Chemical Engineering Kinetics Brief Report

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Abstract

The present paper summarizes Chapter 3, 4, and 6 of the book. Chapter three encompasses principles and explanation of the different types and processes in the transport processes with reaction catalyzed by solids. Chapter four explains the non-catalytic gas-solid reaction, while chapter 6 illustrates the Gas-liquid reaction. The paper is divided into different sections, including an introduction of the three branches, and the specific learning outcomes each chapter seeks to achieve. The presentation also comprises of a definition of the scientific purpose and objective of each chapter under review. After the introduction, the paper uses different scientific tools to explain the theories in the various processes. Theories reflect the technical background of each chapter. The experimental tools aiding in the explanation of the approach merely include mathematical equations, models, formulas, and scientific relations. Finally, the paper provides a conclusion that explains the significance of the theories under review, and their implications in the chemical engineering field, and briefly summarizes the significant results of the passages.

Introduction

Transport Process in Reactions Catalyzed By Solids

The transportation phenomena involved in diffusion processes and reaction in porous media has led to extensive studies due to the wide range of applications it gives. Chapter three of the book deals with the transport processes when solids catalyze reactions .It defines and characterizes molecular, Knudsen, and surface diffusion in pores. Temperature and chemical components' concentrations may not be uniform inside every porous particle in reactions catalyzed by solids. Interfacial gradient effects are the reaction of fluid components at the surface of a solid. Diffusion in a catalyst particle can occur through a pseudocontinuum or heterogeneous medium. Each method has a fundamentally different overview, and approach and their modulus are calculated using different formulas. The effectiveness factors are also different in each type of reaction. The chapter identifies the different effects of intraparticle diffusion limitations. These limitations may falsify rate coefficients and activation energies, and can change the selections of coupled reactions. There are various criteria in evaluating the importance of intraparticle diffusion limitations, such as the intraparticle diffusion (IPD) equation.

Non-Catalytic Gas-Solid Reaction

The majority of non-catalytic reactions occur in the process industries. Non-catalytic gas-solid results include combustion of coke or coal, coal gasification, iron production in the blast furnace, and roasting of ores. The gas-solid reaction process is non-steady. Transport effects and reactions should simultaneously be in consideration in gas-solid reaction outcomes; this is because the conditions inside the pellets change over time when a solid inside a pellet is consumed. Considering both transport effects and reactions simultaneously bring about an aspect that is similar to reactions catalyzed by a porous solid. However, determining whether important gradients inside and around the particle are built up depends on the relative magnitudes of the transport and the reaction rate. The main difference between the reactions is that the conditions inside the particle in gas-solid reactions change with the time. The change of time is because the solid itself is involved in the reaction of the gas-solid effect. When describing gas-solid reactions, three significant models are used; heterogeneous shrinking-core model, the general model, and the truly homogeneous model.

Gas-Liquid Reaction

In the industries, there are many reactions involving gases and liquids. The reactions can be classified into two groups; the first category encompasses gas purification processes like the removal of CO from a synthesis gas. Gas purification processes can be done through several means, such as using aqueous solutions of hot potassium carbonate or by using ethanolamine or sodium hydroxide to remove H, S, and CO from a hydrocarbon cracking gas. The other category of the gas-liquid process is the production processes, which include a reaction between a gaseous CO, stream, and an aqueous ammonia solution to give ammonium carbonate. Numerous equipment, such as the bubbling absorber, are also used in the processes. Models characterizing of operations of the process equipment are also required in designing the absorber. Chapter 6 of the book explores the rate of reaction between components of gas and liquid. Apart from considering actual chemical kinetics setting up rate equations, the reaction requires a consideration of mass and heat transfer rates.

Theories and Learning Outcomes

Transport Process with Reaction Catalyzed By Solids

The chapter starts by analyzing the equation and formulas of a surface reaction between a solid and a fluid. After that, the chapter examines mass and heat transfer resistance in the form of mass transfer coefficients, heat transfer coefficients, and multicomponent diffusion in a fluid. An example of mass and heat transfer in the book is the use of a low effective binary diffusion. Additionally, the chapter defines and formulates a model of concentration or partial pressure and temperature differences between bulk fluid and the surface of a catalyst through the example of an interfacial gradient of ethanol dehydrogenation. The chapter also analyzes the internal structure of a catalyst and gives a general quantitative description of pore diffusion. Furthermore, through surface diffusion and configurational diffusion, it explores the random pore model, the parallel cross-linked pore model, and pore diffusion with adsorption. The chapter additionally defines and calculates the modules and the effectiveness factor of a catalyst for a given reaction.

An example of an equation and model in the chapter is the surface reaction between a solid and a fluid formula which arises if a situation is scrutinized where reactive species in a liquid solution are in contact with a reactive solid only on the active sites of the exterior surface at steady-state conditions. The overall surface reaction is assumed to be first-order considering the concentration of A.

The equation for the consumption rate of A per unit particle surface area will be:

$$rAi = k,CAi$$

rAi = rate of reaction of A at surface, kmol/mp2 hr

k,= rate coefficient for the reaction, mJ3/mP2 hr

CAi = concentration of A at the interface, kmol/mJ3

In determining how mass transfer coefficient can be combined with the rate coefficient for simple reactions

$$N_A = k_g (C_A - C_{Ai})$$

Where kg = mass transfer coefficient, hr _^{hr}! m2p

CAi = molar concentration of A at the interfacial particle area in the fluid

Overall rate coefficient= ^{m3}/ hr -m2$_p$

Non-Catalytic Gas-Solid Reaction

The chapter describes the non-catalytic gas-solid reaction with the general models of interfacial and intraparticle gradients. Moreover, the chapter determines a heterogeneous model with the shrinking unreacted core. A good example of a heterogeneous model with a shrinking unreacted core is the combustion of coke within porous catalyst particles. The book additionally outlines the grain model and pore model accounting for the structure of the solid. Finally, the chapter explains the reaction inside nonisothermal particles. The heterogeneous model with a shrinking unreacted core has the word "heterogeneous" since, in a reacting solid, there are two distinct solid-phase regions; each solid-phase region has a distinct property. The natural chemical reaction in the model is very rapid compared to the transport of the gaseous reactant towards the center of the spherical pellet.

Examples of non-catalytic gas-solid reactions are:

Combustion of coke or coal which is represented by the formula

$2c(s)_2+^3\text{-}0_2$ 2(g) co2 (g) +' CO (g

Coal gasification which is represented by the formulae

C(s) + H20 (g)CO (g) + H2 (g)

Roasting of Ore which is represented by

ZnS(s) +02 (g) ZnO(s) + S02 (g)

Iron production in the blast furnace which is represented by the formula:

Fe203(s) + Cf (s) +-^{1}0 (g) 2Fe (s) +C02 g) +2CO (g)

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Gas-Liquid Reactions

The chapter explains the models for transfer at a gas-liquid interface and the two-film theory for mass transfer with a chemical reaction. It also explores and defines models for a single irreversible reaction with general kinetics and the first-order and pseudo-first-order irreversible results. The chapter also explains single, instantaneous, and irreversible reactions and gives remarks on boundary conditions and utilization. It explains models and provides an equation for complex reactions and surface renewal theory. Consequently, it explains and draws a distinction between single instantaneous reactions and single irreversible (pseudo) first-order reaction. It also describes the two surface elements of limited thickness and provides experimental determination of the kinetics of gas-liquid reactions.

The chapter amplifies the two main classes of gas-liquid reactions, including the gas purification processes. It gives an example of the purification process with the equation of removing CO2 (g) from the synthesis gas [CO (g) +H2 (g), N2 J using a water solution of K2C03 or H2N-CH2 -CH20H (ethanolamine). Moreover, it provides an equation for removal of H2S(g) and C02 (g) from "hydrocarbon cracking gas" using a solution of H2N-CH2 -CH20H (ethanolamine) or NaOH. For example, the gas production processes explained in the book involve the production of ammonium carbonate by the reaction of C02 (g) with ammonia solution in water and air oxidation of CH3 ·CHO (acetaldehyde) and higher aldehydes to yield

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CH_3 -C -OH (acetic acid) and higher acids.

Conclusion

The book contains discussions of features such as chain reactions. It also integrates modem methods of statistical parameter estimation, model discrimination techniques, and mixed media. Some topics in the book are unique and are not easily found in other chemical reaction engineering texts, but are of high current interest in applications. The book entails comprehensive and detailed examples that use real kinetic data that are applicable and used in important industrial processes and integrates research and consulting experiences. Moreover, the publication additionally encompasses practical aspects of engineering and goes into depth to define not only fundamental, but also more abstract topics. The result is that the reader has enough literature to cover the issue discussed. Sufficient literature is essential in research, and the book theories can, therefore, be utilized by both chemical engineering students in school and practicing chemical professionals. The chapters encompass a systematic flow of applied or engineering kinetics and reactor analysis, and design to understand the theories that explain the technical background.