7.1 RECOGNIZING EQUILIBRIUM

Equilibrium:

- reversible reaction ($\Leftrightarrow$ or) $\rightleftarrows$

E.g. 1. A puddle on road –

2. Water in a jar (sealed) –

-

3. Place some $CuSO_4 \cdot 5H_2O$ in water -

▪

Equilibrium = saturation
rate of dissolution = rate of crystallization.
? Temp increase ?

Thought Lab p. 325

Conditions that Apply to all Equilibrium Systems

3 physical processes the reach equilibrium:

1.
2.
3.

2 chemical processes that reach equilibrium:

1. Reaction in which reactants and products are in same phase
   eg. 2 gases - reach **homogeneous** equilibrium

2. Reactants and products with different phases

4 conditions that apply to all equilibrium systems

1.

2.

Summary: ∴

3. Equilibrium can only be reached in a closed system.

Therefore has to be at a constant temperature.

e.g. closed bottle of pop - $CO_{2(g)}$ and $CO_{2(aq)}$

4. Equilibrium can be approached from either direction

e.g. $H_{2(g)} + Cl_{2(g)} \rightleftarrows 2HCl_{(g)}$

7.3 THE EQUILIBRIUM CONSTANT

Law of Chemical Equilibrium:

eg. $N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$

Elementary steps

forward reaction:

reverse reaction;

rate$_f$ =

rate$_r$ =

at equilibrium: forward rate = reverse rate

ratio of rate constants is another constant

K_{eq} –

K_c

*

therefore it can be used for any reaction

$aP + bQ \rightleftharpoons cR + dS$

▪

▪

e.g.

$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$

find K_c

p.336 practice 1-5

The Equilibrium Constant and Temperature

- if a system at equilibrium has a reactant added,
- K_{eq} depends on temp.
-
- Kc is calculated using concentrations at equilibrium

- eg. A mixture of nitrogen and chlorine gases was kept at a certain temp. in a 5.OL reaction flask

  $N_{2(g)} + 3Cl_{2(g)} \rightleftarrows 2NCl_{3(g)}$
- at equilibrium $N_{2(g)}$ = 0.0070 mol,
  $Cl_{2(g)}$ = 0.0022 mol
  $NCl_{3(g)}$ = 0.95 mol
- Calculate Kc

Determine the [ ] of each.

$[N_2]$ =

$[Cl_2]$ =

$[NCl_3]$ =

K_c =

p.338 practice 6-10

Equilibrium Calculations

Use ICE table to assist with these calculations
I –
C –
E –

$CO_{(g)} + H_2O_{(g)} \rightleftharpoons H_{2(g)} + CO_{2(g)}$

At 700 K the Kc = 8.3. suppose that you start with 1.0 mol of $CO_{(g)}$. and 1.0 mol of $H_2O_{(g)}$ in a 5.0 L container. What amount of each substance will be present in the container when the gases are at equilibrium, at 700 K?

Required:

Step 1 -

Step 2 - Set up ICE table
Let Δ [ ] of reactants = "x"

[ ]				
Initial				
Change				
Equil.				

Step 3-

Kc =

eg.#2 What is the equilibrium concentration of a reaction mixture if we start with 0.500 mols of each of H_2 and I_2 in a 1.00 L vessel? Kc = 49.7 at 458 K?

Use an ICE table Let x be the [ ] of reactants

[ ]			
Initial			
Change			
Equil.			

Write the expression for Kc

Solving an Equilibrium Expression Using a Quadratic Equation

The following reaction has an equilibrium constant of 25.0 at 1100 K

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

2.00 mol of $H_{2(g)}$ and 3.00 mol of $I_{2(g)}$ are placed in a 1.oo L reaction vessel at 1100 K. What is the equil. conc. Of each gas?

Set up an ICE table:

[ ]	H_2	$I_{2(}$	HI
Initial	2.00	3.00	0
Change	-x	-x	+2x
Equil.	2.00-x	3.00-x	2x

Write the expression for Kc

$0.840x^2 - 5.00x + 6.00 = 0$

$ax^2 + bx + c = 0$ has the following solution

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

x= 4.3 and x = 1.7 (4.3 is not possible)

From the ICE table we are able to calculate the equil. [ ]
[H2] = 0.3 mol/L
[I2] = 1.3 mol/L
[HI] = 3.4 mol/L

p.347 Practice #11-15

QUALITATIVELY INTERPRETING THE EQUILIBRIUM CONSTANT

When Kc > 1

-
- "Equilibrium lies far to the right"
-
-
-
-
- "Equilibrium lies far to the left"
- [products] < [reactants]

ie. When K is smaller than 10^{-10} products are not formed

e.g. $CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$

at 870 K Kc = 0.20 at 370 K Kc = 4.6×10^{7}

At which temp. is reaction more favourable?
(more products formed)

Practice p. 349 - 350	#16 - 20

THE MEANING OF A SMALL EQUILIBRIUM CONSTANT

-
-
- ∴ possible to use approximations and ignore x (change)

To help decide if you can use approximations

divide initial conc/Kc

if answer is > 500 ⇒
if answer is between 100-500 maybe
if answer is < 100

e.g. $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

0.085 mol/L $N_{2(g)}$ 0.038mol/L $O_{2(g)}$
Kc = 4.2×10^{-8}

What is the [NO] at equil.?

$\frac{\text{initial conc.}}{\text{Kc}}$ = 0.038/ 4.2 x 10^{-8} = 9.0 x 10^{5}

[ ]	$N_{2(g)}$	$O_{2(g)}$	$2NO_{(g)}$
Initial			
Change			
Equil.			

Practice p. 352 # 21-25

7.4 PREDICTING THE DIRECTION OF A REACTION

- How is it possible to predict the direction in which a reaction must proceed to reach equilibrium?

-

- for a reaction

$$aP + bQ \rightleftharpoons cR + dS$$

If Qc = Kc $\Rightarrow$

If Qc > Kc $\Rightarrow$

If Qc < Kc $\Rightarrow$

e.g. In the Haber process for manufacturing ammonia, nitrogen and hydrogen combine in the presence of a catalyst.

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

At 500 ^{o}C Kc = 0.40. The following concentrations are given $[N_2]$ = 0.10 mol/L, $[H_2]$ = 0.30 mol/L, $[NH_3]$ = 0.20 mol/L. Is the mixture at equilibrium? If not which way will the reaction have to shift to reach equilibrium?

Solve for Qc:

Practice p. 356 #26 – 28

Le Châtelier's Principle

Le Châtelier's Principle states that when a stress is applied to a system at equilibrium, the system readjusts itself by favouring the forward or reverse reaction so as to relieve the stress and re-establish equilibrium. The term stress applies to any imposed factor which upsets the balance in rates of the forward and reverse reactions. Remember that as long as the temperature remains constant, the value of K_c will **NOT CHANGE** when equilibrium has been re-established. (The individual concentrations of the reactants/products may change, but K_c will not.)

Consider the following gaseous system at equilibrium:

$$2\ SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\ SO_{3(g)} + \text{heat}$$

For each of the changes below, indicate how the equilibrium system will respond in order to relieve the stress. That is, will the forward or the reverse reaction predominate until equilibrium has been re-established? Briefly justify your answer.

a) $[SO_2]$ is increased.

b) SO_3 is removed from the container.

c) The temperature of the system is decreased.

d) The volume of the container is decreased.

e) Helium gas is added at constant volume so that the total pressure is increased.

f) Helium is added, but the total pressure is kept constant.

g) A catalyst is added.

H.W. p.366 #29-33