CHEMISTRY TOPIC 1 CHEMICAL EQUILIBRIUM : FUNDEMENTALS

JIE YOUNG 2025

Learning Objectives

- Define Reversible reaction
- Define Dynamic/Chemical Equilibrium
- Understand, state and apply the concept/characteristics of Equilibrium

Reversible Reaction

-Chemical Reaction that can take place in both Directions

$$A(g) + B(g) \rightleftharpoons C(g) + D(g)$$

- Left to Right Reaction = Forward Reaction
- Right to Left Reaction = Reverse Reaction

Chemical Equilibrium

-Chemical Reaction that has the same Rate of Reaction in both Forward and Reverse Direction

$$A(g) + B(g) \rightleftharpoons C(g) + D(g)$$

- Concentrations of Reactant & Product remains Constant

Example of Reversible Reaction

- Dissociation of Nitrogen Dioxide
  $$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$
- Contact Process
  $$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$
- Haber Process
  $$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Concept/Characteristics of Equilibrium

- Achievable in Closed system only
- Rate of Forward and Reverse Reaction is Constant
- Concentration is Constant
- Final Equilibrium Position is always Equal Regardless of Starting Point

Dynamic Equilibrium

$$A(g)+B(g)\rightleftharpoons C(g)+D(g)$$

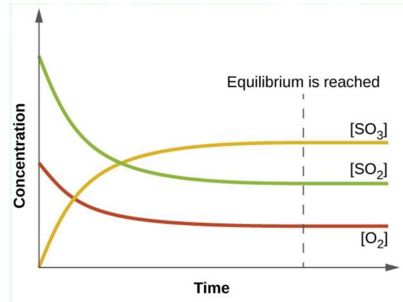
- A & B will be Reactant and C & D will be Product
- When reaction starts, Rate of Forward Reaction will decrease simultaneously with Rate of Reverse Reaction increasing
- At certain point, ROR of Reactant and Product will become Equal, and both reaction will continue indefinitely.
- Chemical Equilibrium is achieved dynamically and be called Dynamic Equilibrium

Key Notes:
When A&B reacts and form C&D, Concentration of A&B decrease, causing ROR to decrease, and as more C&D formed, concentration of C&D increase

Example of Dynamic Equilibrium

- Contact Process

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$



CHEMISTRY TOPIC 1 CHEMICAL EQUILIBRIUM :EQUILIBRIUM LAWS AND CONSTANTS

JIE YOUNG 2025

Learning Objectives

- Define equilibrium law
- Distinguish equilibrium constant (Kc and Kp)
- Write equilibrium constant expression (Kc and Kp) for homogeneous and heterogeneous reactions

Equilibrium Law

For any equilibrium at Constant Temp,Product of Concentration of Product to the power of coefficient divide by Product of Concentration of reactant to the power of coefficient equals to equilibrium constant

$$aA(g) + bB(g) \rightleftharpoons cC(g) + dD(g)$$

Key notes:
It is possible for some equilibrium constant to have no units
#Difference between Kc and Kp:

- Kc: Concentration
- Kp: Pressure

Equilibrium Constant (Kc)

$$aA(g) + bB(g) \rightleftharpoons cC(g) + dD(g)$$

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

#Concentration
Unit = mol/dm3

Equilibrium Constant (Kp)

$$aA(g) + bB(g) \rightleftharpoons cC(g) + dD(g)$$

$$K_p = \frac{[P_C]^c[P_D]^d}{[P_A]^a[P_B]^b}$$

#Partial Pressure
Unit = atm

Expression Constant for Homogenous and Heterogenous Reactions

Homogenous Equilibrium: All Product and Reactant is in the same phase(State)
Heterogenous Equilibrium: Either one in both Product and Reactant is in different phase(State)

Homogenous Example:

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

$$K_c = \frac{[HI]^2}{[H]^2[I]^2}$$

Heterogenous Example:

#Solid and liquid is neglected(they have constant concentration)

$$H_2O(g) + C(s) \rightleftharpoons H_2(g) + CO(g)$$

$$K_c = \frac{[H_2]^1[CO]^1}{[H_2O]^1}$$

CHEMISTRY TOPIC 1 CHEMICAL EQUILIBRIUM :EQUILIBRIUM LAWS AND CONSTANTS(CONT.)

JIE YOUNG 2025

Learning Objectives

- Calculate equilibrium constant (Kc and Kp) and perform other calculations related to equilibrium constant (Kc and Kp)
- Define, determine and apply degree of dissociation

Position of Equilibrium

Key note:

- Equilibrium Constant(k) is important(Based on Equi Law)
- k Large(>1) = Product more than Reactant(Right)
- K Small(<1) = Reactant more than Product(Left)

General Methods to find Kc

1. Balance Eq and State the State
2. Form the Eq
3. Get the Concentration Value of each Product and Reactant
4. Sub in the Eq

ICE Tables

$$aA(g) + bB(g) \rightleftharpoons cC(g) + dD(g)$$

Reaction	aA	bB	cC	dD
Initial				
Change				
Equilibrium				

Key steps:

1. List down the Initial Molarity of what's available
2. Set change as ax/-ax. a will be coefficient of the balanced Eq
3. In a left to right Eq, left side changes is always –ve, right side always +ve
4. Initial can be 0 too if it doesn't exists at first
5. Derive the unknown and find change of mol
6. Divide change of mol with Volume of Solution to find Concentration
7. Use it to find Kc
8. Vice versa with Partial Pressure

Degree of Association

Fraction of a substance dissociated

$$\alpha = \frac{Change\ of\ Mole}{Initial\ mole}$$

Where, α = 1 means there is a complete dissociation(100%)

Pressure Revision

$$P_{Total} = P_A + P_B + \cdots$$

$$X_A = \frac{Mole_A}{Mole_{Total}}$$

$$P_A = X_A P_{Total}$$

CHEMISTRY TOPIC 1 CHEMICAL EQUILIBRIUM :CALCULATION AND RELATIONSHIPS

JIE YOUNG 2025

Learning Objectives

- Understand the relationship between Kc and Kp and perform calculation using the formula Kc(RT)Δn=KP
- Write reaction quotient, Q expression
- Calculate and apply reaction quotient, Q in prediction of direction of a chemical equilibrium

Relationship between kc and kp

Concentration and Partial Pressure can be related using the formula of Gas Laws

$$PV = nRT$$
$$P = \frac{n}{V}RT$$
$$M = \frac{P}{RT}$$

Given,

$$aA(g) + bB(g) \rightleftharpoons cC(g) + dD(g)$$

Substituting M(Concentration) into Kc, we get

$$K_c = \frac{[\frac{P_C}{RT}]^c[\frac{P_D}{RT}]^d}{[\frac{P_A}{RT}]^a[\frac{P_B}{RT}]^b}$$

Thus,

$$K_c(RT)^{\Delta n} = K_P$$

Where dn = Total num of coefficient of product - reactant

Example of Relation between Kc and Kp

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(Haber Process)

The equilibrium constant Kp for the following reaction is 7.73 × 10-4 atm-2 at 350 C. What is the value of Kc for the reaction at the same temperature? Given that (R = 0.0821 L atm K-1 mol-1.)

Key steps:

1. List out the formula and find the suitable variable to sub in:

$$K_c(RT)^{\Delta n} = K_P$$
$$R = 0.0821\ L\ atm\ K^{-1}mol^{-1}$$
$$K_P = 7.73 \times 10^{-4} atm^{-2}$$
$$T = (350 + 273)k$$
$$\Delta n = 2 - (1 + 3)$$

2. Solve the Equation

3. $K_c = \frac{7.73 \times 10^{-4} atm^{-2}}{(0.0821\ L\ atm\ K^{-1}mol^{-1})(623k)^{2-(1+3)}}$

$$K_c = 2.02 mol^{-2}L^{-2}$$

Reaction Quotient

Key Notes:

- It is used to predict the direction of Chemical Reaction
- Formula is same as Equilibrium Constant
- HOWEVER, The concentration is obtained at initial point
- Usage: To Compare with K value

K Value	Direction
Q < K	Forward
Q = K	Equilibrium
Q > K	Reverse

Question involving Reaction Quotient

Key steps:

1. Find the initial Concentration(Derive if it's not given)
2. Sub into the Equation
3. Compare it with the K value table

CHEMISTRY TOPIC 1 CHEMICAL EQUILIBRIUM : LE CHATELIER AND FACTORS AFFECTING CHEMICAL EQUILIBRIUM

JIE YOUNG 2025

Learning Objectives

- Define Le Chatelier's principle
- Determine the factors affecting position and equilibrium constant of a chemical equilibrium
- Describe the effect of concentration, pressure, temperature, addition of inert gas and catalyst on chemical equilibrium
- Explain and understanding the importance of chemical equilibrium in the chemical industry.

Le Chatelier's Principle

If Chemical Equilibrium experience a change in Concentration, Pressure and Temperature, the equilibrium position will be shifted to counteract the effect until a new equilibrium is reached

Factors Affecting Position of Chemical Equilibrium:

- Concentration
- Pressure
- Temperature

Effects of Concentration

- Concentration of Reactant increase, Equilibrium shift to the right(Forward Reaction)
- Reactant still decreases while Product increases at the same rate(Kc remains unchanged)

Effects of Temperature

- Temperature increase, shift to endothermic reaction(Concentration of Product increase, Reactant decrease, Kc Increase)
- Temperature decrease, shift to exothermic reaction(Concentration of Product decrease, Reactant increase, Kc Decrease)
- Forward and Reverse Reaction changed differently, so Kc will be changed

Effects of Pressure

- Affects Gas only
- Change of Partial Pressure = Effect of Concentration
- External Pressure increase, shift to lower number of mole(left in forward reaction),Kc remains unchanged
- If change of coefficient between product and reactant = 0, no effect will happen

Effects of inert gas

- At Constant Pressure, Position of equilibrium will shift to higher number of mole(right in forward reaction)
- At Constant Volume, no changes on position of equilibrium(number of total molecule and pressure rises at the same rate)

Effects of Catalyst

- Forward and Reverse Reaction increases at the same rate
- No changes on Equilibrium position

Factors	Equilibrium
Concentration	Shift
Temperature	Shift and Kc Changed
Pressure	Shift
Catalyst	No effect

Industrial Importance

- Max Product, least waste, least time, least cost

Ex: Haber Process to make ammonia

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

- Formation favours Low T(Forward reaction is Exothermic to right) and High P(change of coefficient exists)
- Using catalyst makes the T high and increase rate of reaction
- Optimum pressure at 200 atm is used to ensure safetiness and lower cost of maintenance