Prize, 1931

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Haber-Bosch Process for NH_3

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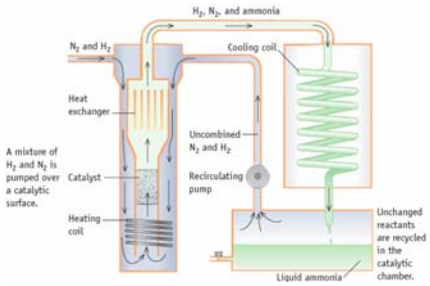

- $N_2(g) + 3\,H_2(g) \leftrightharpoons 2\,NH_3(g)$ + **heat**
- $K = 3.5 \times 10^8$ at 298 K

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