ChE book review

Green Sustainable Process for Chemical and Environmental Engineering and Science: Supercritical Carbon Dioxide as Green Solvent, 1st Edition

Edited by Dr. Inamuddin, Abdullah M. Asiri, & Arun M. Isloor
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This book is part of a review series that delves into specific tools used to design more sustainable processes, such as supercritical water, plant-derived solvents, switchable solvents, solid-state chemistry, and microwaves for organic synthesis, amongst others. The editors present a survey of applications of supercritical carbon dioxide (SC-CO_2). The tome is divided in 19 chapters written by different contributors. Each chapter presents a review of a specific application of SC-CO_2:

- 10 chapters survey applications on extraction of biological compounds.
- 4 chapters discuss SC-CO_2 applications in reactions.
- 3 chapters review solubility of compound classes in supercritical carbon dioxide.
- 1 chapter surveys applications in the textile industry.
- 1 chapter focuses on metal recovery applications.

The extraction chapters focus primarily on applications of biological and bioactive compounds: extraction of catechins from green tea, lipids from algae, propolis, oleoresins and plant phenolics, essential oils, caffeine, and several chemicals from citrus, marigold, saffron, and other plants. The extended focus on extraction and purification of biological compounds is not surprising, since these materials tend to be very sensitive to temperature, making the comparative lower temperatures of SC-CO_2 very attractive. The chapter on decaffeination is particularly well covered, probably given the fact that this extraction has been performed using SC-CO_2 for quite a few years. The extraction chapters include an introduction of the relevance of the compounds extracted, short descriptions of the processes used, and advantages of using SC-CO_2. These chapters also include several summary tables comparing different extraction methods, experimental conditions, alternative solvents, and types of extractions.

Four chapters deal specifically with chemical reactions: alkylations, hydrogenation of oils and fats, and two chapters on polymer production. The alkylation chapter covers advantages and disadvantages of the use of SC-CO_2 as a solvent and provide examples of reactions with quantitative information, including alkylation of olefins, allylic alkylation, trans-alkylation, N-alkylation, and alcoholic and phenolic alkylation. Another chapter provides a summary of the use of SC-CO_2 as an alternative to organic solvents for hydrogenation of fats and oils, including examples from the literature, and comparing the efficiencies under different reaction conditions. The chapters on polymer production provide a review of the methods of polymer synthesis using SC-CO_2, its advantages and disadvantages, an overview of the polymerization processes, and a concise survey of the synthesis of several polymers as case studies.

The solubility chapters cover pharmaceutical, organometallic, and general organic compounds. The pharmaceutical chapter includes a description of applications on drug design including respiratory powders with industrial examples under development, solubility measurement methods, a survey of solubility of common active pharmaceutical ingredients, and a thorough review of solubility mathematical modeling approaches. The chapter on solubility of organic compounds in SC-CO_2 provides a summary of solubility data for organic compounds of economic importance, discussion of correlation of solubility measurements and mathematical models, and brief discussions on a series of reactions for which solubility is key. The chapter on organometallic compounds provides solubility data, reviews different solubility measurement techniques, covers solutions theories applied to SC-CO_2, and discusses different mathematical models, such as equations of state and empirical approaches.

The chapter on applications in the textile industry provides background on dyeing processes and the application of SC-CO_2 as an alternative to water-based processes. It discusses the advantages of using SC-CO_2 in dyeing both natural and synthetic fibers, mass transfer phenomena between fiber and the supercritical solvent, its effects on the fibers, advantages, challenges, limitations, and future prospects.

The chapter on metal recovery describes processes for recycling the waste generated by electrical and electronic equipment such as liquid crystal displays, lithium ion batteries, and circuit boards. The authors cover leaching as one step to recover metals from electronic and electrical waste. Finally, the chapter describes examples of using supercritical fluids to recover metals from particulate matrices, solids, and aqueous solutions with the aid of complexing agents.

The book chapters start from the premise that supercritical carbon dioxide is a "green" solvent. Although most chapters discuss disadvantages and limitations of using SC-CO_2, they do not deeply cover sustainability metrics to evaluate the "greenness" of carbon dioxide as a solvent, including advantages and disadvantages. Chapter 11 on decaffeination is the only chapter to include a substantial discussion on environmental metrics such as life cycle assessment to evaluate the environmental profile of the supercritical carbon dioxide process. If readers are interested in evaluating the environmental profile of using SC-CO_2 compared to other solvents, they will need to look for a different publication.

I believe this book is useful as a technical reference of some applications of supercritical carbon dioxide and is particularly useful in supplying extraction scenarios. The list price is comparable to other books that belong to this type of reference material. This work is not structured as a textbook but could be useful as supporting material for graduate or senior classes covering green chemistry or engineering to offer students practical examples of industrial or research uses of supercritical carbon dioxide. However, this would need to be supported by other references that critically evaluate the environmental profile of using carbon dioxide compared to other alternatives using appropriate metrics. ❐