Preface

The burning of fossil fuels, including coal, oil, and gas meets more than 85% of the world's energy needs today. The associated CO_2 emissions cause detrimental changes to the earth's climate. The scientific community agrees that the solution for mitigating CO_2 emissions lies in a portfolio of strategies, including carbon capture and storage (CCS) and potentially carbon capture and utilization (CCU). The mitigation of CO_2 through its separation from gas mixtures such as power plant emissions, *i.e.*, *Carbon Capture*, will be a critical step toward stabilizing global warming. Amine-based scrubbing for CO_2 capture has been taking place for over 70 years to purify natural gas, but it is unclear whether this technology will be optimal for tackling the scale of CO_2 emitted on an annual basis ($\sim$ 30 Gt worldwide). The next several decades of engineers, chemists, physicists, earth scientists, mathematicians, and social scientists will advance traditional separation technologies. Thus, this book spans a wide range of disciplines, as will the portfolio of solutions.

The core of the book focuses on the most advanced CO_2 capture technologies including absorption, adsorption, and membranes. The book also includes chapters on algae and electrochemical/photocatalytic CO_2-to-fuel conversion processes. The reduction of CO_2 via photosynthesis or electrochemical/photo catalysis are routes to alternative fuels. Along with climate change, the development of alternatives to crude oil for transportation fuels will be a strong drive of policy. These two drivers are likely to remain present for a long time, with indeterminate relative weights. An additional motivation for including these topics is the vision that one day they may be advanced to the extent that CCS can take place in a single process, rather than the current three-step sequence of capture, compression, and storage. The book does not discuss geological storage of CO_2, but focuses solely on methods of capture.

This book is the first of its kind. As an emerging field, carbon capture ranges many disciplines. No single source exists that explains the fundamentals of gas separation and their link to the design process. The closest predecessor to this book is the 2005 IPCC Special Report on CCS, which provides only a high-level overview of CCS options. This book provides the reader with the skillset needed to recognize the limitations of traditional gas-separation technologies in the context of CO_2 capture, and how they may be advanced to meet the scale challenge required to substantially decrease CO_2 emissions.

This book can be used in the classroom at the undergraduate and graduate levels for students examining separations processes in the context of carbon capture. It can be used as educational material for industrial personnel engaged in carbon capture technologies in addition to gas separation processes. The material in this book will benefit scientists and engineers active in the research and development of carbon capture technologies. Finally, engineers evaluating separation processes for carbon capture will find this book useful.

The three core chapters pay significant attention to the pedagogy of absorption, adsorption, and membrane separation processes for CO_2 capture and include many worked examples and end-of-chapter problems. These examples test fundamental concepts, from the chemical physics associated with a given material that binds CO_2, to the unit operations of the process, closely coupled by mass transfer. In general, metric units (*e.g.*, metric tonne) are primarily used throughout the book, with the exception of several instances where US engineering units are used when they are considered the industry standard.

Cover Design: The cover design was motivated by the most advanced CO_2 capture technology: amine scrubbing. The image illustrates that CO_2 is generated from the oxidation of fossil fuels, such as petroleum and coal, and the chemical form of the CO_2 emitted into the atmosphere from fossil-fuel oxidation is of a fairly stable linear structure. An amine capture process involves a complex combination of carbonate and carbamate chemistries dependent upon pH, temperature, and pressure conditions. The chemical process of oxygen (carbonate) or nitrogen (carbamate) binding with the carbon atom of CO_2 forces the molecular structure to transform from a linear geometry (the molecule depicted on the right) to a bent structure (the molecule depicted on the left). This process has an entropy cost in addition to a significant barrier associated with binding, compared to other gas species that already possess the bent structure, *e.g.*, SO_2. Not surprisingly, the reaction rate is faster with SO_2. In an absorption process, CO_2 must bend in preparation for reaction as illustrated in the cover image. The bent structure represents an intermediate stage between the gas and solution phase, in which CO_2 is ultimately captured. Credit is given to artists, Karen Miller and Deborah Hickey for the design of the cover image.

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