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Zhang Long, Gong Changsheng, Dai Bin(Chief Editors)

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Chief editors:

Zhang Long

Gong Changsheng

Dai Bin

Associate chief editors:

Zhang Gongxiao

Yang Jianxin

Li Zhongming

Li Zaifeng

Contributing editors:

Xu Jun

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Yin Xueqiong

Jin Mei

Ma Xiaowei

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张 龙 贡长生 代 斌 主编

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Preface

Green chemistry and technologies is the forefront of international chemistry and chemical engineering development. It combines the latest achievements of modern chemistry, chemical engineering, physics, biology, material science, environmental science and information technology, and a new interdisciplinary 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's 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, Jiangnan 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 — 1**
 - 1.1 Rise and Development of Green Chemistry — 1
 - 1.1.1 The Crisis of the Ecological Environment Calling for Green Chemistry — 1
 - 1.1.2 Promotion of Green Chemistry by Propagation of Environment Protection and Regulations — 2
 - 1.1.3 The Development of Chemical Industry Declaring Green Chemistry — 3
 - 1.1.4 Sustainable Development Promoting the Green Chemistry — 3
 - 1.1.5 Green Chemistry and Technology is Becoming the Hotspot of Various Governments and Academia — 6
 - 1.2 The Contents and Characteristics of Green Chemistry — 7
 - 1.2.1 The Meaning of Green Chemistry — 7
 - 1.2.2 Research Contents of Green Chemistry — 9
 - 1.2.3 The Characteristics of Green Chemistry — 9
 - 1.3 The Developments of Green Chemistry in Domestic and at Abroad — 10
 - 1.3.1 The Developments of Green Chemistry at Abroad — 10
 - 1.3.2 Green Chemistry Research Receiving Much Attention in China — 19
 - 1.4 Green Chemistry is the Only Way for the Sustainable Development of Chemical Industry in China — 20
 - 1.4.1 Industrial Revolution Originated from Green Chemistry — 20
 - 1.4.2 Green Chemistry is the Preferential Mode for the Sustainable Development of Chinese Chemical Industry — 24
 - 1.4.3 Corresponding Solutions — 25
 - Questions — 29
 - References — 29
- 2 Basic principles of green chemistry — 31**
 - 2.1 Waste Prevention Instead of Remediation — 32
 - 2.2 Atom Economy — 33
 - 2.3 Less Hazardous Chemical Synthesis — 34
 - 2.4 Designing Safer Chemicals — 35
 - 2.5 Safer Solvents and Auxiliaries — 35
 - 2.6 Design for Energy Efficiency — 36
 - 2.7 Use of Renewable Feedstocks — 37
 - 2.8 Reduce Derivatives — 37
 - 2.9 Catalysis — 38
 - 2.10 Design for Degradation — 39

- 2.11 Real-time Analysis for Pollution Prevention — 39
- 2.12 Inherently Safer Chemistry for Accident Prevention — 40
- References — 40

3 Green technologies in inorganic synthesis — 41

- 3.1 Hydrothermal Synthesis — 41
 - 3.1.1 Introduction — 41
 - 3.1.2 Principle — 41
 - 3.1.3 Application Examples of Hydrothermal Synthesis — 41
- 3.2 Sol-gel Method — 43
 - 3.2.1 Introduction — 43
 - 3.2.2 Principle — 43
 - 3.2.3 Application of Sol-gel Method — 44
- 3.3 Local Chemical Reaction Method — 44
 - 3.3.1 Dehydration — 45
 - 3.3.2 Intercalation — 45
 - 3.3.3 Ion Exchange Reaction — 46
 - 3.3.4 Isomorphous Substitution — 47
 - 3.3.5 Decomposition — 47
 - 3.3.6 Redox Reaction — 47
- 3.4 Low-temperature Solid-phase Reaction — 48
 - 3.4.1 Introduction — 48
 - 3.4.2 Mechanism of Solid-phase Reaction — 48
 - 3.4.3 Applications of Low-temperature Solid-phase Reaction — 50
- 3.5 Rheological Phase Reaction — 51
 - 3.5.1 Introduction — 51
 - 3.5.2 The Principle of Rheological Phase Reaction — 52
 - 3.5.3 Applications of Rheological Phase Reaction — 52
- 3.6 The Precursor Method — 53
 - 3.6.1 Summary — 53
 - 3.6.2 Application of Precursor Method — 53
- 3.7 Melting Method — 54
- 3.8 Chemical Vapor Deposition — 54
 - 3.8.1 Introduction — 54
 - 3.8.2 The Principle of CVD — 55
 - 3.8.3 The Application of CVD Method — 56
- 3.9 Polymer Template Method — 56
 - 3.9.1 Introduction — 56
 - 3.9.2 Applications of the Template Method — 57
 - Questions — 58
 - References — 58

4	Green organic synthesis — 60
4.1	Efficient Chemical Catalytic Organic Synthesis — 60
4.1.1	Organic Synthesis with Solid Acid Catalysts — 60
4.1.2	Solid Base-catalyzed Organic Synthesis — 79
4.1.3	Ionic Liquid Catalyst — 83
4.2	Biocatalysis in Organic Synthesis — 87
4.2.1	Introduction — 87
4.2.2	Basic Principle of Enzyme Catalysis — 89
4.2.3	Types of Biocatalysts — 92
4.2.4	Typical Process of Biocatalysts Utilization — 93
4.3	Asymmetric Catalytic Synthesis — 94
4.3.1	Overview — 94
4.3.2	Principle and Process Analysis of Asymmetric Catalytic Synthesis — 95
4.3.3	Catalyst Systems in Asymmetric Catalytic Reactions — 98
4.4	Organic Synthesis in Fluorine Biphasic System — 101
4.4.1	Working Principle of Fluorine Two-Phase System — 101
4.4.2	Applications of Fluorine Two-Phase System — 101
4.5	Organic Synthesis by Phase Transfer Catalysis — 102
4.5.1	Overview — 102
4.5.2	Principle of PTC — 103
4.5.3	Applications of PTC — 103
4.6	Combinatorial Chemistry Synthesis — 104
4.6.1	Overview — 104
4.6.2	Principles of Combination of Chemical Synthesis — 105
4.6.3	Applications of Combinatorial Chemical Synthesis — 106
	Questions — 107
	References — 108
5	Green synthesis chemistry for polymer materials — 110
5.1	Introduction — 110
5.2	Polymerization Technology Employing Water as Reaction Medium — 111
5.2.1	The Advantages and Disadvantages — 111
5.2.2	Compositions of Aqueous Polymerization System and Their Function — 113
5.2.3	Principle of Aqueous Polymerization — 116
5.2.4	Application of Green Polymer Latex — 120
5.3	Polymerization Technology in Ionic Liquids — 121
5.3.1	Radical Polymerization — 122
5.3.2	Ionic Polymerization — 124
5.3.3	Polycondensation and Addition Polymerization — 125
5.3.4	Coordination Polymerization — 126
5.3.5	Electrochemical Polymerization — 126

5.4	Polymerization Technology in SCFs — 127
5.4.1	Polymerization in Supercritical Carbon Dioxide — 127
5.4.2	Depolymerization of Polymer in Supercritical Water — 128
5.4.3	Supercritical Enzyme Catalytic Reaction — 129
5.5	Synthesis of Waterborne Polyurethane with Low Residual VOC — 130
5.5.1	Classifications of Waterborne Polyurethanes — 131
5.5.2	Raw Materials of Waterborne Polyurethane — 133
5.5.3	Preparation of Waterborne Polyurethane Resin — 134
5.5.4	Preparation of Anionic Waterborne Polyurethane Resin — 135
5.5.5	Preparation of Cationic Waterborne Polyurethane Resin — 137
5.5.6	Performance of Waterborne Polyurethane — 137
5.5.7	Applications of Waterborne Polyurethane — 137
5.6	Radiation Cross-linking Polymerization Technology — 139
5.6.1	The Basic Principles of Radiation Cross-linking and Pyrolysis — 140
5.6.2	The Main Features of Radiation Polymerization — 142
5.6.3	Effect of Radiation Cross-linking on the Properties of Polymer — 143
5.6.4	Industrial Application of Radiation Cross-linking Technology — 144
5.7	Plasma Polymerization Technology — 144
5.7.1	Types and Characteristics of Plasma — 145
5.7.2	Mechanism of Plasma Polymerization — 146
5.8	Enzyme-catalyzed Polymerization — 147
5.8.1	Enzyme-catalyzed Ring-opening Polymerization — 147
5.8.2	Enzyme-catalyzed Stepwise Polymerization — 150
	Questions — 152
	References — 152
6	Green technology in fine chemical industry — 155
6.1	Greenization of Pharmaceutical Industry — 155
6.1.1	Introduction — 155
6.1.2	Green Chemical Pharmacy — 156
6.1.3	Green Biopharmaceutical — 161
6.1.4	Green Natural Medicine — 165
6.2	Greenization of Pesticide Industry — 169
6.2.1	Introduction — 169
6.2.2	Green Biological Pesticides — 170
6.2.3	Green Chemical Pesticides — 179
6.2.4	Green Pesticide Preparations — 182
6.3	Green Functional Materials — 184
6.3.1	Polyaniline Materials — 184
6.3.2	Graphene — 185
6.4	Green Electronic Chemicals — 188
6.4.1	Photoresist — 188

- 6.4.2 Polyimide Materials — 189
- 6.4.3 Epoxy Molding Compound — 190
- 6.4.3 Green Battery Materials — 191
- Questions — 198
- References — 199

- 7 Green technologies for intermediate product synthesis — 202**
 - 7.1 Introduction — 202
 - 7.2 Green Technologies in Intermediate Product Synthesis — 202
 - 7.2.1 Application of PDO — 202
 - 7.3 Green Technologies in Typical Product Synthesis — 212
 - 7.4 Green Chemical Process — 217
 - Questions — 218
 - References — 218

- 8 Green processes for carbon dioxide resource utilization — 220**
 - 8.1 Overview of Global Carbon Dioxide Emissions — 220
 - 8.1.1 The Source of Carbon Dioxide — 220
 - 8.1.2 The Present Situation and the Trend of Global Carbon Dioxide Emissions — 220
 - 8.2 The Separation and Fixing of CO₂ — 221
 - 8.2.1 The Properties of Carbon Dioxide — 221
 - 8.2.2 Separation Technologies of CO₂ — 221
 - 8.3 Chemical Conversion Principles of Carbon Dioxide — 225
 - 8.3.1 The Structure of Carbon Dioxide — 225
 - 8.3.2 CO₂ Activation Methods — 225
 - 8.4 Utilization Examples of Carbon Dioxide Resources — 227
 - 8.4.1 Application of Carbon Dioxide in Inorganic Synthesis — 228
 - 8.4.2 Applications of Carbon Dioxide in Organic Synthesis — 232
 - Questions — 235
 - References — 235

- 9 Green chemistry and chemical processes for biomass utilization — 237**
 - 9.1 Introduction — 237
 - 9.1.1 Natural Conditions of Biomass — 237
 - 9.1.2 Biomass Concept — 237
 - 9.1.3 Classification of Biomass — 237
 - 9.1.4 Use of Biomass — 238
 - 9.1.5 Biomass Distribution — 239
 - 9.1.6 Comprehensive Utilization of Biomass — 240
 - 9.2 Properties and Analysis Methods of Main Components in Biomass — 243

- 9.2.1 Physical and Chemical Properties of Cellulose — 243
- 9.2.2 Physical and Chemical Properties of Hemicellulose — 248
- 9.2.3 Physical and Chemical Properties of Lignin — 250
- 9.2.4 Biomass Solvent System and Law — 253
- 9.2.5 Biomass Structure Analysis Method — 255
- 9.2.6 Biomass Composition Analysis Method — 261
- 9.3 Chemical Conversion Principle of the Key Components of Biomass — 263
- 9.3.1 Chemical Conversion of Cellulose Components — 263
- 9.3.2 Chemical Conversion of Hemicellulose Components — 265
- 9.3.3 Chemical Conversion of Lignocellulosic Components — 267
- 9.4 Principle and Technology of Clean Separation of Biomass Components — 269
- 9.4.1 Basic Principles of Separation of Components — 269
- 9.4.2 Component Separation Based on Steam Explosion — 270
- 9.4.3 Component Separation Process Based on Alkali Peroxide System — 272
- 9.5 Green Process for Chemical Utilization of Biomass — 273
- 9.5.1 Ethanol Produced from Biomass — 274
- 9.5.2 Butanol and Acetone Production from Biomass — 275
- 9.5.3 Polyols Production from Biomass — 276
- 9.5.4 Levulinic Acid Produced from Biomass — 277
- 9.5.5 Adipic Acid Production from Biomass — 278
- 9.5.6 Hydrogen Produced from Biomass — 279
- 9.6 Green Chemical Conversion of Natural Oils and Fats — 282
- 9.6.1 Profile — 282
- 9.6.2 The Principle of Natural Fatty Acids and of Chemical Conversion — 283
- 9.6.3 Typical Products and Processes of Green Conversion of Natural Fatty Acids — 286
- Questions — 289
- References — 289
- 10 Green chemistry in exploiting marine resources — 293
- 10.1 The Reserves and Application of Marine Resources — 293
- 10.1.1 Marine Resources — 293
- 10.1.2 The Application of the Marine Resources — 295
- 10.2 Extraction and Preparation of Food Additives from Marine Resources — 297
- 10.2.1 Algal Polysaccharide — 297
- 10.2.2 Cod Liver Oil — 302
- 10.3 Extraction and Synthesis of Drugs from Marine Resources — 305
- 10.3.1 Extraction and Degradation of Chitin/Chitosan — 305

- 10.3.2 Total Synthesis of Marine Drugs — 310
- 10.3.3 Extraction of Active Substances from Microbial Secondary Metabolites — 311
- 10.4 Extraction Rare Elements from Ocean — 313
 - 10.4.1 Potassium (K) — 314
 - 10.4.2 Extraction of Bromine — 315
 - 10.4.3 Extraction of Lithium — 317
 - 10.4.4 Extraction of Uranium — 320
- 10.5 Desalination — 322
 - Questions — 327
 - References — 327

- 11 **The greening of the energy industry — 330**
 - 11.1 Clean Utilization Technology of fossil fuel — 330
 - 11.1.1 Impact of Energy Consumption on the Environment — 330
 - 11.1.2 Clean Combustion and Efficient Utilization Technology of Coal — 331
 - 11.2 Research and Development of Biomass Energy — 343
 - 11.2.1 Utilization Status of Biomass Energy at Home and Abroad — 344
 - 11.2.2 Biomass Energy Utilization Technology — 346
 - 11.2.3 Biodiesel — 351
 - 11.3 Development and Utilization of Clean Energy — 358
 - 11.3.1 Solar Energy — 358
 - 11.3.2 Wind Energy — 362
 - 11.3.3 Geothermal Energy — 363
 - 11.3.4 Ocean Energy — 365
 - 11.4 Renewable Energy and Sustainable Development — 370
 - 11.4.1 Renewable Energy — 370
 - 11.4.2 Research of Sustainable Energy Strategy — 371
 - Questions — 375
 - References — 375

- 12 **Circular economy and eco-industrial parks — 377**
 - 12.1 The Theoretical Basis of Eco-industry — 377
 - 12.1.1 Concept and Connotation of Eco-industry — 377
 - 12.1.2 Dual Nature of Traditional Industry — 377
 - 12.1.3 Industrial Eco-economic System — 378
 - 12.1.4 Theoretical Basis of Eco-industry — 379
 - 12.2 Circular Economy — 380
 - 12.2.1 Background of Circular Economy — 380
 - 12.2.2 Basic Principles of Circular Economy — 384
 - 12.2.3 Typical Examples of Circular Economy — 386
 - 12.2.4 Implementing Measures for Circular Economy — 391

- 12.3 Eco-industrial parks — 394
- 12.3.1 Development at Home and Abroad — 395
- 12.3.2 Principles and Contents of Eco-industrial Park Planning — 396
- 12.3.3 Construction of Eco-industrial parks — 400
- 12.3.4 Examples of Eco-industrial parks — 402
- Questions — 412
- References — 413

- 13 Intensification technology and practice in chemical processes — 415**
- 13.1 Overview — 415
- 13.1.1 The Concept of Chemical Process Intensification — 415
- 13.1.2 Origin and Development of Chemical Process Intensification — 417
- 13.2 The Coupling Technology of Reaction Process — 418
- 13.2.1 Membrane Catalytic Reaction — 419
- 13.2.2 Catalytic Distillation/Suspension Catalytic Distillation — 425
- 13.2.3 Suspension Catalytic Distillation Technology — 427
- 13.2.3 Alternating Flow Reaction — 431
- 13.2.4 Stable Magnetic Field Fluidized Bed — 433
- 13.3 The Coupling Technology of Separation Process — 435
- 13.3.1 Reaction Separation Coupling — 436
- 13.3.2 The Coupling of Membrane Separation — 436
- 13.3.3 Adsorptive Distillation — 438
- 13.4 Microchemical Technology — 439
- 13.4.1 Introduction — 440
- 13.4.2 The Principle of Microreactor — 440
- 13.4.3 The Application and Prospect of Microchemical Technology — 443
- 13.5 Intensification Technology Based on Energy Field — 445
- 13.5.1 Microwave Technology — 445
- 13.5.2 Ultrasonic Technology — 450
- 13.5.3 Radiation Technology — 454
- 13.5.4 Plasma Technology — 457
- 13.6 Other Intensification Techniques — 459
- 13.6.1 Hydrodynamic Cavitation Technology — 459
- 13.6.2 Supercritical Fluid Technology — 463
- 13.6.3 Pulse Combustion Drying Technology — 465
- 13.6.4 Supergravity Intensification Technology — 468
- 13.6.5 Mechanochemical Process — 470
- 13.7 Chemical Process Intensification Equipment — 473
- 13.7.1 Static Mixing Reactor — 474
- 13.7.2 Monolithic Reactor — 476
- 13.7.3 Rotating Disk Reactor — 478
- 13.7.4 Oscillating Flow Reactor — 480

13.7.5	Impinging Stream Reactor —	481
13.7.6	Supergravity Reactor —	484
	Questions —	485
	References —	486
14	Green chemistry assessment and practice —	491
14.1	Basic Principles of Green Chemistry Assessment —	491
14.1.1	Twelve Well-known Principles of Green Chemistry —	491
14.1.2	Twelve Additional Principles of Green Chemistry —	491
14.1.3	Twelve Principles of Green Chemical Engineering —	492
14.2	Life Cycle Assessment —	493
14.2.1	Meaning of Life Cycle Assessment —	493
14.2.2	Steps of LCA —	494
14.2.3	Purposes of LCA —	495
14.3	Assessment of Green Chemistry and Chemical Process —	496
14.3.1	Greenization of Chemical Reaction Process —	496
14.3.2	Measures of Greenization Chemistry and Chemical Process —	498
14.3.3	Assessment of Green Chemistry and Chemical Process —	502
14.4	Building Green Chemical Industry and Promoting Green Development —	509
	Questions —	510
	References —	510
Index —		513

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

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