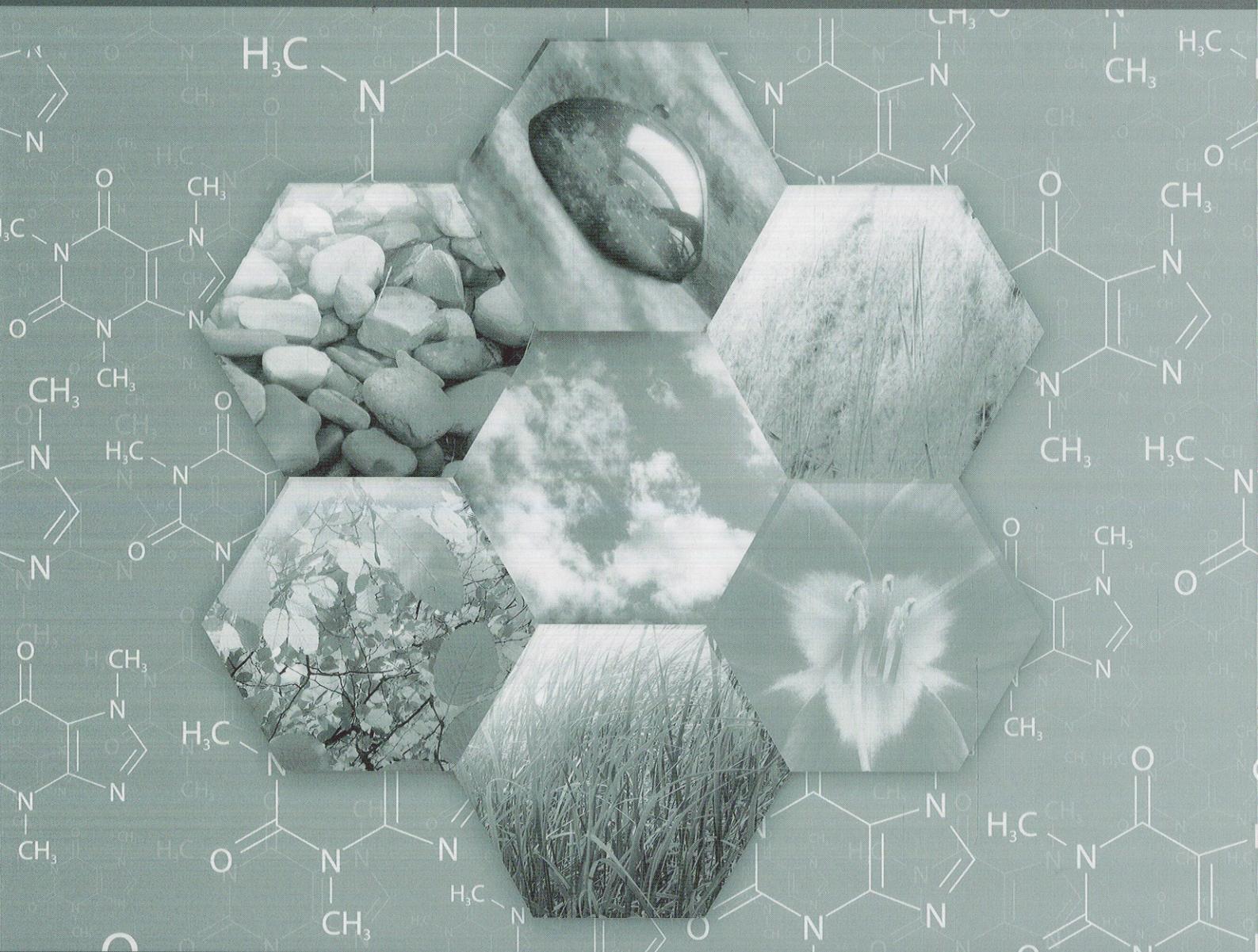


# INTRODUCTION TO GREEN CHEMISTRY

SECOND EDITION



ALBERT S. MATLACK

# Contents

|   |     |
|---|-----|
| Preface to Second Edition .....   | vii |
| Preface to First Edition .....  | ix  |
| <br>  |     |
| Chapter 1. Introduction .....   | 1   |
| 1.1 General Background.....   | 1   |
| 1.2 Toxicity of Chemicals in the Environment .....                          | 2   |
| 1.3 Accidents with Chemicals .....  | 7   |
| 1.4 Waste and Its Minimization .....  | 13  |
| 1.5 Conclusions .....   | 17  |
| 1.6 Summary of Some Important Points.....                                   | 18  |
| References .....  | 19  |
| Recommended Reading .....   | 24  |
| Exercises.....  | 25  |
| <br>  |     |
| Chapter 2. Doing without Phosgene, Hydrogen Cyanide, and Formaldehyde ..... | 27  |
| 2.1 Introduction .....  | 27  |
| 2.2 Preparation of Isocyanates .....  | 28  |
| 2.3 Polycarbonates.....   | 39  |
| 2.4 Summary and Conclusions for Phosgene .....                              | 41  |
| 2.5 Replacements for HCN.....   | 43  |
| 2.6 Eliminating Formaldehyde.....   | 45  |
| References .....  | 45  |
| Recommended Reading .....   | 48  |
| Exercises.....  | 48  |
| <br>  |     |
| Chapter 3. The Chlorine Controversy .....                                   | 51  |
| 3.1 The Problem .....   | 51  |
| 3.2 Toxicity of Chlorine Compounds .....                                    | 54  |
| 3.3 Estrogen Mimics .....   | 56  |
| 3.4 Bleaching Paper.....  | 58  |
| 3.5 Disinfecting Water .....  | 59  |
| 3.6 Chlorofluorocarbons and Ozone Depletion.....                            | 60  |
| 3.7 Chlorinated Solvents .....  | 63  |
| 3.8 Syntheses Where Chlorine Is Not in the Final Product .....              | 64  |
| 3.9 Summary and Conclusions.....  | 66  |
| References .....  | 67  |
| Recommended Reading .....   | 74  |
| Exercises.....  | 74  |
| <br>  |     |
| Chapter 4. Toxic Heavy-Metal Ions .....                                     | 75  |
| 4.1 The Problem .....   | 75  |
| 4.2 End-of-the-Pipe Treatments .....  | 78  |
| 4.3 Biocides .....  | 80  |
| 4.4 Catalysts for Reactions Other Than Oxidation .....                      | 82  |
| 4.5 Dyes and Pigments.....  | 83  |
| 4.6 Electrical Uses.....  | 84  |
| 4.7 Leather.....  | 85  |
| 4.8 Metal Finishing .....   | 85  |
| 4.9 Oxidation .....   | 86  |
| 4.10 Miscellaneous: Asbestos as a Toxic Material .....                      | 100 |

|  |     |
|--|-----|
| References .....   | 100 |
| Recommended Reading .....  | 108 |
| Exercises.....   | 108 |
| <br>   |     |
| Chapter 5. Solid Catalysts and Reagents for Ease of Workup ..... | 109 |
| 5.1 Introduction .....   | 109 |
| 5.2 The Use of Inorganic Supports .....                          | 110 |
| 5.3 Ion-Exchange Resins .....                                    | 119 |
| 5.4 Combinatorial Chemistry .....                                | 124 |
| 5.5 Other Uses of Supported Reagents.....                        | 127 |
| 5.6 Cyclodextrins.....   | 133 |
| References .....   | 135 |
| Recommended Reading .....  | 143 |
| Exercises.....   | 143 |
| <br>   |     |
| Chapter 6. Solid Acids and Bases .....                           | 145 |
| 6.1 Introduction .....   | 145 |
| 6.2 Polymeric Sulfonic Acids.....                                | 147 |
| 6.3 Polymer-Supported Lewis Acids.....                           | 148 |
| 6.4 Sulfated Zirconia.....                                       | 149 |
| 6.5 Supported Metal Oxides.....                                  | 149 |
| 6.6 Rare Earth Triflates .....                                   | 150 |
| 6.7 Solid Bases .....  | 151 |
| 6.8 Zeolites and Related Materials.....                          | 154 |
| 6.9 Metal Organic Frameworks.....                                | 164 |
| 6.10 Clays .....   | 166 |
| 6.11 Heteropolyacids .....                                       | 170 |
| References .....   | 175 |
| Recommended Reading .....  | 185 |
| Exercises.....   | 185 |
| <br>   |     |
| Chapter 7. Chemical Separations.....                             | 187 |
| 7.1 The General Picture .....                                    | 187 |
| 7.2 Inclusion Compounds .....                                    | 191 |
| 7.3 Separation of Ions.....                                      | 194 |
| 7.4 Membrane Separations .....                                   | 197 |
| References .....   | 205 |
| Recommended Reading .....  | 213 |
| Exercises.....   | 213 |
| <br>   |     |
| Chapter 8. Working without Organic Solvents .....                | 215 |
| 8.1 Advantages and Disadvantages of Solvents .....               | 215 |
| 8.2 Working without Solvent.....                                 | 217 |
| 8.3 Process Intensification.....                                 | 221 |
| 8.4 Carbon Dioxide as a Solvent .....                            | 226 |
| 8.5 Water as a Reaction Medium .....                             | 230 |
| 8.6 Ionic Liquids.....   | 236 |
| 8.7 Surfactants and Cleaning .....                               | 238 |
| 8.8 Coatings.....  | 241 |
| References .....   | 246 |
| Recommended Reading .....  | 258 |
| Exercises.....   | 259 |
| <br>   |     |
| Chapter 9. Biocatalysis and Biodiversity .....                   | 261 |
| 9.1 Biocatalysis.....  | 261 |

|  |     |
|--|-----|
| 9.2 Biodiversity .....                                     | 286 |
| References .....   | 293 |
| Recommended Reading .....                                  | 310 |
| Exercises.....   | 311 |
| <br>Chapter 10. Stereochemistry.....                       | 313 |
| 10.1 Importance of Optical Isomers .....                   | 313 |
| 10.2 Chiral Pool .....                                     | 314 |
| 10.3 Resolution of Racemic Mixtures.....                   | 315 |
| 10.4 Asymmetrical Synthesis.....                           | 323 |
| References .....   | 338 |
| Recommended Reading .....                                  | 343 |
| Exercises.....   | 343 |
| <br>Chapter 11. Agrochemicals.....                         | 345 |
| 11.1 The Nature and Use of Agrochemicals .....             | 345 |
| 11.2 Problems with Agrochemicals .....                     | 347 |
| 11.3 Alternative Agriculture .....                         | 352 |
| 11.4 Lawns .....   | 371 |
| 11.5 Genetic Engineering.....                              | 373 |
| 11.6 Integrated Pest Management .....                      | 373 |
| References .....   | 375 |
| Recommended Reading .....                                  | 386 |
| Exercises.....   | 386 |
| <br>Chapter 12. Materials for a Sustainable Economy .....  | 387 |
| 12.1 Introduction .....                                    | 387 |
| 12.2 Commodity Chemicals from Renewable Raw Materials..... | 387 |
| 12.3 Use of Natural Polymers .....                         | 399 |
| 12.4 Polymers from Renewable Raw Materials .....           | 404 |
| 12.5 Conclusions and Recommendations.....                  | 408 |
| References .....   | 409 |
| Recommended Reading .....                                  | 417 |
| Exercises.....   | 417 |
| <br>Chapter 13. Chemistry of Long Wear.....                | 419 |
| 13.1 Why Things Wear Out .....                             | 419 |
| 13.2 Stabilizers for Polymers .....                        | 421 |
| 13.3 Lubrication, Wear, and Related Subjects .....         | 426 |
| 13.4 Inhibition of Corrosion.....                          | 430 |
| 13.5 Mending .....   | 433 |
| 13.6 Miscellaneous.....                                    | 434 |
| 13.7 The Future .....                                      | 434 |
| References .....   | 434 |
| Recommended Reading .....                                  | 439 |
| Exercises.....   | 439 |
| <br>Chapter 14. Chemistry of Recycling.....                | 441 |
| 14.1 Waste .....   | 441 |
| 14.2 Recycling.....  | 442 |
| 14.3 Methods and Incentives for Source Reduction.....      | 458 |
| 14.4 Overall Picture .....                                 | 465 |
| References .....   | 466 |
| Recommended Reading .....                                  | 475 |
| Exercises.....   | 475 |

|  |     |
|--|-----|
| Chapter 15. Energy and the Environment.....                          | 477 |
| 15.1 Energy-Related Problems.....                                    | 477 |
| 15.2 Heating, Cooling, and Lighting Buildings .....                  | 485 |
| 15.3 Renewable Energy for Electricity and Transport.....             | 490 |
| 15.4 Use of Less Common Forms of Energy for Chemical Reactions ..... | 498 |
| References .....   | 502 |
| Recommended Reading .....  | 515 |
| Exercises.....   | 516 |
| Chapter 16. Population and the Environment .....                     | 517 |
| 16.1 The Problems.....   | 517 |
| 16.2 Chemistry of Human Reproduction .....                           | 519 |
| 16.3 The Chemistry of Family Planning.....                           | 521 |
| 16.4 Summary of the Problem .....                                    | 527 |
| References .....   | 528 |
| Recommended Reading .....  | 531 |
| Exercises.....   | 532 |
| Chapter 17. Environmental Economics.....                             | 533 |
| 17.1 Introduction .....  | 533 |
| 17.2 Nature's Services .....   | 533 |
| 17.3 Environmental Accounting .....                                  | 535 |
| 17.4 Corporations .....  | 538 |
| 17.5 Environmental Economics of Individuals.....                     | 541 |
| 17.6 Government Actions Affecting Environmental Economics .....      | 542 |
| References .....   | 546 |
| Recommended Reading .....  | 552 |
| Exercises.....   | 552 |
| Chapter 18. Greening .....   | 553 |
| 18.1 Introduction .....  | 553 |
| 18.2 Individuals.....  | 553 |
| 18.3 Nongovernmental Organizations .....                             | 555 |
| 18.4 Government.....   | 557 |
| 18.5 Corporations.....   | 558 |
| References .....   | 567 |
| Recommended Reading .....  | 573 |
| Exercises.....   | 573 |
| Index .....  | 575 |