Chapter 9:
Chemical Equilibrium

Short Questions (Exercise)

1. (i) Differentiate between forward and reverse reactions:

Aspect	Forward Reaction	Reverse Reaction
Definition	The reaction proceeds from reactants to products.	The reaction proceeds from products to reactants.
Direction	Left to right in the chemical equation.	Right to left in the chemical equation.
Energy Change	May release or absorb energy.	Opposite energy change of the forward reaction.

1. (ii) What is chemical equilibrium?

Chemical equilibrium occurs when the rate of the forward reaction equals the rate of the reverse reaction, resulting in constant concentrations of reactants and products in a closed system.

1. (iii) Write two chemical equations of reversible reactions:

1. $N_2 + 3H_2 \leftrightarrow 2NH_3$ (Haber process).
2. $CaCO_3 \leftrightarrow CaO + CO_2$ (Thermal decomposition of calcium carbonate).

1. (iv) Write down the conditions for equilibrium:

1. Closed System: No substances can enter or leave the reaction system.
2. Dynamic Process: Both forward and reverse reactions occur at equal rates.
3. Constant Temperature and Pressure: External conditions should remain steady.
4. Constant Concentrations: The concentrations of reactants and products remain unchanged at equilibrium.

2. Write forward and reverse reactions for the given equation:

Reaction: $CO(g) + 3H_2(g) \leftrightarrow CH_4(g) + H_2O(g)$

- Forward Reaction: $CO(g) + 3H_2(g) \rightarrow CH_4(g) + H_2O(g)$
- Reverse Reaction: $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$

3. How does temperature affect cobalt chloride equilibrium?

Reaction: $CoCl_2(aq) + 6H_2O \leftrightarrow [Co(H_2O)_6]^{2+}(aq) + 2Cl^-(aq)$

- At higher temperatures, the equilibrium shifts to the left to favor the formation of $CoCl_2$ (blue color, endothermic direction).
- At lower temperatures, the equilibrium shifts to the right to form the hydrated complex $[Co(H_2O)_6]^{2+}$ (pink color, exothermic direction).

Think Tank

Reversible Chemical Reaction for the Decomposition of Bromine Chloride (BrCl\text{BrCl}BrCl):

The reversible reaction for bromine chloride decomposing into bromine and chlorine is as follows:

2BrCl↔Br2+Cl22\text{BrCl} \leftrightarrow \text{Br}_2 + \text{Cl}_22BrCl↔Br2+Cl2

Explanation:

1. **Forward Reaction:** Bromine chloride (BrCl\text{BrCl}BrCl) breaks down into bromine (Br2\text{Br}_2Br2) and chlorine (Cl2\text{Cl}_2Cl2).
2. **Reverse Reaction:** Bromine (Br2\text{Br}_2Br2) and chlorine (Cl2\text{Cl}_2Cl2) react to reform bromine chloride (BrCl\text{BrCl}BrCl).

This reaction is reversible and reaches equilibrium under suitable conditions. Let me know if you'd like this explanation in a Word file!

Extera Short Questions (Topic Wise)

9.1: Reversible Reactions and Dynamic Equilibrium

What are reversible reactions?

Reversible reactions can proceed in both forward and reverse directions under the same conditions. Example: The Haber process: $N_2 + 3H_2 \leftrightarrow 2NH_3$.

What is dynamic equilibrium?

Dynamic equilibrium occurs in a closed system when the rate of the forward reaction equals the rate of the reverse reaction, and the concentrations of reactants and products remain constant.

Does dynamic equilibrium mean the reaction has stopped?

No, dynamic equilibrium means the reactions continue but at equal rates, so no net change occurs in concentrations.

What factors affect equilibrium?

Factors include concentration of reactants/products, temperature, and pressure (for gases).

9.2: Le Chatelier's Principle

What is Le Chatelier's Principle?

It states that if a dynamic equilibrium is disturbed by changing conditions, the system adjusts to counteract the disturbance and restore equilibrium.

What happens if the concentration of a reactant is increased?

The equilibrium shifts to the right (toward the products) to reduce the increased concentration of the reactant.

What happens if the pressure is increased in a gaseous equilibrium system?

The equilibrium shifts to the side with fewer gas molecules. Example: $N_2 + 3H_2 \leftrightarrow 2NH_3$; increasing pressure shifts equilibrium to the right.

What happens if the temperature is increased in an exothermic reaction?

The equilibrium shifts to the left (toward the reactants) to absorb the added heat.

9.3: Equilibrium Constants

What is the equilibrium constant (K)?

It is the ratio of the concentrations of products to reactants at equilibrium, raised to the power of their stoichiometric coefficients.

What does a large value of K indicate?

A large K value means the equilibrium lies toward the products (forward reaction is favored).

What does a small value of K indicate?

A small K value means the equilibrium lies toward the reactants (reverse reaction is favored).

Does the equilibrium constant change with temperature?

Yes, K changes with temperature. For an exothermic reaction, K decreases with increasing temperature; for an endothermic reaction, K increases.

Extera Long Questions (Topic Wise)

Explain reversible reactions and dynamic equilibrium with examples.

Reversible reactions are chemical reactions where the products can react to reform the original reactants under the same conditions.
These reactions are represented by a double arrow (↔).

Example: The Haber process for ammonia synthesis:
$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + Heat$.

Dynamic equilibrium occurs in a closed system when the rate of the forward reaction equals the rate of the reverse reaction.
At equilibrium:
- The concentrations of reactants and products remain constant.
- Both reactions continue to occur, but there is no net change.

Factors Affecting Equilibrium:
1. Concentration: Adding more reactants shifts equilibrium toward the products.
2. Pressure (for gases): Increasing pressure favors the side with fewer gas molecules.
3. Temperature: For exothermic reactions, increasing temperature shifts equilibrium to the reactants.

Example: In the decomposition of calcium carbonate:
$CaCO_3(s) \leftrightarrow CaO(s) + CO_2(g)$,
equilibrium is achieved when decomposition and recombination occur at equal rates.

What is Le Chatelier's Principle? Explain with examples.

Le Chatelier's Principle states that if a dynamic equilibrium is disturbed by a change in concentration, pressure, or temperature, the system will adjust to counteract the disturbance and restore equilibrium.

Applications of Le Chatelier's Principle:
1. Change in Concentration:
   - Increasing the concentration of a reactant shifts the equilibrium toward the products.
   - Example: $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$; adding more N_2 shifts equilibrium to the right, producing more ammonia.

2. Change in Pressure (for gases):
   - Increasing pressure shifts equilibrium toward the side with fewer gas molecules.
   - Example: In the same reaction, there are 4 gas molecules on the left and 2 on the right. Increasing pressure shifts equilibrium to the right.

3. Change in Temperature:
   - For exothermic reactions, increasing temperature shifts equilibrium toward the reactants.
   - Example: For the exothermic reaction $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + Heat$, raising the temperature shifts equilibrium to the left.

Importance: Le Chatelier's Principle helps optimize industrial processes like the Haber process and understand how equilibrium systems respond to changes.

What are equilibrium constants (K), and how are they calculated? Provide examples.

The equilibrium constant (K) is a ratio of the concentrations of products to reactants at equilibrium, with each raised to the power of its stoichiometric coefficient.

Expression for K:
For a general reaction: $aA + bB \leftrightarrow cC + dD$,
$K = [C]^n[D]^n / [A]^n[B]^n$.

Types of Equilibrium Constants:
1. Kc (Concentration-based): Used when concentrations are measured in mol/L.
2. Kp (Pressure-based): Used for gaseous reactions, with pressures measured in atm.

Example Calculation:
For the reaction $H_2(g) + I_2(g) \leftrightarrow 2HI(g)$, if $[H_2] = 0.1$ mol/L, $[I_2] = 0.1$ mol/L, $[HI] = 0.2$ mol/L,
$Kc = [HI]^2 / [H_2][I_2] = (0.2)^2 / (0.1)(0.1) = 4$.

Significance of K:
- Large K Value: Indicates the reaction favors the products.
- Small K Value: Indicates the reaction favors the reactants.

Temperature Dependence of K:
- For exothermic reactions, K decreases with increasing temperature.
- For endothermic reactions, K increases with increasing temperature.

MCQS

Q1: What is a reversible reaction?

- a) A reaction that proceeds only in the forward direction
- b) A reaction that can proceed in both forward and reverse directions ✓
- c) A reaction that stops at completion
- d) A reaction that does not produce products

Q2: What happens at dynamic equilibrium?

- a) The forward reaction stops
- b) The reverse reaction stops
- c) The rates of the forward and reverse reactions are equal ✓
- d) The concentrations of reactants and products change

Q3: What is required for dynamic equilibrium to occur?

- a) A constant temperature
- b) A closed system ✓
- c) A catalyst
- d) Continuous removal of products

Q4: What does dynamic equilibrium mean?

- a) The reaction stops completely
- b) The forward and reverse reactions occur at the same rate ✓
- c) Reactants are completely converted to products
- d) Products are consumed faster than reactants

Q5: Which of the following is a reversible reaction?

- a) $N_2 + 3H_2 \leftrightarrow 2NH_3$ ✓
- b) Combustion of methane
- c) Decomposition of hydrogen peroxide
- d) Freezing of water

Q6: What does Le Chatelier's Principle state?

- a) The reaction rate decreases when disturbed
- b) The equilibrium remains unchanged after a disturbance

- c) The system adjusts to counteract the disturbance and restore equilibrium ✓
- d) The reaction stops upon disturbance

Q7: What happens if the concentration of a reactant is increased?

- a) Equilibrium shifts to the left
- b) Equilibrium shifts to the right ✓
- c) Equilibrium does not shift
- d) The system remains unchanged

Q8: What happens if the pressure of a gaseous system is increased?

- a) Equilibrium shifts to the side with more gas molecules
- b) Equilibrium shifts to the side with fewer gas molecules ✓
- c) Equilibrium remains constant
- d) No effect on equilibrium

Q9: What happens if the temperature is increased in an exothermic reaction?

- a) Equilibrium shifts to the left (toward reactants) ✓
- b) Equilibrium shifts to the right (toward products)
- c) Equilibrium remains unchanged
- d) The reaction stops

Q10: What happens if the temperature is increased in an endothermic reaction?

- a) Equilibrium shifts to the left
- b) Equilibrium shifts to the right ✓
- c) Equilibrium remains constant
- d) Reaction rate decreases

Q11: What is the effect of adding a catalyst to a system at equilibrium?

- a) It shifts equilibrium to the right
- b) It shifts equilibrium to the left
- c) It speeds up both the forward and reverse reactions equally ✓
- d) It changes the equilibrium constant

Q12: How does removing a product affect equilibrium?

- a) It shifts equilibrium to the left
- b) It shifts equilibrium to the right ✓

- c) No effect on equilibrium
- d) The reaction stops

Q13: What happens when pressure is decreased in a gaseous equilibrium system?

- a) Equilibrium shifts to the side with fewer gas molecules
- b) Equilibrium shifts to the side with more gas molecules ✓
- c) Equilibrium remains unchanged
- d) Reaction rate decreases

Q14: What is an example of equilibrium shifting due to pressure change?

- a) Combustion of methane
- b) $N_2 + 3H_2 \leftrightarrow 2NH_3$ ✓
- c) Decomposition of hydrogen peroxide
- d) Freezing of water

Q15: What happens if the temperature is decreased in an exothermic reaction?

- a) Equilibrium shifts to the left
- b) Equilibrium shifts to the right ✓
- c) No change occurs
- d) Reaction stops

Q16: What does the equilibrium constant (K) represent?

- a) The ratio of products to reactants at equilibrium ✓
- b) The speed of the reaction
- c) The total energy change of the reaction
- d) The pressure in the system

Q17: What does a large value of K indicate?

- a) The reaction favors the products ✓
- b) The reaction favors the reactants
- c) The reaction is slow
- d) The reaction is endothermic

Q18: What does a small value of K indicate?

- a) The reaction is fast

- b) The reaction favors the reactants ✓
- c) The reaction favors the products
- d) The system is not at equilibrium

Q19: What is the expression for Kc for the reaction $N_2 + 3H_2 \leftrightarrow 2NH_3$?

- a) $Kc = [N_2][H_2]/[NH_3]$
- b) $Kc = [NH_3]/[N_2][H_2]$
- c) $Kc = [NH_3]^2 / [N_2][H_2]^3$ ✓
- d) $Kc = [N_2][H_2]^2 / [NH_3]^3$

Q20: Which factor changes the equilibrium constant K?

- a) Temperature ✓
- b) Pressure
- c) Concentration
- d) Catalyst

Q21: What happens to K for an exothermic reaction as temperature increases?

- a) K increases
- b) K decreases ✓
- c) K remains constant
- d) K becomes zero

Q22: What happens to K for an endothermic reaction as temperature increases?

- a) K increases ✓
- b) K decreases
- c) K remains constant
- d) K becomes zero

Q23: How is K affected by adding a catalyst?

- a) K increases
- b) K decreases
- c) K is not affected ✓
- d) K depends on pressure

Q24: What is Kp used for?

- a) Reactions in solution

- b) Solid-phase reactions
- c) Gaseous reactions ✓
- d) Reactions involving catalysts

Q25: What is the unit of Kc for the reaction $2NO \leftrightarrow N_2 + O_2$?

- a) mol/L
- b) No unit ✓
- c) L/mol
- d) atm

Q26: What is required for equilibrium to be achieved?

- a) A closed system ✓
- b) A catalyst
- c) A high temperature
- d) Continuous removal of products

Q27: What is a characteristic of dynamic equilibrium?

- a) The rates of forward and reverse reactions are equal ✓
- b) Reactants are completely converted to products
- c) No reaction occurs
- d) Products dominate completely

Q28: What happens if the temperature is decreased in an endothermic reaction?

- a) Equilibrium shifts to the left
- b) Equilibrium shifts to the right ✓
- c) Equilibrium remains constant
- d) Reaction stops

Q29: What is the effect of increasing the temperature in an exothermic reaction?

- a) K increases
- b) K decreases ✓
- c) No effect on K
- d) K becomes infinite

Q30: Which reaction has an equilibrium constant expression involving pressure (Kp)?

- a) $2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$ ✓
- b) $NaCl(s) \leftrightarrow Na^+(aq) + Cl^-(aq)$
- c) $NH_4Cl(s) \leftrightarrow NH_4^+(aq) + Cl^-(aq)$
- d) $HCl(aq) \leftrightarrow H^+(aq) + Cl^-(aq)$