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GREEN CHEMISTRY AND TECHNOLOGIES

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Preface

Green chemistry and technologies is the forefront of international chemistry and chemical engineering development. It combines the latest achievements o f modern chemistry, chemical engineering, physics, biology, material science, environmental science and information technology, and a new interdiscipline with defined scientific destination and essential social demands.

In a recent decade, green chemistry and technology has gained more and more attentions by governments, academics, and industries. The direct participation of governments, close cooperation of industries with research institutions, and international technological exchange and cooperation boost the development of green chemistry and technology. As the research on green chemistry is comprehensive, its key role in the sustainable development of the world is clearly revealed.

Therefore, elucidation and summary of the latest progress and applications of green chemical technologies is an essential task, especially, employing these new achievements to solve the problems of the efficient, clean, and high-quality utilization of resources, and the clean production of chemicals and materials has been a new task undertaking by green chemistry and technology in view of sustainable development.

This book comprises 14 chapters. Chapter 1 describes the origins, background of development, and the nature of green chemistry and technology. Chapter 2 elucidates the 12 principles of green chemistry and green chemical process. Chapter 3 and 4 summarize concisely the principles and advanced technologies in green inorganic synthesis and green organic synthesis, respectively. Chapter 5 describes the green synthetic methods and technologies of polymers. Chapter 6 describes mainly the green synthetic processes in medical industry, agricultural drugs, and industrial assistants. Chapter 7 describes the environmental-friendly chemical and the concept of green engineering. Chapter 8 summarizes the green processes for the complex utilization of carbon dioxide. Chapter 9 describes the green chemistry and chemical processes for the biomass transformations. Chapter 10 describes the green chemistry and chemical processes for the ocean resources transformations. Chapter 11 elucidates mainly the evaluation principles and index used in the evaluation of a green chemical process and application procedures. Chapter 12 describes the clean coal combustion technologies and renewable energies. Chapter 13 summarizes the chemical process intensification technologies and their utilizations in clean chemical processes. Chapter 14 introduces the essential concept and models of recycling economy and ecological industrial parks. In a word, this book is focused on the extended utilizations of the principles of green chemistry and chemical technologies in the new fields of clean synthesis and resources utilization. It characterizes the combination of theory with practice and creative development.

This book' chief editors are Zhang Long , Gong Changsheng , and Dai bin and associate chief editors are Zhang Gongxiao , Yang jianxin, Li Zhongming , and Li Zaifeng. The division of work is as follows: Chapter 1 (Gong Changsheng, Wuhan University of Engineering; Yang jianxin, Hainan University), Chapter 2 (Xu Jun, Zhengzhou University), Chapter 3 and 4 (Zhang Long, Changchun University of Technology), Chapter 5 (Li Zaifeng, Qingdao University of Science and Technology), Chapter 6 (Yang jianxin), Chapter 7 (Li Zhongming, Jin Mei, Jianghan University), Chapter 8 (Zhang Long), Chapter 9 (Liu Xin, Changchun University of Technology; Du Guangming , Xinjiang agricultural University), Chapter 10 (Yin Xueqiong, Hainan University), Chapter 11 and 12 (Dai Bin, Ma Xiaowei, Shihezi University), Chapter 13 (Zhang Gongxiao, Taishan Medical College) and Chapter 14 (Gong Changsheng, Li Zhongming and Jin Mei). Zhang Long makes the whole revision and modification of the manuscript.

We sincerely thank the editors from Huazhong University of Science and Technology Press and Germany De Gruyter Press for their excellent work to make this book publishable!

As green chemistry and technologies is a newly launched and multidiscipline research area with various sciences and technology understandings and the limits of the authors academic level, there should be some mistakes in the book, we sincerely welcome all suggestions and comments from the readers! And much appreciation is given for the authors all over the world, whose publications have been cited in this book!

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Contents

1 Introduction

Green chemistry, also called sustainable chemistry, is an area of chemistry and chemical engineering that focuses on the designing of products and processes that minimize the use and generation of hazardous substances [1]. Environmental chemistry focuses on the effects of polluting chemicals on nature, whereas green chemistry focuses on technological approaches to preventing pollution and reducing consumption of nonrenewable resources [2–4]. Green chemistry overlaps with all subdisciplines of chemistry but with a particular focus on chemical synthesis, chemical process, and chemical engineering in industrial applications. To a lesser extent, the principles of green chemistry also affect laboratory practices. The overarching goals of green chemistry – namely, more resource-efficient and inherently safer design of molecules, materials, products, and processes – can be pursued in a wide range of contexts.

Green chemistry originated in the 1990s, targeting explicit social needs and scientific goals, and has now become the international frontier of chemistry research [1]. It is also one of the most significant research areas of chemistry and chemical engineering in the twenty-first century. The core of green chemistry is to apply chemical theories and novel chemical technologies, guided by the principle of atom economy, to reduce or eliminate pollution from the source, to meet the needs of sustainable development to a maximum extent in terms of rational utilization of resources, ecological balance, environmental protection, and so on, and moreover to realize the coordination and harmony between human being and nature. Therefore, green chemistry and its corresponding applicable technologies have become key research focuses and are pursued by numerous governments, academia, and industries.

1.1 Rise and Development of Green Chemistry

1.1.1 The Crisis of the Ecological Environment Calling for Green Chemistry

The ecological environment of human being is deteriorating due to the rapid growth of world population, acceleration of industrialization processes, excessive consumption of nonrenewable resources and energy, emissions of industrial and agricultural pollutants and domestic wastes, and so on. The main manifestation includes atmosphere pollution, acid rain, global warming, destruction of ozone layer, scarcity and pollution of freshwater resources, marine pollution, degradation and desertification of land resources, forest decline, reduction of biodiversity, and pollution of solid waste.

The essence of contemporary global issues is the crisis of human survival, since the natural environment of humans is being destroyed. In other words, the

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contradiction between humans and nature is intensifying. Green stands for life and is also regarded as a symbol of harmony between humans and nature. Therefore, green chemistry is an inevitable choice for human survival and the development of social sustainability.

1.1.2 Promotion of Green Chemistry by Propagation of Environment Protection and Regulations

We have only one Earth. To protect our homeland, to strengthen pollution management, and to protect the ecological environment have become the common aspirations and the concerned focuses of people all over the world. The promulgation of laws and regulations pertains to environmental protection and also promotes the rise and development of green chemistry.

In 1962, R. Carson, a woman marine biologist, published a book *Silent Spring*, which describes in detail the negative effects of dichlorodiphenyltrichloroethane (DDT) and other pesticides to various birds. The pesticides, for example DDT, not only reduce the population of bald eagles sharply via food chain but also endanger other bird species. Therefore, the previous beautiful and rigorous spring turns into "silence." In addition, these chemicals enter human bodies through skin contact and enter digestive tract thereby poisoning the victims. With the circulation of earth's atmosphere, they can be brought to any corner of the world. Even Arctic seals and Antarctic penguins were detected to have DDT in their bodies. This book greatly arouses the attention for protecting the ecological environment and is considered as a masterpiece of warning.

In 1972, the United Nations Conference on Human Environment was held, and then the declaration of the environment was issued.

In 1987, the United Nations Committee of Environment and Development released a long report, titled as "Our Common Future."

In 1990, the US Congress passed the act of pollution prevention, and set it as a national policy aiming to prevent the pollution at the origin.

In 1991, the American Chemical Society (ACS) and the Environmental Protection Agency (EPA) initiated the program of green chemistry. The purpose is to promote and develop novel or improved chemical products and technological processes that are benign to human health and ecological environment.

In June 1992, the United Nations Conference on Environment and Development was held in Rio de Janeiro, Brazil. Rio declaration and Agenda 21 were signed.

In 1994, the Chinese government published a white paper of "China's agenda 21," relying on the strategies of prospering the nation with science and education and sustainable development, and declared to follow the harmonious development

of economy and society, and meanwhile place the clean production as a priority in key areas.

1.1.3 The Development of Chemical Industry Declaring Green Chemistry

Chemistry, as a creative subject, has acquired brilliant achievements from its birth to date. Chemistry and chemical industry have provided abundant chemical products for daily life, and so far more than 6 million compounds have been synthesized, including more than 50,000 industrially produced products. Recently, the global annual output of chemical products exceeds 1.5 trillion dollars. China manufactures over 40,000 chemicals, and the output of petroleum and chemicals in 2001 is 1.099 trillion yuan RMB, accounting for 9.8% of the national industrial output. These chemical products create enormous material wealth and enrich the material life for human beings, and moreover promote the social civilization and progresses. Therefore, the chemical industry is playing an extremely important role in national economy, and is becoming the fundamental and pillar of national economy.

However, harmful substances originated from the production and usage of a huge amount of chemicals result in serious pollution toward the ecological environment, and the contemporary challenges of global ecological environment issues are directly or indirectly related to chemical pollution. Table 1.1 lists eight typically global pollution incidents since the 1930s.

It is necessary to point out that the industrial development experience of western developed countries should be introspected and taken into consideration. The extensive model of "treatment after pollution" causes the waste of natural resources and energy, leads to excessive investment without resolving virtual issues, and might even trigger the risk of secondary pollution. Therefore, the development of traditional chemical industry continuously seeks the solutions of reduction and elimination of chemical wastes to the environment. Green chemistry and its applicable technologies are just the effective ways to solve the environmental pollution by chemical industry. The core and goal of green chemistry is to prevent the pollution from its origin and realize "zero emission" by implementation of clean production technologies [5, 6].

1.1.4 Sustainable Development Promoting the Green Chemistry

Sustainable development is a new scientific concept of development which has been developed since the late 1980s. With the development of science and technology and the great improvement of social productivity, humans have created unprecedented material wealth and accelerated the progress of social civilization. Meanwhile, the world's rapid growing population, excessive consumption of the exhausted resources