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Capture and Utilization of Carbon Dioxide with Polyethylene Glycol

Springer

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Green Chemistry for Sustainability

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ISSN 2191-5407 ISSN 2191-5415 (electronic)
ISBN 978-3-642-31267-0 ISBN 978-3-642-31268-7 (eBook)
DOI 10.1007/978-3-642-31268-7
Springer Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Foreword by Michele Aresta

Carbon dioxide is produced in several anthropogenic activities at a rate of *ca.* 35 Gt/y. The main sources are: (1) the combustion of fossil carbon (production of electric energy, transport, heating, industry), (2) the utilization of biomass (combustion to obtain energy, fermentation), and (3) the decomposition of natural carbonates (mainly in the steel and cement industry). Due to the fact that the natural system is not able to buffer such release by dissolving CO_2 into oceans (or water basins in general) or by fixing it into biomass or inert carbonates, CO_2 is accumulating in the atmosphere with serious worries about its influence on climate change. This has pushed toward finding solutions that may avoid that its atmospheric concentration may increase well beyond the actual 391 ppm (the preindustrial era value was 275 ppm). The growth of the energy demand by humanity makes the solution not simple as, according to most scenarios, at least 80 % of the total energy will still be produced from fossil carbon in the coming 30 years or so. This adds urgency to implementing technologies that may reduce both the amount of CO_2 released to the atmosphere and the utilization of fossil carbon. Therefore, besides efficiency technologies (in the production and use of energy) other routes must be discovered that may reduce either the production of CO_2 or its emission into the atmosphere. Among the former, perennial energy sources (such as: sun, wind, hydro, geothermal) are under exploitation. The reduction of the release of CO_2 to the atmosphere is based on its capture from continuous point sources (power-, industrial-, fermentation-, cement-plants) by using liquid or solid sorbents or membranes, a high-cost technology, today.

Such captured CO_2 can be either disposed in geologic cavities and aquifers or recycled. The former option corresponds to the CO_2 Capture and Storage (CCS) technology, the latter to the CO_2 Capture and Utilization (CCU) technology. CCS is believed to be able to manage in general larger amounts of CO_2 than CCU. The latter, on the other side, is able to recycle carbon, reducing the extraction of fossil carbon. CCS is energy demanding and economically unfavorable, CCU may or may not require energy (depending on the nature of the species derived from CO_2) and is economically viable, as all compounds derived from CO_2 or any use of CO_2 will have an added value. A concern about the utilization of CO_2 lays in the

amount of energy eventually necessary that cannot be derived from fossil carbon. This has prevented so far a large utilization of CO_2. But in a changing paradigm of deployment of primary energy sources, if the use of perennial sources will be more and more implemented, the conversion of CO_2 into chemicals and fuels may become economically convenient and energetically feasible. The deployment of wind and sun will play a key role in this direction. The former can be coupled with electricity generation and subsequent use of such form of energy in the conversion of CO_2, the latter can be used in a direct (photochemical, thermal) or indirect (photoelectrochemical) conversion of CO_2. The products obtainable from CO_2 are of various nature: fine chemicals, intermediates, fuels.

The CO_2 utilization option is a hot topic today and attracts the attention of several research groups all around the world. Dedicated reviews in peer reviewed journals and books make an analysis of possibilities. This book is a comprehensive and timely review of the use of PEG as solvent for CO_2 capture or for CO_2 conversion. The solvent plays a key role in the conversion of CO_2 as the decrease of entropy (gaseous CO_2 is converted into a liquid or solid) is against the reaction equilibrium which is shifted to the left. The use of good solvents for CO_2 or the use of supercritical CO_2 itself as solvent and reagent can help to push the reaction to the right. After an analysis of the phase behavior of the PEG/CO_2 system, the author describes the PEG/sc CO_2 biphasic solvent system and the role of functionalized-PEG as catalysts for CO_2 conversion. The use of PEG in the CO_2 capture and subsequent conversion closes the list of topics in the book. All together, the analysis of the PEG/CO_2 system presented by the author is complete, and very useful as it is accompanied by a quite exhaustive literature search.

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Foreword by Chang-jun Liu

A great effort has been made worldwide toward CO_2 capture and utilization. There are some good progresses in the capture technologies. The question is: how can we handle the captured CO_2? Obviously, storage is not a good option. There are many potential problems with the storage in addition to the expensive cost with the capture and storage. The utilization could finally become the only solution with the serious CO_2 issue. Indeed, we have several processes with CO_2 as feedstock. However, compared to the huge amount of CO_2 generated, we need much more economically feasible processes to use CO_2. One has to face the challenges in energy and many others. Especially, any utilization technologies should not lead to more CO_2 emission. Unfortunately, we do not see a significant progress in CO_2 utilization. We need to work hard to develop such utilization technologies. To do so, more fundamental studies should be conducted. We have to acknowledge that not much fundamental studies are available with CO_2 utilization. For example, alumina is the most used catalyst support for CO_2 reforming and others. However, no information was available for how CO_2 adsorb and convert on it when we started to investigate it in 2009.

CO_2 utilization needs further intense fundamental studies, which will lead to novel utilization technologies and finally solve the problem of CO_2 emission. In this regard, I am very glad to see that Prof. Liang-Nian He in Nankai University has conducted excellent works in the development of polyethylene glycol-promoted CO_2 utilization technology. His group successfully studied the phase behavior of PEG/CO_2 system and reaction mechanism at molecular level. The materials they applied are cheap, green, and easy to be processed. And, a significant advantage of

the process Prof. He developed is that it combines the capture and utilization of CO_2. It has a great potential for a practical application. I believe that one will be very happy to read the book 'Capture and Utilization of CO_2 with Polyethylene Glycol' and find it very useful for future development. This book will be also an excellent reference for textbooks of green chemistry, catalysis, chemical engineering, and others.

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Acknowledgments

Our work on CO_2 chemistry presented in this book is the fruit derived from the exceptional talented students whose names may appear in the references, Dr. Ya Du, Dr. Jing-Quan Wang, Dr. Jing-Lun Wang, Dr. Cheng-Xia Miao, Dr. De-Lin Kong, Dr. Xiao-Yong Dou, Dr. Jie-Sheng Tian, Miss Ying Wu, Dr. Yuan Zhao, Miss Fang Wu, Dr. Jian Gao, Mr. An-Hua Liu, Mr. Bin Li, Mr. Bing Yu, Miss Yu-Nong Li, Miss Yan-Nan Zhao to whom we give warm thanks for their devotion, sincerity and contribution. Special thanks are extended to Professor Michele Aresta, and Professor Chang-jun Liu for their kind support and great contribution to the Foreword. This work was financially supported by the National Natural Science Foundation of China (Grants No. 21172125), the "111" Project of Ministry of Education of China (Project No. B06005), Key Laboratory of Renewable Energy and Gas Hydrate, Chinese Academy of Sciences (No. y207k3), and the Committee of Science and Technology of Tianjin.