substitutions support the authors' conclusions is both very important and encouraging for future studies. The third chapter by M. D. Bednarski is a compendium of the enzymatic reactions involving the formation of carbon-carbon bonds. It is likely to be useful for synthetic organic chemists, but unfortunately it does not provide any specifics on enzymology or on applied aspects such as rates of reaction, effects of solvents, and so on. In contrast, the contribution by K. G. Nillson is a well balanced review of the enzymatic synthesis of complex sugars. The author not only presents a comprehensive overview of the enzymatic reactions in sugar synthesis, he also provides a wealth of practical information. This chapter is accompanied by an extensive reference list and should be an excellent introduction to this increasingly important application of enzymatic catalysis. Finally, the last chapter by S. Riva discusses the biotransformation of steroids. Because of the low solubility of steroids, special emphasis is placed on processes carried out in aqueous-organic mixtures and in low water environments. This part complements the material discussed in the first two chapters.

In summary, judging from the first volume, the series *Applied Biocatalysis* is expected to be an important reference for anyone interested in enzyme technology. Several of the chapters can also be useful as reading material for advanced graduate students in biochemical engineering. Unfortunately at $99.50, the book is beyond the reach of most graduate students (and for that matter even senior investigators). One minor shortcoming is the heterogeneity in the style of the literature citations; for a book like this it is desirable to include the full titles of references as is done in the last two chapters.

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Affinity Membranes: Their Chemistry and Performance in Adsorptive Separation Processes

By Elias Klein, Wiley, New York, 152 pp., 1991

The monograph by Elias Klein on affinity membranes is an easy-to-read tutorial on the history and principles of affinity separations and membrane separations. It also presents compelling arguments of how the two may be combined to yield purification strategies which might have both high specificity and high productivity. The underlying thesis of this book is that the common tool of affinity chromatography is able to achieve biochemical separations with a high degree of purity but at a slow rate, whereas microporous membranes are able to process solutions at a relatively high rate but with relatively low selectivity. Although practical demonstration of the concept is limited to date, it is proposed that affinity membranes would offer many advantages for product recovery from gene-modified cell cultures and as membrane-bound enzyme reactors or therapeutic devices.

The book is divided into ten chapters. Chapter 1 is an introduction that covers the history of membrane separations and of affinity chromatography. The basic features and applications of each of these two subjects are discussed, and the goal of combining them to achieve large-scale biological separations with high specificity is introduced.

Chapter 2 describes the principles of affinity adsorption. An immobilized ligand is used to capture a ligate from solution to form a complex. The key to a successful separation is that the ligand must have a much higher affinity for the particular ligate molecule of interest than for other, perhaps similar, molecules that may be present in solution. Examples of affinity interactions cited include ionic forces, van der Waals attractions, and hydrogen bonding. Biological examples of ligand/ligate complexes with high affinity include an enzyme and its substrate, an antibody and its antigen, and a nucleic acid and its complementary strand.

Chapter 3 focuses on substrates, the support materials to which the ligands are bound. Common materials such as agarose, cellulose, and acrylics are described. The desired properties of these cross-linked hydrogels and polymers include the contradictory physical requirements of high porosity and sufficient mechanical strength to withstand compaction under pressure. Organic reactions used for preparing these substrates to covalently bind ligands to their pore surfaces are described in Chapter 4, whereas Chapter 5 discusses some of the more common ligands employed. Nonspecific ligands include ion-exchange resins which bind ligates of opposite charge. Group-specific ligands are those based on biological recognition parameters, but not targeted to a very specific sequence or conformation of the ligate. Examples of group-specific ligands include lectins, proteins A and G, and various coenzymes. Specific ligands, on the other hand, have a highly specific interaction with a given ligate, as characterized by a very small dissociation constant for the ligand-ligate complex. These include enzymes and their substrates or inhibitors and antibodies and their antigens.

Chapter 6 describes the concept of the capacity of affinity matrices such as used in elution chromatography. The capacity of an affinity matrix refers to the quantity of the target ligate that can be bound and later recovered. The capacity increases with the surface area of the porous matrix and with the number of active ligand sites per area. However, the increase is not necessarily proportional to these two quantities, as high surface areas may involve pores too small to be accessed by the ligand-ligate complex, and high active-site densities may also have steric constraints that prevent ligates from binding to adjacent sites. This chapter also describes frontal analysis or breakthrough curves which give the concentration of ligate leaving a sorbent bed as a function of the volume perfused when the column is continuously loaded with a fixed concentration of ligate. These calculations depend on knowledge of the diffusivity of the ligate within the porous support material and also on the kinetics of its interaction with the ligand sites.

The focus of the book then changes from concepts of affinity chromatography to a review of membranes and their applications. Chapter 7 describes the polymeric materials used in reverse osmosis, ultrafiltration, and microfiltration membranes, as well as common techniques for making these membranes. Chapter 8 then reviews various techniques for characterizing membranes. These include determination of macroscopic information such as flux and permeability, and microscopic information such as pore-size distributions. This is followed in Chapter 9 by a more detailed discussion of microfiltration, presumably because it has higher potential for affinity membrane applications

than do reverse osmosis or ultrafiltration (although this is not made clear). A review of theories for both deadend and cross-flow microfiltration is presented.

The final chapter describes possible applications and advantages of affinity microfiltration membranes. The chapter primarily is a comparison of chromatographic and membrane separations. In affinity chromatography, which is commonly used for separations of biologicals, the typical process is to perform a batch adsorption process by perfusing a ligate-containing solvent through a cylindrical column packed with ligand-containing beads, until saturation occurs. This is followed by an elution step in which the solvent conditions are changed so that the ligate desorbs from the absorbents. Although the purification achieved by affinity chromatography may be very high, it is argued that the capacity is low and the processing rate is slow. Order-of-magnitude estimates are given to indicate that the slow step is the diffusion of ligate molecules into and out of the porous adsorbent beads. The primary hypothesis of Chapter 10 is that affinity membranes have much shorter diffusion paths than do chromatography beads (on the order of 1 μm instead of 100 μm). This is because the solvent is forced to flow through the membrane pores, so that the ligate is convected to within a pore radius of the active sites. Thus, it is proposed that affinity membranes would not be limited by a slow diffusion step. Recent studies on perfusion chromatography have shown that beads having some relatively large through-pores can also experience significant internal convective flow through them as a result of the imposed pressure drop, which reduces the diffusional transport limitations of conventional chromatography, but these studies are not mentioned in the book. By extrapolating previous experimental studies using affinity chromatography or conventional membranes, the chapter concludes with the proposal that cross-flow microfiltration with ligand-containing membranes may yield both high purification and high processing rates for applications such as the recovery of enzymes from fermentation broths or cell lysates.

The book does not include homework problems or even worked example problems, and so would be of limited use as a textbook. It better serves the role of an introductory monograph of both affinity chromatography and membrane separations. It is disappointing that no data or actual demonstration of affinity membrane systems are presented. Even the limited work on affinity membranes mentioned in the introduction chapter is not elaborated on in subsequent chapters. Thus, the reader is left with a sense that this is a book written before its time. I look forward to reading a sequel in a few years, when the conjecture is hopefully replaced by laboratory demonstrations and practical applications of affinity membrane systems.

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Active Carbon

By H. Jankowska, A. Swiatkowski, and J. Choma, Ellis Horwood, West Sussex, England, and Prentice-Hall, Englewood Cliffs, NJ, 1991, 280 pp.

The term "active carbon" appeared in the old literature and is still seen occasionally in European literature. Since the term "activated carbon" is more common and is the only term used in the U.S., it will be used in this review.

The book was first published in Polish in 1985 by the three authors, all of whom were from the Military Technical Academy in Warsaw. The English translation was published in 1991. Through no fault of the authors, it is already outdated in many places.

The activated carbon used today had a noble origin—it was developed as a sorbent during World War I for the protection of human lives against chemical agents. It remains the most useful sorbent, due to its large surface area (around 1,000 m^2/g) and hydrophobicity. Because adsorption is the main application for activated carbon, it is also the main subject of the book. The book contains ten chapters (in my abbreviated terms): (1) Introduction, (2) How to Make Activated Carbon, (3) Structure and Surface Chemistry, (4) Adsorption Isotherms, (5) Micropore Filling Theories, (6) Heat of Adsorption, (7) Adsorption from Liquid Solution, (8) How to Measure Adsorption and Pore Structure, (9) Applications, and (10) Regeneration.

The literature discussed in the book is heavily drawn, understandably, from the Russian and Polish literature. Chapter 2 addresses the principles and processes for making activated carbon. It is a good chapter; however, the vast amount of U.S. patent literature is hardly mentioned. Chapter 5 gives an excellent account of the potential theory of micropore filling. Two of the authors of the book are accomplished researchers on this subject. Because of the microporosity and nonuniform pore-size distribution of activated carbon, the potential theory is particularly useful for this sorbent. Chapter 9 contains an authoritative discussion on the impregnated carbon that is used for the retention of chemical agents in chemical warfare. The carbon is impregnated with metal oxides which react with the different agents to form harmless gaseous products. The complex chemical reactions involved are effectively summarized. Most of the other chapters, however, are inviting criticism because of their obvious weaknesses. For example, adsorption from binary solutions is discussed in two places (in Chapters 3 and 7). Yet, the important theories and models for predicting mixture adsorption from pure-component isotherms, from both gas and liquid phases, are missed. Hysteresis is an important phenomenon occurring in activated carbon, but is overlooked. Molecular sieve carbon, a relatively new and useful form of activated carbon, is also overlooked. The main portion of Chapter 8 describes old experimental techniques for measuring adsorption and pore structure, employing glass vacuum manostats with McLeod gauges. It is quite outdated: in fact, it resembles a similar chapter in Young and Crowell's 1962 book on adsorption. The weaknesses mentioned above are partly attributable to the author's very limited access to the Western literature in 1985, the time the book was written.

Despite the weaknesses, the book does contain a wealth of information and should be a useful reference for scientists and engineers who deal with activated carbon and adsorption.

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