

# 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  $K_c$  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  $\Delta n$  for any homogeneous or heterogeneous reaction.
- Know that  $K_c = K_p$  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  $n^{\text{th}}$  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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## **Table of Contents Pkg Acp Cer Gen Chem Ii Lab Chem 131**

1. Understanding the eBook Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - The Rise of Digital Reading Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Advantages of eBooks Over Traditional Books
2. Identifying Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - User-Friendly Interface
4. Exploring eBook Recommendations from Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Personalized Recommendations
  - Pkg Acp Cer Gen Chem Ii Lab Chem 131 User Reviews and Ratings
  - Pkg Acp Cer Gen Chem Ii Lab Chem 131 and Bestseller Lists

5. Accessing Pkg Acp Cer Gen Chem Ii Lab Chem 131 Free and Paid eBooks
  - Pkg Acp Cer Gen Chem Ii Lab Chem 131 Public Domain eBooks
  - Pkg Acp Cer Gen Chem Ii Lab Chem 131 eBook Subscription Services
  - Pkg Acp Cer Gen Chem Ii Lab Chem 131 Budget-Friendly Options
6. Navigating Pkg Acp Cer Gen Chem Ii Lab Chem 131 eBook Formats
  - ePub, PDF, MOBI, and More
  - Pkg Acp Cer Gen Chem Ii Lab Chem 131 Compatibility with Devices
  - Pkg Acp Cer Gen Chem Ii Lab Chem 131 Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Highlighting and Note-Taking Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Interactive Elements Pkg Acp Cer Gen Chem Ii Lab Chem 131
8. Staying Engaged with Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Pkg Acp Cer Gen Chem Ii Lab Chem 131
9. Balancing eBooks and Physical Books Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Pkg Acp Cer Gen Chem Ii Lab Chem 131
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Setting Reading Goals Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Fact-Checking eBook Content of Pkg Acp Cer Gen Chem Ii Lab Chem 131
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

#### 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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