CHAPTER 12: Chemical Equilibrium

Part 1:-What is equilibrium?

- Chemical equilibrium is a state in which the forward and reverse reactions balance each other because they take place at equal rates.

Equilibrium is a state of action, not inaction.

A reversible reaction is a chemical reaction that can occur in both the forward and reverse directions, such as the formation of ammonia. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The law of chemical equilibrium states that at a given temperature, a chemical system might reach a state in which a particular ratio of reactant and product concentrations has a constant value

The value of **Keq** is constant only at a specified temperature.

$K_{eq} > 1$: Products are favored at equilibrium

$K_{eq} < 1$: Reactants are favored at equilibrium

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

- This reaction is a homogeneous equilibrium, which means that all the reactants and products are in the same physical state.

The Equilibrium Constant Expression

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

[A] and [B] are the molar concentrations of the reactants. [C] and [D] are the molar concentrations of the products.

The exponents *a*, *b*, *c*, and *d*, are the coefficients in the balanced equation.

The equilibrium constant expression is the ratio of the molar concentrations of the products to the molar concentrations of the reactants with each concentration raised to a power equal to its coefficient in the balanced chemical equation.

- When the reactants and products are present in more than one physical state, the equilibrium is called a heterogeneous equilibrium. $C_2H_5OH(l) \rightleftharpoons C_2H_5OH(g)$.

•For a given reaction at a given temperature, K_{eq} will always be the same regardless of the initial concentrations of reactants and products.

1 **A reaction that occurs in both the forward and reverse directions …**

CH 12 **A** Complete reaction **B** Reversible reaction **C** Incomplete reaction **D** Imbalanced reaction

A reversible reaction is a chemical reaction that can occur in both the forward and reverse directions →B

2 **The state in which the forward and reverse reaction rates are equal ...**

CH 12 **A** Chemical equilibrium **B** Active site **C** Equivalence **D** Standard reaction

Chemical equilibrium is a state in which the forward and reverse reactions balance each other because they take place at equal rates. →A

3 **At chemical equilibrium the rates of the forward and reverse reactions is ...**

CH 12 **A** High **B** Zero **C** Equal **D** Different

Chemical equilibrium is a state in which the forward and reverse reactions balance each other because they take place at equal rates. →C

4 **The value of the equilibrium constant is constant for a given ____.**

CH 12 **A** Temperature **B** Pressure **C** Volume **D** Density

The value of K_{eq} is constant only at a specified temperature. →A

5 **A … equilibrium, which means that all the reactants and products are in the same physical state.**

CH 12 **A** Homogeneous **B** Heterogeneous **C** Endothermic **D** Exothermic

A homogeneous equilibrium, which means that all the reactants and products are in the same physical state. →A

6 **The equilibrium constant of the reaction: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$**

CH 12 **A** $K_{eq} = \frac{[HI]}{[H_2]^2[I_2]}$ **B** $K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$ **C** $K_{eq} = \frac{[HI]}{[H_2][I_2]}$ **D** $K_{eq} = \frac{[HI]}{[H_2][I_2]^2}$

$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$ →B

7 **Numerical value of the ratio of product concentrations to reactant concentrations ...**

CH 12 **A** Reaction order **B** Reaction rate constant **C** Equilibrium constant **D** Interaction reaction

Numerical value of the ratio of product concentrations to reactant concentrations is Equilibrium constant →C

8 **If the reactants' concentration is greater than the products' concentration at equilibrium then ...**

CH 12 **A** $K_{eq} < 1$ **B** $K_{eq} = 1$ **C** $K_{eq} > 1$ **D** $K_{eq} \geq 1$

The value of Keq is constant only at a specified temperature.

Keq > 1: Products are favored at equilibrium

Keq < 1: Reactants are favored at equilibrium →A

9 **If the products' concentration is greater than the reactants' concentration at equilibrium then ...**

CH 12 **A** $K_{eq} < 1$ **B** $K_{eq} = 1$ **C** $K_{eq} > 1$ **D** $K_{eq} \geq 1$

The value of Keq is constant only at a specified temperature.

Keq > 1: Products are favored at equilibrium

Keq < 1: Reactants are favored at equilibrium →C

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Part 2: Factors Affecting Chemical Equilibrium

• Le Châtelier's Principle was proposed in 1888 and states that if stress is applied to a system at equilibrium, the system shifts in the direction that relieves the stress.
• Stress is any kind of change in a system that upsets the equilibrium.
• Adjusting the concentrations of either the reactants or the products puts stress on a system in equilibrium.
- Adding reactants increases the number of effective collisions between molecules and upsets the equilibrium. The equilibrium shifts to the right to produce more products.
• The addition or removal of a reactant or product shifts the equilibrium in the direction that relieves the stress.

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

Equilibrium shifts to the right.

1. $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ — Add a reactant: $CO(g)$
2. $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ — Remove a product: $H_2O(g)$

Equilibrium shifts to the left.

3. $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ — Remove a reactant: $CO(g)$
4. $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ — Add a product: $H_2O(g)$

• Increasing pressure shifts the system to the right, and more products are formed.
• Changing the volume (and pressure) of an equilibrium system shifts the equilibrium only if the number of moles of gaseous reactants is different from the moles of gaseous products.
• If the number of moles is the same on both sides of the balanced equation, changes in pressure and volume have no effect on the equilibrium. When the volume of the reaction vessel is decreased, the equilibrium position shifts towards whichever side has fewer total moles of gases. Changes in temperature alter the equilibrium position and the equilibrium constant.
• If heat is added to an equilibrium system, the equilibrium shifts in the direction in which the heat is used up.
• Any change in temperature results in a change in Keq.

Exothermic Reaction

Equilibrium shifts to the left.

1. $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g) + heat$ — Raise the temperature: heat

Equilibrium shifts to the right. Lower the temperature.

2. $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g) + heat$

Endothermic Reaction

Equilibrium shifts to the right.

3. $heat + N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$ — Raise the temperature: heat

Equilibrium shifts to the left.

4. $heat + N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$ — Lower the temperature: heat

• A catalyzed reaction reaches equilibrium more quickly, but with no change in the amount of product formed.

10 **Which does NOT result in a shift of t equilibrium to the right?**
CH 12
A Removing products
B Adding reactants
C Increasing concentration of reactants
D Adding products
Increasing pressure shifts the system to the right, and more products are formed. →D

11 **Any change in ____ results in a change in Keq.**
CH 12
A Temperature **B** Pressure
C Volume **D** Concentration
Any change in temperature results in a change in Keq. →A

12 **A change in ____ alters both the equilibrium position and the equilibrium constant.**
CH 12
A Pressure **B** Temperature
C Volume **D** Density
A change in temperature alters both the equilibrium position and the equilibrium constant. →B

13 **What will happen if the arrow points to the left?**
A + B ⇌ C + D + Heat
CH 12
A Temperature decreases **B** Temperature increases
C Products increase **D** Reactants decrease
Increasing temperature in exothermic reaction will shift to the left. →B

14 **Ethylene (C_2H_4) reacts with hydrogen to form ethane (C_2H_6).**
$C_2H_4(g) + H_2(g) \leftrightarrow C_2H_6(g) + heat.$
How could you increase the amount of hydrogen in the system?
CH 12
A Increase the heat.
B Decrease the heat.
C Increase the C_2H_4.
D Decrease the C_2H_6.
Increasing temperature →A

15 **If a stress is applied to a system at equilibrium, the system shifts**
CH 12
A To the right
B In the direction that relieves the stress
C To the left
D In the direction that increases the stress
In the direction that relieves the stress →B

16 **Which of the following is a factor affecting chemical equilibrium?**
CH 12
A Changes in pressure and volume
B Changes in concentration
C Changes in temperature
D All the previous
Pressure, concentration, and temperature factor affecting chemical equilibrium →D