MEMBRANE SEPARATIONS TECHNOLOGY
PRINCIPLES & APPLICATIONS

Membrane Science and Technology Series, 2

MEMBRANE SEPARATIONS TECHNOLOGY
Principles and Applications

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Preface

The field of membrane separation technology is presently in a state of rapid growth and innovation. Many different membrane separation processes have been developed during the past half century and new processes are constantly emerging from academic, industrial, and government laboratories. Microfiltration, which is very similar to conventional filtration, is probably the oldest and still the most widely used of these processes. Almost all other membrane separation processes found significant industrial applications only after the 'breakthrough' development of asymmetric polymer membranes by Loeb and Sourirajan in the early 1950s. Thus, ultrafiltration and reverse osmosis (sometimes called hyperfiltration) reached maturity in the 1960s, whereas membrane processes for the separation of gas mixtures started to be used on an industrial scale in the late 1970s and in the 1980s. Huge membrane plants for the separation of the uranium isotopes ^{235}U and ^{238}U by 'gaseous diffusion' were built in the United States much earlier, during the 1940s. However, the products of these plants were intended for military purposes.

Pervaporation and vapor permeation are the latest membrane separation processes to become economically competitive for some industrial applications. The first large-scale industrial pervaporation plant started operation in 1985 in Karlsruhe-Maxau (Germany) and another shortly thereafter in Betheniville (France). Both plants are being used for the dehydration of 94% ethanol. The first commercial vapor permeation plant, also designed for ethanol dehydration, became operative in September 1989 in Heilbron (Germany). Promising new applications are expected in future years for facilitated-transport membranes and catalytic membrane reactors.

While new membrane separation processes are being conceived with remarkable frequency, existing processes are also being constantly improved in order to enhance their economic competitiveness. Significant improvements are currently being made in many aspects of membrane separation technology: in the development of new membrane materials with higher selectivity and/or permeability, in the fabrication methods for high-flux asymmetric or composite membranes (whether in flat-sheet, hollow fiber, or tubular form), in membrane module construction and in process design (e.g., of hybrid separation processes).

Membrane separation technology is presently being used in an impressive variety of applications and has generated businesses totalling over one billion U.S. dollars annually. It is not surprising, therefore, that it has been the subject

of many monographs, books and review papers, and that an entire journal, the *Journal of Membrane Science* (Elsevier), is dedicated to it. The main objective of the present text is to present the principles and applications of a variety of membrane separation processes from the unique perspectives of investigators who have made important contributions to their fields. Another objective is to provide the reader with an authoritative resource on various aspects of this rapidly growing technology. The text can be used by someone who wishes to learn about a general area of application as well as by the knowledgeable person seeking more detailed information. The various chapters differ significantly in length, emphasis, and detail. No uniformity has been sought in the presentation of the subject matter or in nomenclature in order to preserve the perspective and personal style of the contributors. Also, very little editing has been done on the chapters whose authors used English as a second language, in order to avoid possible errors of interpretation or changes in emphasis.

The chapters in this text cover a wide variety of topics. Some of the authors have chosen to cover all aspects of certain membrane separation processes. Other authors have preferred to discuss specific topics in greater detail, such as process and module design, process economics, special applications of industrial or biotechnological interest, and emerging applications. It is hoped that the present text will not only provide readers interested in membrane separation technology with useful data and information, but also with the insights of well-known investigators who have contributed to its development and promise.

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