Equilibrium Lecture #1

Schweitzer

What is equilibrium?

- Remember
  - Equilibrium process between to competing reactions.
  - At equilibrium the forward process is equal to the reverse process.
  - *** It appears that nothing is happening***

Practice Problem

(Ebbing14.10)

A state of dynamic equilibrium exists at constant temperature in

1. a stoppered flask half full of water
2. an open pan of boiling water.
3. a stoppered flask of a solution of sodium carbonate solution

a. 1 only
b. 2 only
c. 3 only
d. 1 and 2 only
e. 1 and 3 only

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Writing equilibrium Expressions

- 2A(s) + B(aq) <=> 2C(g) + D(aq)
  - Notice: There are now substances on both sides of the reaction.
- Kc
  - This is a K for a general reaction
  - “c” stands for general concentrations.
- $Kc = [C]^2[D]/[B]$
  - Note: The solid does not show up in Equilibrium Expression.

What is the difference between Kc and Kp

- Kc
  - Measures all units in Moles/Liter
  - Can not include pure solids and liquids

- Kp
  - Measures all units in Atmospheres
  - Only includes **gases**

Practice writing equilibrium expressions

- 2A(s) + B(aq) <=> 2C(g) + D(aq)
- Kp
  - This is a K for a general reaction
  - “p” stands for Pressure (atmospheres).
- $Kp = [C]^2/1$
  - Note: Only include gases

Write an equilibrium expression

$2A(g) + B(s) \Leftrightarrow 2C(l) + D(aq)$

Kc = $[D]/[A]^2$

Kp = $1/[A]^2$

Remember: all units are in ATM and only gases are used

Problems involving Equilibrium

- What information can a problem give you?
  - They can give you the equilibrium constant.
  - They can give you initial conditions
  - They can give you equilibrium conditions

    Note:

    - Equilibrium conditions can be put directly into the equilibrium expression.
    - THE FOLLOWING PROBLEMS ARE GOING TO BE DIFFERENT COMBINATIONS OF THIS INFORMATION. THERE ARE NOT THAT MANY DIFFERENT TYPES OF PROBLEMS KEEP TRACK...

Solving for Concentration given: K and starting materials

$$CO(g) + H_2O\ (g) \Leftrightarrow H_2(g) + CH_4(g)$$

Suppose you start with1 mol of each CO and water in a 50.0L vessel. How many moles of each substance are in the equilibrium mixture at 1000C? Kc = 0.58

What are they giving you here in this problem?

Answer

$CO(g) + H_2O\ (g) \Leftrightarrow H_2(g) + CH_4(g)$

1/50

I	.02	.02	0	0
C	-x	-x	x	x
E	(.02-x)	(.02-x)	x	x

$Kc = [H_2][CH_4]/[H_2O][CO]$

$.58 = x^2 / (.02-x)(.02-x)$ Solve for X

Notice the short cut can NOT be used in this problem

Look for alternate methods

$.58 = x^2 / (.02-x)(.02-x)$ Solve for X

$.58 = x^2 / (.02-x)^2$

Square root both sides

$\pm.76 = x/0.0200 - x$

Solve for x (x must be positive) = 0.0086

Substitute into the equilibrium expression

$CO(g) + H_2O(g) \Leftrightarrow H_2(g) + CH_4(g)$

.57	.57	.43	.43

Practice problem

- Ebbing597

Carbon monoxide and hydrogen react according to the following equation

$$CO(g) + 3H_2\ (g) \Leftrightarrow CH_4\ (g) + H_2O(g)$$

When 1 mol CO and 3 mol of H_2 are placed in a 10 L vessel at 927C and allowed to come to equilibrium, the mixture is found to contain 0.387 mol of H_2O.

What is the concentration of each substance at equilibrium and what is Kc for the reaction.

Answer

$$CO(g) + 3H_2\ (g) \Leftrightarrow CH_4\ (g) + H_2O(g)$$

	$CO(g)$	$3H_2\ (g)$	$CH_4\ (g)$	$H_2O(g)$
I.	.1M	.3M	0	0
C	-x -.0387	-3x -.1161	x .0387	x .0387
E	? .0613	? .184	? .0387	? .0387 .0387

Note: This is simply a stoichiometry problem.

.1 - .0387 = .0613

.0387 * 3 = .1161

More Practice!!!

(Ebbing603)

Hydrogen Iodide decomposes at a moderate temperature according to the following reaction

$$2HI(g) \Leftrightarrow H_2(g) + I_2(g)$$

When 4.00mol of HI was placed in a 5.00L vessel at 458C, the equilibrium mixture was found to contain 0.422 mol of $I_{2.}$ What is the value of Kc for this reaction at the specified temperature?

Answer

	$2HI(g) \Leftrightarrow H_2(g) + I_2(g)$		
I.	.8	0	0
C	-2x	+x	+x
E	.636	.0844	.0844

Plug these concentrations into Kc expression

Kc = .0201

What if they give you equilibrium concentrations?

- An ***equilibrium*** mixture of gases contains .30 mol CO, 0.10 mol of $H_{2,}$ and 0.20 mol H_2O, plus an unknown amount of $CH_{4.}$ The total volume of the system is 1 Liter. Kc for this reaction = 3.92

$$CO(g) + 3H_2(g) \Leftrightarrow H_2O(g) + CH_4(g)$$

Answer

$$CO(g) + 3H_2(g) \Leftrightarrow H_2O(g) + CH_4(g)$$

	$CO(g)$	$3H_2(g)$	$H_2O(g)$	$CH_4(g)$
I				
C				
E	.30	.10	.020	?

Note: These are all equilibrium conditions.

These can be plugged directly in the Kc expression.

$3.92 = [CH_4][.02]/[.30][.10]^3$

$CH_4 = 0.059M$

Calculating percent change

- Very often the percent change will be used to tell the extent of a reaction (amount it moves to product)
- Or they will want you to calculate % Change
- % change = Change/original x 100

Using percent change

- Reaction A(g) = 2B(g) + C(g) is ran at 100C and the initial concentration of A was .1M. Kc(A) = 1.0 E-8)
- What is the percent change of A in this reaction at equilibrium

Answer

- % change = Change/original x 100

$A(g) = 2B(g) + C(g)$

	A(g)	2B(g)	C(g)
I.	.1	0	0
C	-x	+2x	+x
E	.1-x	2x	x

$1.0E\text{-}8 = [2x]^2 [x]/.1$

$1.0E\text{-}8 = 4x^3 /.1$

Predicting the direction of a reaction using reaction quotient

- We used the reaction quotient when we predicted whether a reaction would precipitate or not.
- If $Q > K$ Then the mixture has too much product and will therefore shift toward reactant.
- If $Q < K$ Then the mixture has too much reactant and will therefore shift toward product.

Practice

(Ebbing610)

A 50.0L reaction vessel contains 1.0 mol N_2 , 3.00 mol H_2 , and .500 mol of NH_3. Will more ammonia, NH_3 be formed or will it dissociate when the mixture goes to equilibrium?

The equilibrium constant(k) = 0.500

Answer

- $Q = [NH_3]^2 /[N_2][H_2]^3$
- $Q = (0.0100)^2/(0.0200)(0.0600)^3$
- $Q = 23.1$

And

$K = 0.500$

So

$Q > K$ So we have to much product.

Reaction will shift back toward reactant