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Chapter 16 - Chemical Equilibrium Today's Topics

- Product-favored reactions
- Reactant-favored reactions
- Calculating the reaction quotient Q
- Calculating the Equilibrium Constant K

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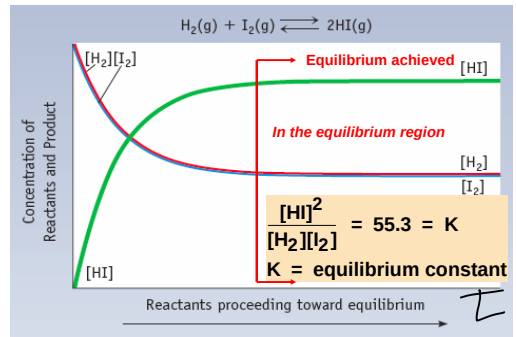
Reaction Quotient & Equilibrium Constant



$$\frac{[HI]^2}{[H_2][I_2]} = 55.3 = K$$

K = equilibrium constant

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THE EQUILIBRIUM CONSTANT

For any type of chemical equilibrium of the type

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

the following is a CONSTANT (at a given T)

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

conc. of products — always on top

conc. of reactants → always on bottom

equilibrium constant

If K is known, then we can predict concs. of products or reactants.

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The Reaction Quotient, Q

In general, ALL reacting chemical systems are characterized by their REACTION QUOTIENT, Q.

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

exponents

Under Any Reaction Conditions

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

Product concentrations

Reactant concentrations

If Q = K, then system is at equilibrium.

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IDEAL GAS LAW

$$P\,V = n\,R\,T$$

How can we relate concentration (used in K expressions) with pressure?

$\frac{n}{V}$ = Conc.

$\frac{mole}{l} = M$

Units of R → ?

0,082 $\frac{l\,atm}{K\,mol}$

8,31 $J/K\,mol$

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Determining K

$$2\,NOCl(g) \leftrightarrows 2\,NO(g) + Cl_2(g)$$

Place 2.00 mol of NOCl is a 1.00 L flask. At equilibrium you find 0.66 mol/L of NO. Calculate K.

Solution

Set of an "ICE" table of concentrations

	[NOCl]	[NO]	$[Cl_2]$
Initial	2.00	0	0
Change	-0,66	+0,66	+0,33
Equilibrium	1,34	0.66	0,33

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Determining K

$2\ NOCl(g) \leftrightharpoons 2\ NO(g) + Cl_2(g)$

	[NOCl]	[NO]	[Cl_2]
Initial	2.00	0	0
Change	-0.66	+0.66	+0.33
Equilibrium	1.34	0.66	0.33

$$K = \frac{[NO]^2[Cl_2]}{[NOCl]^2}$$

$$K = \frac{[NO]^2[Cl_2]}{[NOCl]^2} = \frac{(0.66)^2(0.33)}{(1.34)^2} = 0.080$$

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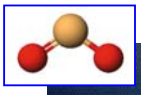
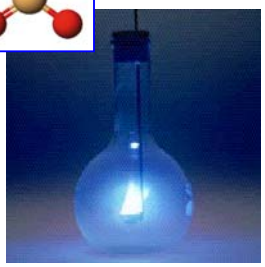
Writing and Manipulating K Expressions

Solids and liquids *NEVER* appear in equilibrium expressions.





$S(s) + O_2(g) \leftrightharpoons SO_2(g)$

$$K = \frac{[SO_2]}{[O_2]}$$

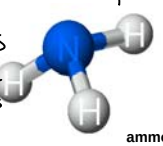
Writing and Manipulating K Expressions

Solids and liquids *NEVER* appear in equilibrium expressions.

aq ≡ aqueous

$NH_3(aq) + H_2O(liq) \leftrightharpoons NH_4^+(aq) + OH^-(aq)$

$$K = \frac{[NH_4^+][OH^-]}{[NH_3]} = \frac{\text{products}}{\text{reactants}}$$



ammonia

The Meaning of K

1. Can tell if a reaction is product-favored or reactant-favored.

For $N_2(g) + 3\ H_2(g) \leftrightharpoons 2\ NH_3(g)$

$$K_C = \frac{[NH_3]^2}{[N_2][H_2]^3} = 3.5 \times 10^8$$

> 1

$\frac{A}{B} = 1$

< 1

Conc. of products is **much greater** than that of reactants at equilibrium. The reaction is strongly **product-favored**.

The Meaning of K

For $AgCl(s) \leftrightharpoons Ag^+(aq) + Cl^-(aq)$

$K_c = [Ag^+]\ [Cl^-] = 1.8 \times 10^{-5}$

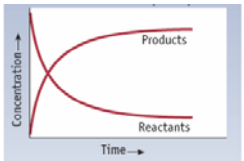
Conc. of products is **much less** than that of reactants at equilibrium.

The reaction with small K is strongly **reactant-favored**.

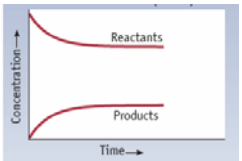
$Ag^+(aq) + Cl^-(aq) \leftrightharpoons AgCl(s)$ is product-favored.

$$K_c' = \frac{1}{[Ag^+][Cl^-]}$$

Product- or Reactant Favored



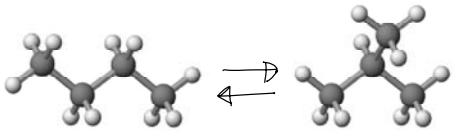
Product-favored
K > 1



Reactant-favored
K < 1

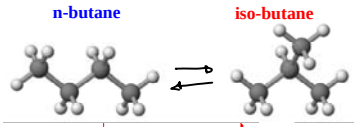
The Meaning of K

2. Can tell if a reaction is at equilibrium. If not, which way it moves to approach equilibrium.



$$K_c = \frac{[\text{isobutane}]}{[\text{butane}]} = 2.50 \text{ at } 298 \text{ K}$$

The Meaning of K



$$K = \frac{[\text{iso}]}{[\text{n}]} = 2.5$$

If [iso] = 0.35 M and [n] = 0.15 M, are you at equilibrium?

If not, which way does the reaction "shift" to approach equilibrium?

The Meaning of K

All reacting chemical systems are characterized by their REACTION QUOTIENT, Q.

$$Q = \frac{\text{product concentrations}}{\text{reactant concentrations}}$$

If Q = K, then system is at equilibrium.

$$Q = \frac{\text{conc. of iso}}{\text{conc. of n}} = \frac{0.35}{0.15} = 2.3$$

Q (2.33) < K (2.5)

Reaction is NOT at equilibrium, so [iso] must become ___↑___ and [n] must ___↓___.