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Chapter 1 : Separation Process Principles by J.D. Seader

Exercise (i) Known: Fluorocarbons can be produced from the reaction of carbon tetrachloride and hydrogen fluoride followed by a number of separation steps.

Keith Roper Ralph E. Vice President and Executive Publisher: Don Fowley Acquisitions Editor: Jennifer Welter Developmental Editor: Debra Matteson Editorial Assistant: Alexandra Spicehandler Marketing Manager: Christopher Ruel Senior Production Manager: Janis Soo Assistant Production Editor: The cover was printed by Courier Westford. This book is printed on acid free paper. Our company is built on a foundation of principles that include responsibility to the communities we serve and where we live and work. In , we launched a Corporate Citizenship Initiative, a global effort to address the environmental, social, economic, and ethical challenges we face in our business. Among the issues we are addressing are carbon impact, paper specifications and procurement, ethical conduct within our business and among our vendors, and community and charitable support. 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From to , he worked for Chevron Research, where he designed petroleum and petrochemical processes, and supervised engineering research, including the development of one of the first process simulation programs and the first widely used vaporliquid equilibrium correlation. From to , he supervised rocket engine research for the Rocketdyne Division of North American Aviation on all of the engines that took man to the moon. Seider, of the Warren K. In , as part of the AIChE Centennial Celebration, he was named one of 30 authors of groundbreaking chemical engineering books. He received his B. He has authored or coauthored 72 technical articles and 12 books, the most recent one being Probabilistic Risk Management for Scientists and Engineers. An active consultant, he holds nine patents, and served on the Board of Directors of Maxxim Medical, Inc. Keith Roper is the Charles W. H er eceived aB. He has authored or coauthored more than 30 technical articles, one U. He was instrumental in developing one viral and three bacterial vaccine products, six process documents, and multiple bioprocess equipment designs. His current area of interest is interactions between electromagnetism and matter that produce surface waves for sensing, spectroscopy, microscopy, and imaging of chemical, biological, and physical systems at nano scales. These surface waves generate important resonant phenomena in biosensing, diagnostics and therapeutics, as well as in designs for alternati ve energy, optoelectroni cs, and micro-electromechanical systems. This page intentionally left blank This page intentionally left blank Preface to the Third Edition Separation Process Principles was first published in to provide a comprehensive treatment of the major separation operations in the chemical industry. Both equilibrium-stage and mass-transfer models were covered. Included also were chapters on thermodynamic and mass-transfer theory for separation operations. In the second edition, published in , the separation operations of ultrafiltration, microfiltration, leaching, crystallization, desublimation, evaporation, drying of solids, and simulated moving beds for adsorption were added. This third edition recognizes the growing interest of chemical engineers in the biochemical industry, and is renamed Separation Process Principlesâ€”Chemical and Biochemical Operations. In , the National Research Council NRC , at the request of the National Institutes of Health NIH , National Science Foundation NSF , and the Department of Energy DOE , released a report calling on the United States to launch a new multiagency, multiyear, multidisciplinary initiative to capitalize on the extraordinary advances being made in the biological fields that could significantly help solve world problems in the energy, environmental, and health areas. To help provide instruction in the important bioseparations area, we have added a third author, D. Keith Roper, who has extensive industrial and academic experience in this area. Bioseparations are corollaries to many chemical engineering separations. Accordingly, the material on bioseparations has been added as new sections or chapters as follows: An introduction to bioseparations, including a description of a typical bioseparation process to illustrate its unique features. Thermodynamic activity of biological species in aqueous solutions, including discussions of pH, ionization, ionic strength, buffers, biocolloids, hydrophobic interactions, and biomolecular reactions. Molecular mass transfer in terms of driving forces in addition to concentration that are important in bioseparations, particularly for charged biological components. These driving forces are based on the Maxwell- Stefan equations. Extraction of bioproducts, including solvent selection for organic-aqueous extraction, aqueous twophase extraction, and bioextractions, particularly in Karr columns and Podbielniak centrifuges. Microfiltration is now included in Section 3 on transport, while ultrafiltration is covered in a new section on membranes in bioprocessing. A revision of previous Sections A new section on electrophoresis for separating charged particles such as nucleic acids and proteins is added. Because of the importance of phase separations in chemical and biochemical processes, we have also added this new chapter on mechanical phase separations covering settling, filtration, and centrifugat ion, including mechanical separations in biotechnology and cell lysis. Other features new to this edition are: Study questions at the end of each chapter to help the reader determine if important points of the chapter are understood. Boxes around important fundamental equations. Shading of examples so they can be easily found. Answers to selected exercises at the back of the book. Increased clarity of exposition: This third edition has been completely rewritten to enhance clarity. Sixty pages were eliminated from the second edition to make room for biomaterial and updates. More examples, exercises, and references: The second edition contained examples, homework exercises, and references. This third edition contains examples, homework exercises, and more than 1, references. Throughout the book, reference is made to a number of software products. The solution to many of the examples is facilitated by the use of spreadsheets with a Solver tool, Mathematica, MathCad, or Polymath. It is particularly important that students be able to use such programs for solving nonlinear equations. They are all described at websites on the Internet. Not only are these simulators useful for designing separation equipment, but they also provide extensive physical property databases, with methods for computing thermodynamic properties of mixtures. Hopefully, those studying separations have access to such programs. This edition is divided into five parts. Part 1 consists of five chapters that present fundamental concepts applicable to all subsequent chapters. Chapter 1 introduces operations used to separate chemical and biochemical mixtures in industrial applications. Chapter 2 reviews organic and aqueous solution thermodynamics as applied to separation problems. Chapter 3 covers basic principles of diffusion and mass transfer for rate-based models. Use of phase equilibrium and mass-balance equations for single equilibrium-stage models is presented in Chapter 4, while Chapter 5 treats cascades of equilibrium stages and hybrid separation systems. The next three parts of the book are organized according to separation method. Part 2, consisting of Chapters 6 to 13, describes separations achieved by phase addition or creation. Chapters 6 through 8 cover absorption and stripping of dilute solutions, binary distillation, and ternary liquidâ€”liquid extraction, with emphasis on graphical methods. Chapters 9 to 1 present computer-based methods widely used in process simulation programs for multicomponent, equilibriumbased models of vaporâ€”liquid and liquidâ€”liquid separations. Chapter 12 treats multicomponent, rate-based models, while Chapter 13 focuses on binary and multicomponent batch distillation. Part 3, consisting of Chapters 14 and 15, treats separations using barriers and solid agents. These have found increasing applications in industrial and laboratory operations, and are particularly important in bioseparatio ns. Chapter 14 covers rate-based models for membrane separations, while Chapter 15 describes equilibrium-based and rate-based models of adsorption, ion exchange, and chromatography, which use solid or solid-like sorbents, and electrophoresis. Parte 1 de

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Chapter 2 : Seader, Henley: Separation Process Principles - Instructor Companion Site

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Fluorocarbons can be produced from the reaction of carbon tetrachloride and hydrogen fluoride followed by a number of separation steps. Austin, pages Fig. Draw a process flow diagram and describe the process. Two main reactions occur: The HF contains a small amount of water as an impurity. The normal boiling points in oC of these components in the order of decreasing volatility are: The distillate enters absorber A1, where HCl is absorbed by water to produce a byproduct of aqueous HCl. The effluent liquid from A2 is waste. The exit liquid from A3 is also waste. The gas leaving A3 is distilled in D2 to obtain CCl2F2 as a distillate, which is then dried in S1 by adsorption with activated alumina. Bottoms from D3, containing residual CCl4, is recycled to reactor R1. Mixing is spontaneous, but separation is not. Explanation for why mixing and separation are different. Mixing is a natural, spontaneous process. It may take time, but concentrations of components in a single fluid phase will tend to become uniform, with an increase in entropy. By the second law of thermodynamics, a natural process tends to randomness. The separation of a mixture does not occur naturally or spontaneously. Energy is required to separate the different molecular species. Separation of a mixture requires a transfer of energy to it or the degradation of its energy. The first and second laws of thermodynamics. Explain why the separation of a mixture requires energy. As an example, consider the isothermal minimum reversible work of separation of an ideal binary gas mixture. Therefore, the change in enthalpy is zero. However, there is a change in entropy, determined as follows. From a chemical engineering thermodynamics textbook or Table 2. This minimum work is independent of the process. If the MSA is incompletely recovered, a small amount of contamination may result. An ESA separation is easier to design. Producing ethers from olefins and alcohols. Process flow diagram and for production of methyl tert-butyl ether MTBE. List the separation operations. The reactor effluent contains 1-butene, isobutane, n-butane, methanol, and MTBE. The separation steps are as follows: Separation Step Products Distillation Distillate: Conversion of propylene to butene-2s. Process flow diagram and for production of butene-2s. Use of osmosis for separating a chemical mixture. The definition of osmosis. Explain why osmosis can not be used for separating a mixture. Osmosis is the transfer of a solvent through a membrane into a mixture of solvent and solute. Thus, it is a mixing process, not a separation process. Osmotic pressure for the separation of water from sea water by reverse osmosis with a membrane. Sea water containing 0. Minimum required pressure difference in kPa across the membrane Analysis: The minimum pressure difference across the membrane is equal to the osmotic pressure of the sea water, since the osmotic pressure of pure water on the other side is zero. Use of a liquid membrane to separate the components of a gas mixture Given: A liquid membrane of ethylenediaminetetraacetic acid, maintained between two sets of microporous, hydrophobic hollow fibers, packed into a cell, for removing sulfur dioxide and nitrogen oxides from flue gas. A sketch of the membrane device. A sweep fluid is generally required. In some cases, a vacuum could be pulled on the permeate side. The membrane device is shown below. The differences, if any, between adsorption and gas-solid chromatography. Adsorption can be conducted by many techniques including fixed bed, moving bed, slurry, and chromatography. In chromatography, unlike the other adsorption techniques, an eluant is used to carry the mixture through the tube containing the sorbent. Multiple pure products are obtained because of differences in the extent and rate of adsorption, resulting in different residence times in the tube. The tube is made long enough that the residences do not overlap. Is it essential in gas-liquid chromatography that 1.

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Chapter 4 : J. D. Seader, Ernest J. Henley, D. Keith Roper-Separation Process Principles

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