

Chapter 3 Separation Processes (Unit operations)

(Refs: Geankoplis, Chapter 1 for an overview and other chapters for various separation processes; Doran: Cht 10 Unit operations. Earle: Unit Operations in Food Processing: <http://www.nzifst.org.nz/unitoperations/>).

1. Introduction

In most chemical and biochemical production processes, the desired product (s) from chemical and bioreactors is (are) in a mixture with other components, such as unconverted reactants, by-products and others required for the reaction such as catalysts, and the components of solvent or reaction media. Therefore, separation is needed to attain the products in desired purity and form.

The term "**unit operation**" has been used in the chemical industry and chemical engineering textbooks for a long time to refer to the various separation processes for the recovery and purification of products. So named is because that these separation processes can be viewed as separate and distinct steps or units in a production process, and a given unit operation will have the same principles and basic operations in different production processes. Nowadays, **separation processes** are more widely used than unit operations, especially in biotechnology. Among the common separation processes are evaporation, distillation, absorption, crystallization, filtration, centrifugation, drying and membrane processes. Separation processes are primarily based on physical means and some on physico-chemical means.

This chapter is to introduce the general concepts of separation technology and some common separation processes in chemical and bioprocess technology.

2. General concepts and characteristics of separation processes

Separation of components in a mixture is always based on the **difference** in a physical property among the mixture components. Based on the nature or physical mechanism of separation, various **separation processes can be classified into**,

- 1) *Mechanical separations*: separations based on size and/or density differences of different components in a mixture, for separation of solid from liquid (e.g. filtration and centrifugation).
- 2) *Diffusional separations (mass transfer operations)*: separations based on molecular movement toward a favourable phase, for separation of dissolved components (e.g. distillation, absorption, extraction). (Note: Mass transfer is the transfer of solute molecules from one point to another or from one phase to another.)
- 3) *Membrane separations*: use of a *semipermeable* membrane to **separate molecules** with difference in size or some other properties.

Phase equilibrium relationships are the theoretical bases for most separation processes depending on mass transfer between phases (in 2: all classified as *contact-equilibrium* processes). **Phase equilibrium** is a thermodynamic state established between two (or more) phases. For a multiple component system, at equilibrium, the concentrations of all components in each phase no longer change, and the distribution of components in the two phases is completed and will be maintained. The equilibrium state (and concentrations) may change with temperature, pressure and composition.

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Jin-Ying Zhang



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Chemical and Bioprocess Engineering Siddharth Venkatesh, 2025-02-20 *Chemical and Bioprocess Engineering Innovations* is a comprehensive and accessible guide exploring the intricate world where chemistry and biology converge. Tailored for a global audience with a focus on the United States, this book is an indispensable resource for students, professionals, and researchers in chemical and bioprocess engineering. The book demystifies complex concepts, offering a user-friendly journey through fundamental principles such as chemical engineering thermodynamics and fluid mechanics. Grounded in real-world applications, each chapter bridges theory and practice, emphasizing the role of chemical and bioprocess engineering in shaping the nation's technological landscape. Uniquely, this book addresses traditional chemical processes and delves into bioprocessing, covering genetic engineering, fermentation, and bioseparations. As the US leads in technological innovation, readers gain the knowledge and skills to navigate challenges and opportunities in chemical and biological processes. Emphasizing sustainability and green engineering, the book includes real-world case studies from diverse industries, highlighting eco-friendly practices. It integrates the latest advancements in bio-based materials, preparing the next generation of engineers for sustainable and ethical practices. Promoting a holistic understanding that transcends traditional boundaries, the book draws from biology, chemistry, and engineering. Exercises and practical examples in each chapter foster critical thinking and problem-solving skills, encouraging active contribution to the field. *Chemical and Bioprocess Engineering Innovations* serves as a valuable reference for seasoned professionals and a companion for learners, keeping readers abreast of the latest developments in this ever-evolving field.

Chemical Reaction Technology Dmitry Yu. Murzin, 2022-01-19 The book discusses the sciences of operations, converting raw materials into desired products on an industrial scale by applying chemical transformations and other industrial technologies. Basics of chemical technology, combining chemistry, physical transport, unit operations, and chemical reactors, are thoroughly prepared for an easy understanding.

Micro Process Engineering Norbert Kockmann, 2013-03-26 This edition of *Micro Process Engineering* was originally published in the successful series *Advanced Micro Nanosystems*. Authors from leading industrial players and research institutions present a concise and didactical introduction to *Micro Process Engineering*, the combination of microtechnology and process engineering into a most promising and powerful tool for revolutionizing chemical processes and industrial mass production of bulk materials, fine chemicals, pharmaceuticals, and many other products. The book takes the readers from the fundamentals of engineering methods, transport processes, and fluid dynamics to device conception, simulation, and modelling, control interfaces, and issues of modularity and compatibility. Fabrication strategies and techniques are examined, next focused on the fabrication of suitable microcomponents from various materials such as metals, polymers, silicon, ceramics, and glass. The book concludes with actual applications and operational aspects of micro process systems, giving broad coverage to industrial efforts in America, Europe, and Asia, as well as laboratory equipment and education.

Reactive Separation Processes

Kulprathipanja,2019-01-15 This book summarizes the available information in six known areas of reactive separation reaction distillation reaction extraction reaction absorption reaction adsorption reaction membrane and reaction crystallization

Solid-liquid Separation Processes and Technology Ladislav Svarovsky,1985 Separation Process Principles J. D. Seader,Ernest J. Henley,D. Keith Roper,2016-01-11 Separation Process Principles with Applications Using Process Simulator 4th Edition is the most comprehensive and up to date treatment of the major separation operations in the chemical industry The 4th edition focuses on using process simulators to design separation processes and prepares readers for professional practice Completely rewritten to enhance clarity this fourth edition provides engineers with a strong understanding of the field With the help of an additional co author the text presents new information on bioseparations throughout the chapters A new chapter on mechanical separations covers settling filtration and centrifugation including mechanical separations in biotechnology and cell lysis Boxes help highlight fundamental equations Numerous new examples and exercises are integrated throughout as well **Transport Processes and Separation Process Principles** Christie John

Geankoplis,Allen Hersel,Daniel H. Lepek,2018-05-02 The Complete Unified Up to Date Guide to Transport and Separation Fully Updated for Today s Methods and Software Tools Transport Processes and Separation Process Principles Fifth Edition offers a unified and up to date treatment of momentum heat and mass transfer and separations processes This edition reorganized and modularized for better readability and to align with modern chemical engineering curricula covers both fundamental principles and practical applications and is a key resource for chemical engineering students and professionals alike This edition provides New chapter objectives and summaries throughout Better linkages between coverage of heat and mass transfer More coverage of heat exchanger design New problems based on emerging topics such as biotechnology nanotechnology and green engineering New instructor resources additional homework problems exam questions problem solving videos computational projects and more Part 1 thoroughly covers the fundamental principles of transport phenomena organized into three sections fluid mechanics heat transfer and mass transfer Part 2 focuses on key separation processes including absorption stripping humidification filtration membrane separation gaseous membranes distillation liquid liquid extraction adsorption ion exchange crystallization and particle size reduction settling sedimentation centrifugation leaching evaporation and drying The authors conclude with convenient appendices on the properties of water compounds foods biological materials pipes tubes and screens The companion website trine edu transport5ed contains additional homework problems that incorporate today s leading software including Aspen CHEMCAD MATLAB COMSOL and Microsoft Excel

Separation Process Engineering Phillip C. Wankat,2007 Reviewing core concepts such as equilibrium and unit operations this title introduces a step by step process for solving separation problems It looks at each leading processes including advanced processes such as membrane separation adsorption and chromatography For each process it presents principles techniques equations and examples **Distillation Control & Optimization: Operation Fundamentals through**

Software Control Alessandro Brambilla, 2014-04-10 The latest methodologies for the control of distillation processes Written by an expert with more than 30 years of industry experience Distillation Control and Optimization Operation Fundamentals through Software Control is filled with proven solutions to control problems in distillation processes This authoritative guide discusses regulatory control and the development of advanced control systems such as multivariable predictive control Realworld examples of commercial units analyzed using the results of rigorous simulation models are included Detailed diagrams illustrate the proven methods presented in this practical resource **COVERAGE INCLUDES** Two product columns Multiproduct columns Liquid and vapor sidestream columns Column operating pressure Column capacity and efficiency Two product column basic control Two product column quality control Disturbances to the column Multiproduct column control Crude oil fractionators control Multivariable predictive control technology Inferentials in distillation Quality estimators of refinery distillation products Heat Transfer in Process Engineering Eduardo Cao, 2009-08-12 Cutting edge heat transfer principles and design applications Apply advanced heat transfer concepts to your chemical petrochemical and refining equipment designs using the detailed information contained in this comprehensive volume Filled with valuable graphs tables and charts Heat Transfer in Process Engineering covers the latest analytical and empirical methods for use with current industry software Select heat transfer equipment make better use of design software calculate heat transfer coefficients troubleshoot your heat transfer process and comply with design and construction standards Heat Transfer in Process Engineering allows you to Review heat transfer principles with a direct focus on process equipment design Design rate and specify shell and tube plate and hairpin heat exchangers Design rate and specify air coolers with plain or finned tubes Design rate and specify different types of condensers with tube or shellside condensation for pure fluids or multicomponent mixtures Understand the principles and correlations of boiling heat transfer with their limits on and applications to different types of reboiler design Apply correlations for fired heater ratings for radiant and convective zones and calculate fuel efficiency Obtain a set of useful Excel worksheets for process heat transfer calculations **Fundamentals and Modeling of Separation Processes: Absorption, Distillation, Evaporation, and Extraction** Charles Donald Holland, 1974 Revue Roumaine de Chimie, 1993 **Chemistry and Industry**, 1990 **Principles of Industrial Chemistry** Chris A. Clausen, Guy Mattson, 1978-11-20 *Mineral Liberation* Gilles Barbery, 1991 *Studies in Computer-aided Modelling, Design, and Operation* Iván Pallai, Zsolt Fonyó, G. E. Veress, 1992 **Physical Principles of Chemical Engineering** Peter Grassmann, 1971 Pollution Prevention Kenneth L. Mulholland, James A. Dyer, 1999 As many industries are beginning to learn pollution prevention technologies offer more than just a way to comply with regulations or even to do the right thing It also makes smart business sense The authors of this book both veterans of DuPont s in house waste reduction team have put together a how to guide for locating and implementing the best pollution prevention strategies for particular manufacturing processes The book codifies elements of fundamental pollution prevention knowledge that are easily understood and broadly

applicable across a wide range of industries At the heart of the book is what the authors call the 10 Step Method for Engineering Evaluations of Pollution Prevention Methods which breaks down the process to such simple steps as defining problems setting goals and identifying defining and evaluating alternative strategies **Protein Purification** Michael R. Ladisch,1990 This practical volume gives real life examples of how separation techniques are used in industry with recombinant proteins and emphasizes which techniques might be more useful than others An introductory chapter ties together the various topics and associates the methods used with examples of large scale methodologies The emphasis of the volume is on how series can be applied to developing strategies and appropriate approaches for difficult protein separation problems This valuable book provides an update on some of the existing technology used in industry and presents separation examples of several commercially important and recently developed proteins *Reactor Handbook: Fuel processing, edited by S. M. Stoller and R. B. Richards ,1960*

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