

CHEM 162: Final Exam Study Guide

Chapter 16: Chemical Equilibrium

equilibrium: state where the **forward and reverse reactions or processes occur at the same rate**

- know that **concentrations are not changing at equilibrium**, but they need not be equal to one another
- be able to indicate when equilibrium is achieved given concentration vs. time plots

Use the **law of mass action** to write **equilibrium expressions for K_c or K_p** for homogeneous and heterogeneous reactions.

- include only gases, omit pure liquids and solids.

For general reaction, $jA + kB \rightleftharpoons lC + mD$

$$K_c = \frac{[C]^l [D]^m}{[A]^j [B]^k} \quad \text{or} \quad K_p = \frac{P_C^l P_D^m}{P_A^j P_B^k}$$

Extent of reaction

- For **large values of K_c or K_p ($>10^3$)**, the reaction essentially goes to completion.
 - The equilibrium mixture consists mostly of products (**product favored**)
 - The **equilibrium lies to the right**
- For **small values of K_c or K_p ($<10^{-3}$)**, the reaction does not occur to any significant degree.
 - The equilibrium mixture consists mostly of reactants (**reactant favored**)
 - The **equilibrium lies to the left**
- For **intermediate values ($10^{-3} < K_c \text{ or } K_p < 10^3$)**, the equilibrium mixture contains appreciable amounts of both reactants and products.
 - For $K_c \text{ or } K_p > 1$, **equilibrium lies to the right**

Equilibrium positions: Set of equilibrium concentrations or partial pressures of reactants and products for a system.

- While K_c or K_p for a reaction are constant for a given temperature, various equilibrium positions are possible for that reaction depending on the initial concentrations of reactants and products.

Relating K_c and K_p : $K_p = K_c(RT)^{\Delta n}$

- be able to solve for Δn for any homogeneous or heterogeneous reaction.
- know that $K_p = K_c$ for $\Delta n = 0$

Know K_c or K_p are unitless!

Reaction Quotient (Q): instant state of system, not necessarily at equilibrium.

- Also determined using law of mass action
- $Q < K$: too many reactants
 - **System shifts right** to make more products
- $Q > K$: too many products
 - **System shifts left** to make more reactants
- $Q = K$: system at equilibrium

Determination of K_c or K_p

- be able to solve for either using a variety of experimental data.
 - Given equilibrium concentrations or partial P's
 - Given initial & changes in conc. or partial P's
 - Given total pressure at equilibrium

Equilibrium Problems: Solving for K_c or K_p

1. Get balanced chemical equation
2. Write equilibrium expression
3. Set up equilibrium ICE table.
 - Let x =change in conc. or partial pressure
4. Substitute equilibrium conc. or pressures into equilibrium expression for K_c or K_p
5. Solve for x , using quadratic method if necessary.
6. Substitute value for x into equilibrium conc. or pressures to solve for K_c or K_p

Le Chatelier's Principle

- A system at equilibrium will shift (if possible) to minimize any stress (change in concentration, pressure, volume, or temperature)
- Predict shifts in equilibrium given specific changes
- **Only changes in temperature (T) affect K_c or K_p**
 - For endothermic reactions, K_c and K_p $\uparrow$ as T $\uparrow$
 - For exothermic reactions, K_c and K_p $\downarrow$ as T $\uparrow$

Characteristics of the Equilibrium Expressions

- For reverse reaction, equilibrium expression is reciprocal of that for forward reaction
- Multiplying coefficients by factor, n , raises equilibrium constant to n^{th} power
- **Multiple Equilibria**
 - When a reaction can be expressed as a sum of two or more reactions, the **equilibrium constant for the overall reaction is simply the product of the equilibrium constants for the individual reactions**
 - be able to manipulate a series of reactions to determine the equilibrium constant for an overall reaction

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