# General & organic Chemistry

Lecture-7

L7: Ch4 cont
+ Ch13

## Chemical Equilibrium

# ★ General & organic chemistry , L7: Ch4 cont + Ch13

★**Redox reactions** : Reaction in which one or more electrons are trasferred

where one atom is oxidized and the other is reduced

oxidation state

Ex: $2\overset{0}{Na}_{(s)} + \overset{0}{Cl_2}_{(g)} \rightarrow 2\overset{+}{Na}\overset{-}{Cl}_{(s)}$

loss of $\bar{e}$, oxidation

gain of $\bar{e}$, reduction

Rules of assigning oxidation states

① oxidation state of an atom in an element = 0 ⇒ ex: $\overset{0}{Zn}$, $\overset{0}{Pb}$

② oxidation state of monoatomic ion = Charge of ion ⇒ ex: $Cu^{2+}$, $Mg^{2+}$

③ oxygen's oxidation state is = −2 in covalent compounds except in Peroxides where its = −1 ⇒ ex: $H_2O_2$ ↳ −1
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④ Hydrogen's oxidation state = +1 in covalent compounds except when in compounds with groups 1A, 2A, 3A its −1
↳ with Metals

⑤ Fluorine = −1 in compounds

⑥ sum of oxidation states in compounds = 0 ⇒ $H_2Cr_2O_7^{\div}$

⑦ Sum of oxidation states = charge of the ion in ions

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Calculating oxidation states:

$H_2Cr_2O_7$ Cr = +6
↳ +1 ↳ n ↳ −2

$2(+1) + 2(n) + 7(-2) = 0$

$2 + 2n - 14 = 0$

$2n = 12$

$\boxed{n = +6}$

$\overset{0}{PCl_5}$
↳ −1

$1(n) + 5(-1) = 0$

$\boxed{n = +5}$ P = +5

$CO_3^{2-}$

$1(n) + 3(-2) = 2-$

$n = -2 + 6$

$\boxed{n = +4}$

C = +4

①

## ★ Redox Characteristics :

★ Transfer of electrons

★ Transfer may occur to form ions

- Oxidation : increase in oxidation state (oxidation number)
  [Loss of electrons]
  and is called ~~a~~ reducing agent
  because it causes the other substace
  to be reduced

- Reduction : decrease in oxidation state (oxidation number)
  [gain of electrons]
  and is called an oxidizing agent
  bc it causes the other substance
  to be oxidized

decrease in oxidation number
, reduction , oxidizing agent

Ex : $\overset{0}{Zn}_{(s)} + 2\overset{+}{H}\overset{-}{Cl}_{(aq)} \longrightarrow \overset{2+}{Zn}\overset{-}{Cl}_{2(aq)} + \overset{0}{H}_{2(g)}\uparrow$

increase in oxidation number
, oxidation , reducing agent

didn't change

$\overset{+6}{\underline{Cr_2}}\underset{-2}{O}_7^{2-}{}_{(aq)} + 2\overset{-2}{O}\underset{+1}{H}^{-}_{(aq)} \longrightarrow 2\overset{+6}{\underline{Cr}}\underset{2-}{O}_4^{2-}{}_{(aq)} + \overset{+1}{\underline{H_2}}\overset{2-}{O}_{(L)}$

didn't change　didn't change

This is NOT
a Redox reaction
- it is an Acid-Base reaction
- nothing changed in the oxidation states

$2\overset{1+}{\underline{Cu}}\overset{-}{Cl}_{(aq)} \longrightarrow \overset{2+}{Cu}\overset{-}{Cl}_{2(aq)} + \overset{0}{\underline{Cu}}_{(s)}$

oxidation number increase
oxidize , reducing agent

reduction , oxidating agent

self oxidation reduction reaction
- a part of substuce oxidized and the rest was reduced

## ★ Balancing oxidation-Reduction reactions by oxidation states

① write unbalanced equation

② Determine the oxidation states of all atoms in the reactants and Products

③ show electrons gained or lost using (tie lines)

④ use coefficients to equalize the electrons gained and lost

⑤ Balance the rest of the equation by inspection

⑥ add appropriate states (s, L, g, aq --)

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Balance this equation:

solid Zinc and aqueous hydrochloric acid to Produce aqueous Zinc (II) chloride & hydrogen gas

gained 1e⁻, reduced

$$\overset{0}{Zn}_{(s)} + \underline{\underline{2}}\overset{+}{H}\overset{-}{Cl}_{(aq)} \longrightarrow \overset{2+}{Zn}\overset{-}{Cl}_{2\,(aq)} + \overset{0}{H}_{2(g)}\uparrow$$

Lost 2 e⁻, oxidized

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gained 2e⁻ ⇝ x 7

excersise: $\overset{-3}{C}_2\overset{+}{H}_{6(g)} + \overset{0}{O}_{2\,(g)} \longrightarrow 2\overset{+4}{C}\overset{-2}{O}_{2(g)} + \overset{+1}{H}_2\overset{-2}{O}_{(g)}$

Lost 7e⁻ ⇝ x 2

$$2\overset{3-}{C} + 6H^{+} + 2O_2 \longrightarrow 2\overset{+4}{C} + 2\overset{2-}{O} + 3.2\overset{+}{H} + O^{2-}$$

~~$2C_2H_6 + 7O_2 \longrightarrow$~~

$$2\,C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$$

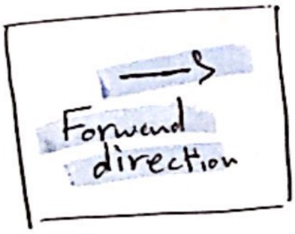
# Ch 13 : Chemical Equilibrium

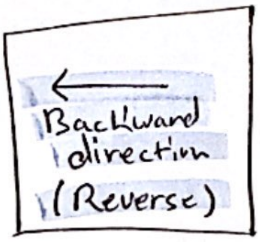
## Chemical Equilibrium :

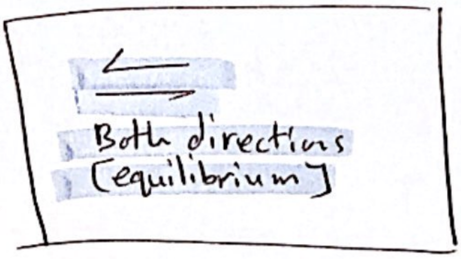
- Describes reactions that do NOT go to Completion [Not all reactants will become Products ]

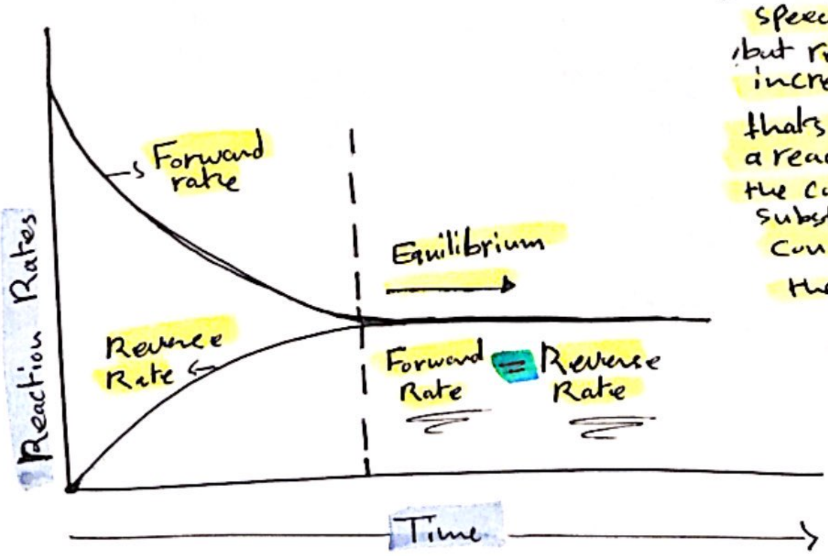
- After Equilibrium is reached, none of the reactants or Products has a concentration of Zero

Reactants ⇌ Products









with time, Forward Rate speed decrease, but reverse Rate increases

thats because the Rate of a reaction depends on the concentration of substance & when concentration decrease the Rate decreases

The changes in time in the rates of forward & Reverse Reactions

★ Equilibrium doesn't mean same Concentration for reactants & products

# ★ Chemical Equilibrium ★

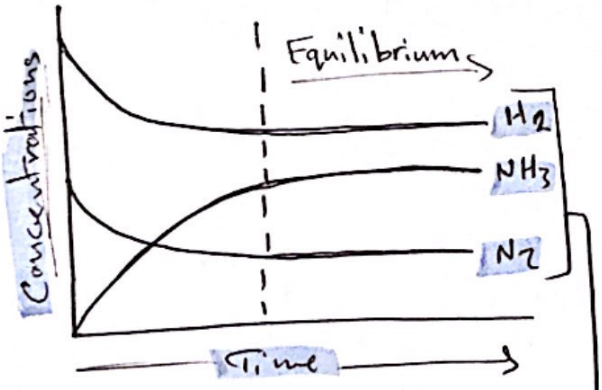
- A state of the system where the concentrations of all reactants & products remain Constant with time and NOT necessarily equal

- Forward & Reverse reactions have the same speed

- The equilibrium is Dynamic

  ↳ Means that [concentrations reach levels where the rate of the forward reaction is equal to the rate of the reverse reaction]

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



This is the change of concentration with time

at time = 0 concentration of Product ($NH_3$) is Zero and increase with time

↳ See how at equilibrium the concentration is constat and NOT equal meaning if some time Passed and Some reactats turned to Products, in return some Products will turn back to reactant's to keep the concentration constut

# ★ The equilibrium Constant ★

- Considering the following reaction at Equilibrium :

$$jA + kB \rightleftharpoons mC + nD$$

$$K = \frac{[C]^m \cdot [D]^n}{[A]^j \cdot [B]^k}$$

j, k, m & n represent **Coeffeciects**

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to know if the reaction in/at Equilibrium is Shifted to the forward or Reverse direction more [mens, does most of the reaction gives Products at equilibrium, or is it more reactants ]

we represent that through the :

$$\rightarrow K\text{ equilibrium} = \frac{\text{Concentration of Products}}{\text{Concentra' of Reactants}} \text{ to the orders of each}$$

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Ex: Consider the following equilibria :

$$H_2O_{(g)} + CO_{(g)} \longrightarrow H_{2(g)} + CO_{2(g)} \quad : K = \frac{[H_2] \cdot [CO_2]}{[H_2O] \cdot [CO]}$$

} if we multiPly by 2

$$2H_2O_{(g)} + 2CO_{(g)} \rightarrow 2H_{2(g)} + 2CO_{2(g)} \quad : K' = \frac{[H_2]^2 \cdot [CO_2]^2}{[H_2O]^2 \cdot [CO]^2} = \left(\frac{[H_2][CO_2]}{[H_2O][CO]}\right)^2 = K^2$$

} if we reverse the first reaction

$$H_{2(g)} + CO_{2(g)} \rightarrow H_2O_{(g)} + CO_{(g)} \quad : K'' = \frac{[H_2O] \cdot [CO]}{[H_2][CO_2]} = \frac{1}{K}$$

* Conclusions about the equilibrium expression :

- Equilibrium expression for a reaction is the reciprocal of that for the reverse reaction
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$$K' = \frac{1}{K}$$

- when the balanced equation for the reaction is multiplied by a factor of n, the equilibrium expression for the new reaction is the original expression raised to the n-th Power

$$K_{new} = (K_{original})^{n}$$

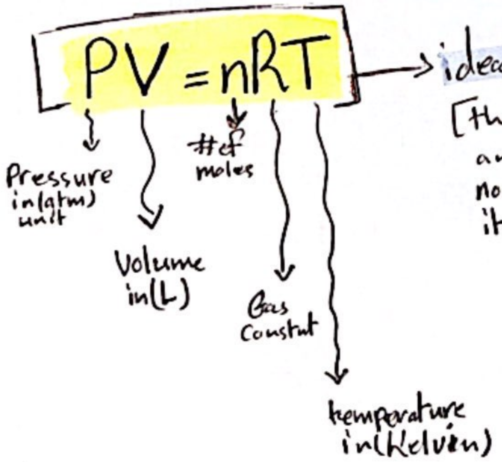
- K values are usually written without units
  ↳ it is a temperature variable so it has the same value at a given temperature regardless of the amounts of reactants or products present initially

## ★ Equilibrium Expressions involving Pressures

- K or Kc is the Equilibrium expression in terms of [Concentrations]
- while K'p is the Equilibrium expression in terms of [Partial Pressures] of the gaseous constituents of the reaction
  ↳ must be Gas

thats because when dealing with substances in the gaseous state its easier & better expressing its concentration using Pressure rather than molarity, So we use K'p

So we must find a relation between Concentration and Pressure



→ ideal gas law
[there is no such thing as an ideal gas which has no bonding at all between its particles]

$$R = 0.08206 \frac{L\cdot atm}{mol\cdot K}$$
Gas Constant

To create a relation :

$$\underset{[\ ]}{\text{Concentration}} = \frac{n}{V}$$

$$\frac{PV}{V} = \frac{nRT}{V}$$

$$P = \frac{n}{V}RT$$

$$\boxed{P = [\ ]RT}$$

$$\text{So } [\ ] = \frac{P}{RT}$$

Ex:

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

$$\underbrace{K = \frac{[NH_3]^2}{[N_2][H_2]^3} \qquad K_p = \frac{(P_{NH_3})^2}{(P_{N_2})(P_{H_2})^3}}$$

to create a relation

$$P = [\,]RT$$

$$① \; K_p = \frac{([NH_3]RT)^2}{([N_2]RT)([H_2]RT)^3} = ② \; \frac{[NH_3]^2\cancel{RT^2}}{[N_2]\cancel{RT}\cdot[H_2]^3RT^{\cancel{3}}}$$

$$③ \; K_p = \frac{[NH_3]^2}{[N_2][H_2]^3}\cdot(RT)^{2-}$$

$$④ \; K_p = K\cdot(RT)^{2-} \Longrightarrow ⑤ \; K_p = \frac{K}{(RT)^2} \text{ or } K = K_p\cdot(RT)^2$$

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So in general

$$K_p = K_c\cdot(RT)^{\underline{\underline{\Delta n_g}}} \rightarrow \Delta n_g = n_{\substack{\text{moles}\\\text{Product}}} - n_{\substack{\text{moles}\\\text{reactant}}}$$

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

↳ 4 mol $\qquad$ 2 mol

3+1

$\Delta n_g = 2-4 = -2$

So $K_p = K_c\cdot(RT)^{-2}$

*So The general map is :

* $P = [\ ]RT$

$$xX_{(g)} + yY_{(g)} \rightleftharpoons zZ_{(g)} + wW_{(g)}$$

$$K_P = \frac{(P_W)^w \cdot (P_Z)^z}{(P_Y)^y \cdot (P_X)^x} \quad \& \quad K = \frac{[W]^w \cdot [Z]^z}{[X]^x \cdot [Y]^y}$$

Putting them in relation :

$$K_P = \frac{[W]^w \cdot [Z]^z}{[X]^x \cdot [Y]^y} \cdot (RT)^{z+w-y-x}$$

$$\left.\begin{aligned} \Delta n_g &= n_p - n_R = w+z-(x+y) \\ &= w+z-x-y \end{aligned}\right\}$$

NoTe : we take those who are in the gaseous state.

Therefore : $K'_p = K'(RT)^{\Delta n_g}$

For example, if there was another product that isn't a gas

Ex :

$$xX_{(g)} + yY_{(g)} \rightleftharpoons wW_{(g)} + zZ_{(g)} + qQ_{(s)}$$

$$\Delta n_g = w+z-x-y$$

we dont include (q) bc its not gas

Example:

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

using the value $K'_p = 3.9\times10^4$

Calculate $K'_c$ if $T = 35°C$

$C° \rightarrow K°$

solution:-

$K'_p = K'_c (RT)^{\Delta ng}$

$T_{K} = 35° + 273.15$

$T_{K} = 308.15° K$

$3.9\times10^4 = K'_c (0.08206 \cdot 308.15)^{2-}$

$\boxed{K'_c = 2.49\times10^7}$

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we notice:

- $K_p < K'$ when [$\Delta ng$ is negative, ($\Delta ng < 0$)]

  Ex: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \Rightarrow \Delta ng = -2$

  (decrease in n of gaseous product) $K'_p = K'_c (RT)^{-2}$

- $K'_p = K'$ when $\Delta ng = 0$

  Ex: $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)} \Rightarrow \Delta ng = 0$

  $K'_p = K'_c (RT)^0$

  $K'_p = K'_c$

- $K'_p > K'$ when [$\Delta ng > 0$, (is Positive)]

  Ex: $N_2O_{2(g)} \rightleftharpoons 2NO_{2(g)} \rightarrow \Delta ng = 1$

  $K_p = K_c (RT)$

  (increase in n of gaseous product)