

Book Review **Membrane Technology and Applications 3rd and 4th Edition**

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ABSTRACT

The book *Membrane Technology and Applications* by Richard W. Baker has long served as a foundational reference for researchers in the field of membrane technology. It covers a wide range of fundamental concepts and practical applications of membranes in areas such as gas separation, water purification, and pervaporation. This review highlights the key differences between the third and fourth editions of the book. Significant updates and new data introduced in the fourth edition are also discussed. The inclusion of up-to-date technologies aligned with the latest 12 years of development in membrane science provides valuable insights to researchers, ensuring the book remains relevant and reflective of current trends in the field. As membrane technology continues to evolve, the design of treatment systems has become increasingly complex, requiring more advanced configurations and integration with other processes. At the same time, the nature of the chemicals to be treated—ranging from emerging contaminants to high-strength industrial effluents—has also grown more diverse and challenging. This complexity underscores the need for up-to-date knowledge, like that provided in the book, to support researchers in developing effective and innovative membrane solutions.

Keywords: Membrane preparation, gas transport mechanism, membrane application, membrane module, membrane contactors

1.0 BOOK REVIEW SUMMARY

The third edition (3rd) of *Membrane Technology and Applications* by Richard W. Baker was published in 2012. Twelve years later, in 2024, the fourth edition (4th) was released [1]. Within a short period of time, the 4th edition of the book has impressively garnered over 8,900 citations as of 1st July 2025. The high number of citations highlights the significance of the book in the field of membrane science and

technology, reflecting its comprehensive coverage of both fundamental principles and practical industrial applications. The wealth of knowledge presented in the book offers great convenience to researchers, especially those who struggle to find such comprehensive and integrated information in most scholarly articles.

In the fourth edition, the book begins with an overview of membrane science and technology. It elaborates on the gas transport mechanism, with a focus on

the solution-diffusion mechanism, which remains a key concept in membrane transport. It also discusses the characteristics and transport mechanisms of microporous membranes and how these relate to the design of membrane modules for various applications. Challenges such as concentration polarization are also addressed.

The book continues with a comprehensive discussion of water purification technologies, including reverse osmosis (hyperfiltration), ultrafiltration, and microfiltration. Gas separation is covered in a dedicated chapter, followed by other membrane applications such as pervaporation/vapor permeation, ion-exchange membrane processes, and carrier-facilitated transport.

Toward the end of the book, additional topics are explored, including membrane contactors, medical applications, and specialized membrane processes such as metal membranes, ion-conducting membranes, charge mosaic membranes, and piezodialysis.

Overall, the fourth edition retains most of the content from the third edition, with some updates and refinements. The following sections outline the key differences between the two editions.

2.0 STRUCTURAL AND ORGANIZATIONAL DIFFERENCES

For the chapter numbering and titles, the 4th edition renumbers some chapters (e.g., "Membrane Transport Theory" is Chapter 2 in both, but subsequent chapters shift). The 4th edition adds new chapters or consolidates topics (e.g., "Membrane Contactors" is Chapter 13 in the 4th edition, while the 3rd edition covers it under "Other Membrane

Processes"). The 4th edition splits "Ion Exchange Membrane Processes" into more focused subchapters (e.g., redox flow batteries and reverse electro dialysis are standalone sections in the 4th edition but integrated in the 3rd).

3.0 CONTENT UPDATES AND ADDITIONS

There are some new topics have been added in the 4th Edition. Membrane Contactors section has been expanded into a dedicated chapter (Chapter 13) with detailed applications (liquid/liquid, liquid/gas, gas/liquid and gas/gas applications). For liquid/liquid contactor application, the 4th edition discussed on the membrane distillation, pressure-retarded osmosis (PRO), forward osmosis (RO) and dialysis. For liquid/gas and gas/liquid contactors application, the 4th edition covers liquid degassing, membrane absorber-strippers and membrane structured packing. For gas/gas contactor application, the 4th edition reported on the water recovery in hydrogen fuel cells, membrane energy recovery ventilation system (ERVs) and selective exhaust gas recycle.

For Medical Applications, the 4th edition allocates a subsection for the monolithic system for drug delivery systems (Chapter 14). Noted that monoliths system is also discussed in 3rd edition under sub-section of membrane diffusion-controlled system. The derivation for a number of geometries for the release kinetics from a monolithic solution system can be found from 3rd edition.

For Carrier Facilitated Transport, a more enhanced discussion of coupled/facilitated transport has been included for the membrane and processes development (Chapter 12 in the 4th edition vs. Chapter 11 in the 3rd).

Limitation and breakthrough were discussed in the chapter.

For Other Processes, the 4th edition adds "Metal Membranes" (Chapter 15), which were less highlighted in the 3rd edition. Noted that pressure-retarded osmosis (PRO) and reverse electrodialysis (RED) for 4th edition have been moved to Chapter 13 (Membrane Contactors) and Chapter 11 (Ion Exchange Membrane Processes), respectively.

On the other hand, some of the sections have been revised or expanded. For Gas Separation, the 4th edition (Chapter 9) classifies the membrane into dense and microporous membranes. Metal membrane which is classified under Chapter 8 for 3rd edition has been moved to Chapter 15 for 4th edition.

For Pervaporation, the 4th edition (Chapter 10) integrates "Vapor Permeation" and hybrid processes (e.g., distillation/membrane systems), which is useful for the separation of azeotropes mixtures or of close-boiling mixtures. Three hybrid flow schemes for the separation of azeotropes and close-boiling mixtures are included.

For Reverse Osmosis, the 4th edition (Chapter 6) adds "Hyperfiltration" and pretreatment. For pretreatment, an example of complete flow scheme for seawater reverse osmosis plant is shown. For 3rd edition, the content is classified together with Organic Fouling.

4.0 THEORETICAL AND TECHNICAL ENHANCEMENTS

For the Overview of Membrane Science and Technology, 4th edition outlines the membrane processes to be more specific, including reverse osmosis, ultrafiltration, microfiltration, electrodialysis, gas separation, pervaporation, hyperfiltration,

membrane contactors, carrier transport and medical applications.

Besides, the 3rd edition covers "Pore-Flow Membranes" separately (Section 2.4), while the 4th edition integrates it into microporous membranes (Chapter 3). The pore-flow mechanism for the gas separation mainly consists of surface adsorption and diffusion, Knudsen diffusion, molecular sieving and pore blocking. For liquid permeation, the discussion is covered for screen and depth filters.

For Concentration Polarization, both editions cover this, but the 4th edition discussed the concentration polarization in membrane contactors and related processes like dialysis (Chapter 5). 3rd edition has a detailed discussion on the concentration polarization induced by cross-flow, co-flow and counter-flow schemes in membrane module.

5.0 APPLICATIONS AND CASE STUDIES

For Ultrafiltration, the 4th edition classifies all the applications, such as industrial applications, municipal water treatment/membrane bioreactor and biotechnology under one sub-section. For industrial applications, the food industry stated in 3rd edition has been splitted into few sub-sections, such as cheese production and clarification of fruit juices. Drinking water sterilization has also been added as another sub-section in 4th edition. The application for municipal water treatment/membrane bioreactor in 4th edition is mainly contributed by the submerged membrane modules mentioned in 3rd edition. In addition, the cross-flow modules in 3rd edition have been renamed to tangential-flow in 4th edition.

For Ion-exchange membranes, 4th edition integrates redox flow batteries,

reverse electro dialysis and water splitting using bipolar membranes under subsection of Other Electrochemical Processes. These

contents are covered in 3rd edition as well, with a slightly brief description. Table 1 shows the comparison between the 3rd and 4th editions of the book on membrane science and technology.

Table 1 Comparison between 3rd and 4th editions of the book “Membrane Science and Technology” written by Richard W. Baker

Category	3 rd Edition	4 th Edition	Key Differences
Chapter Organization	13 chapters	15 chapters	4th edition adds dedicated chapters (e.g., Membrane Contactors, Metal Membranes), offering specialized insight into novel systems.
Membrane Transport Theory	Chapter 2 (Solution-Diffusion + Pore-Flow)	Chapter 2 (Focus on Solution-Diffusion)	4th edition integrates pore-flow into microporous membranes, clarifying modeling of different transport mechanisms. (Chapter 3).
Microporous Membranes	Part of Chapter 2 & 3	Expanded in Chapter 3	3rd edition includes materials, like polymers of intrinsic microporosity (PIMs).
Concentration Polarization	Chapter 4	Chapter 5	4th edition includes contactor and related processes applications, highlighting how mass transfer resistances affect performance in hybrid units.
Reverse Osmosis	Chapter 5	Chapter 6 (Renamed "Hyperfiltration")	4th edition includes pretreatment, including pH, scale, particulates and biological fouling.
Ultrafiltration	Chapter 6	Chapter 7 (Classification of Applications)	4 th edition classifies industrial applications, municipal water treatment/membrane bioreactor and biotechnology into another subsection.
Gas Separation	Chapter 8	Chapter 9	4th edition combines oxygen/nitrogen, natural gas and carbon dioxide separation under air separation. “To-be-developed Applications” has also been added for carbon capture, hydrogen and carbon dioxide separation.

Table 1 (continue)

Category	3 rd Edition	4 th Edition	Key Differences
Pervaporation	Chapter 9	Chapter 10 (Includes "Vapor Permeation")	4th edition adds hybrid distillation/membrane processes, which is useful for the separation of azeotropes and close-boiling mixtures. Hybrid flow schemes that highlight the combination of distillation and membrane permeation can be seen.
Ion Exchange Membranes	Chapter 10	Chapter 11	4th edition integrates reverse electrodialysis for energy production. For redox flow batteries, the transition region in a bipolar membrane can be found.
Carrier Facilitated Transport	Chapter 11	Chapter 12	The histories are included in the subsection of Introduction. 4th edition enhances the membrane and process development, better detail on two categories of carrier transport: (i) facilitated transport and (ii) coupled transport.
Membrane Contactors	Part of Chapter 13	Dedicated Chapter 13	4th edition expands on liquid/liquid, liquid/gas, gas/liquid and gas/gas applications. It includes technical expansion into direct contact and air gap membrane distillation.
Medical Applications	Chapter 12	Chapter 14	4th edition adds monolithic dispersion system for drug delivery systems. The graph showing the release of the drug that dispersed in the matrix can also be found in the chapter. Advantages of the system has also been discussed.
Other Processes	Chapter 13 (PRO, RED, etc.)	Chapter 15 (Metal Membrane)	Noted that PRO and RED for 4th edition have been moved to Chapter 13 and Chapter 11, respectively.

Despite the comprehensive coverage in both editions, certain gaps still persist—particularly in areas such as the lack of modelling tools for

membrane process optimization, limited integration of machine learning in membrane design, and the absence of detailed real-world scale-up case

studies. Addressing these gaps would further enhance the book's value as a complete reference for both academic research and industrial application.

6.0 FINAL REMARKS

The 4th edition is more comprehensive and updated, with new chapters, expanded applications, and integrated theories. Notably, two new chapters have been added, focusing on microporous membranes and membrane contactors. The content has been significantly expanded to include advanced topics such as hybrid processes in pervaporation, detailed application for membrane contactors and a broader range of medical applications. Theoretical sections have been reorganized for better clarity, with pore-flow concepts now integrated into

the discussion on microporous membranes, and the solution-diffusion model emphasized in membrane transport theory. Additionally, the edition features updated applications, including membrane and process development. Both editions maintain core principles, but the 4th reflects advances in materials (e.g., monolith systems, redox flow batteries, reverse electro dialysis) and hybrid processes. In summary, the 4th edition is preferable for current research and applications, while the 3rd edition may suffice for foundational knowledge.

REFERENCES

- [1] Baker, R. W. (2023). *Membrane technology and applications*. John Wiley & Sons.