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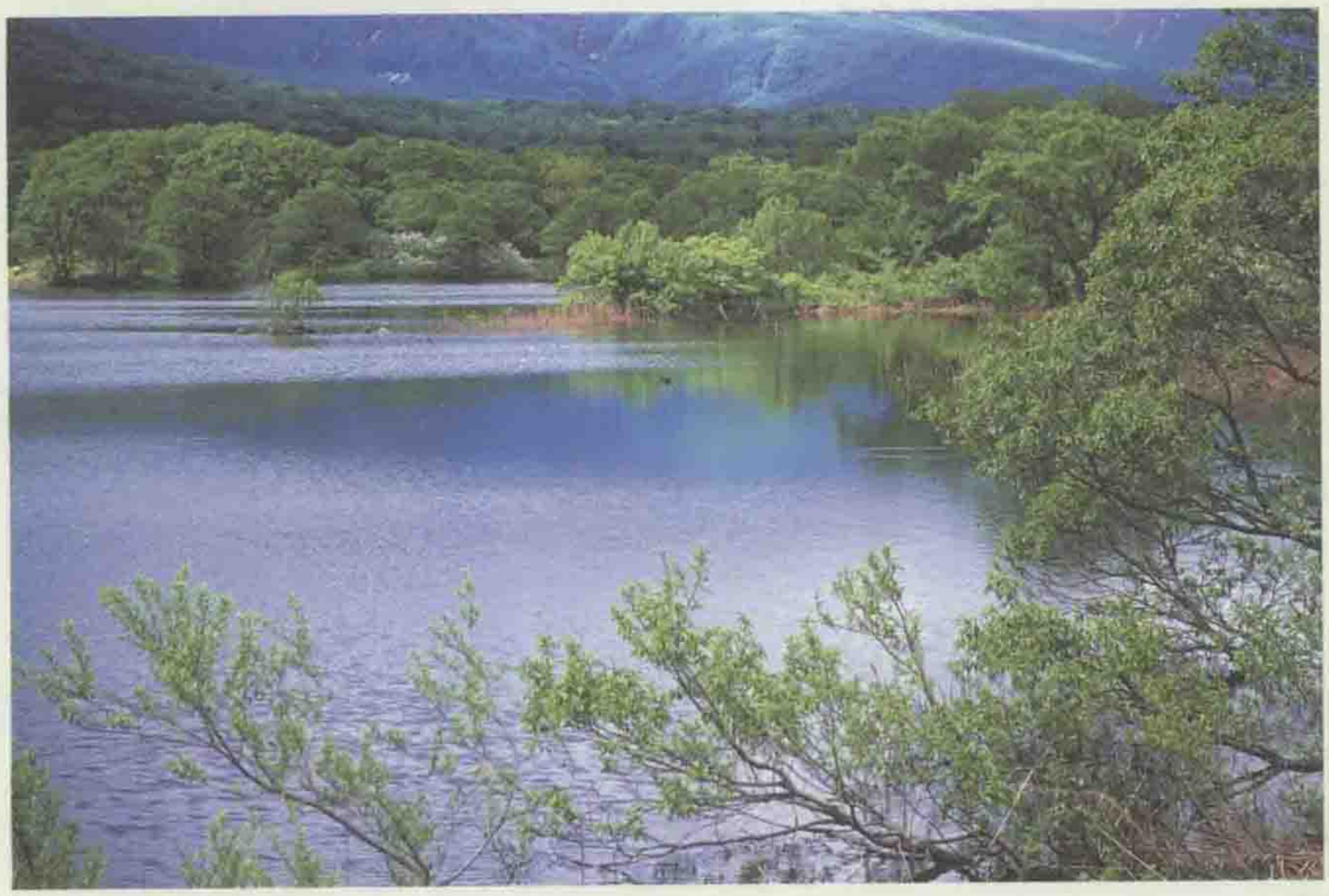
Clair N. Sawyer Perry L. McCarty Gene F. Parkin

Chemistry for Environmental Engineering and Science

(Fifth Edition)

环境科学与工程化学

（第5版）



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Chemistry for Environmental Engineering and Science (Fifth Edition)
EISBN: 0-07-248066-1

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图书在版编目(CIP)数据

环境科学与工程化学=Chemistry for Environmental Engineering and Science：第 5 版 / 索耶（Sawyer, C. N.），麦卡蒂（McCarty, P. L.），帕金（Parkin, G. F.）著. —影印本. —北京：清华大学出版社，2003
（大学环境教育丛书）
ISBN 7-302-07817-3

Ⅰ. 环…　Ⅱ. ①索… ②麦… ③帕…　Ⅲ. 环境化学—高等学校—教材—英文　Ⅳ. X13

中国版本图书馆 CIP 数据核字（2003）第 117307 号

出 版 者：清华大学出版社　　地　　址：北京清华大学学研大厦
　　http://www.tup.com.cn　　邮　　编：100084
　　社总机：(010) 6277 0175　　客户服务：(010) 6277 6969
责任编辑：柳　萍
印 刷 者：清华大学印刷厂　　装 订 者：三河市新茂装订有限公司
发 行 者：新华书店总店北京发行所
开　　本：185×230　印 张：48.5
版　　次：2004 年 1 月第 1 版　2004 年 1 月第 1 次印刷
书　　号：ISBN 7-302-07817-3/X・56
印　　数：1~3000
定　　价：59.00 元

出版前言

在21世纪初，面临各种环境问题，人类清醒地认识到要走可持续发展之路。而发展环境教育是解决环境问题和实施可持续发展战略的根本。高等学校的环境教育，是提高新世纪建设者的环境意识，并向社会输送环境保护专门人才的重要途径。为了反映国外环境类教材的最新内容和编写风格，同时也为了提高学生阅读专业文献和获取信息的能力，我们精选了一些国外优秀的环境类教材，组成大学环境教育丛书影印版和翻译版，本书即为其中的一册。所选教材均在国外被广泛采用，多数已再版，书中不仅介绍了有关概念、原理及技术方法，给出了丰富的数据，还反映了作者不同的学术观点。

我们希望这套丛书能对高等院校师生和广大科技人员有所帮助，同时为我国环境教育的发展作出贡献。

清华大学出版社

TO OUR FAMILIES Martha, Annette, Kyle, and Eric who sacrificed much for this current effort.

PREFACE

Education in environmental engineering and science has historically been conducted at the graduate level, and up to the present time has drawn mainly on students with a civil engineering background. In general, education in civil engineering does not prepare a student well in chemistry and biology. Since a knowledge of these sciences is vital to the environmental engineer, the graduate program must be designed to correct this deficiency. In recent years, students from other engineering disciplines and from the natural sciences have been attracted to this field. Some have a deficiency in chemistry and biology similar to that of the civil engineer and need exposure to general concepts of importance.

A current trend in the United States is the introduction of an undergraduate environmental engineering option or degree program within civil engineering departments. These students also require an introduction to important concepts in chemistry and biology.

This book is written to serve as a textbook for a first course in chemistry for environmental engineering and science students with one year of college-level chemistry. Environmental professionals need a wide background in chemistry, and in recognition of this need, *Chemistry for Environmental Engineering and Science* summarizes important aspects from various areas of chemistry. This treatment should help orient the students, aid them in choosing areas for advanced study, and help them develop a better "feel" for what they should expect to gain from further study.

The purpose of this book is twofold: It (1) brings into focus those aspects of chemistry that are particularly valuable for solving environmental problems, and (2) it lays a groundwork of understanding in the area of specialized quantitative analysis, commonly referred to as water and wastewater analysis, that will serve the student as a basis in all the common phases of environmental engineering practice and research.

Substantial changes continue to occur in the emphasis of courses for environmental engineers and scientists. The trend is toward a more fundamental understanding of the chemical phenomena causing changes in the quality of surface and groundwaters, of waters and wastewaters undergoing treatment, and of air. This fundamental understanding of chemistry is absolutely critical as environmental professionals attempt to solve complex problems such as hazardous waste pollution, air pollution from emission of toxic compounds, radioactive waste disposal, ozone depletion, and global climate change.

Chemistry for Environmental Engineering and Science is organized into two parts. Part One is concerned solely with fundamentals of chemistry needed by environmental engineers and scientists. It includes chapters on general chemistry,

physical chemistry, equilibrium chemistry, organic chemistry, biochemistry, colloid chemistry, and nuclear chemistry. Each emphasizes environmental applications. In this new edition, the chapters on general and physical chemistry have been updated, and new homework problems have been added. The chapter on equilibrium chemistry has been revised, with many new example and homework problems. The chapter on organic chemistry includes an added emphasis on organic compounds of environmental significance (e.g., chlorinated solvents). Sections are included on the behavior (fate) of organic compounds in the environment and in engineered systems and on the use of structure-activity relationships. The chapter on biochemistry has been updated. We feel that these revisions make the text even more suitable for lecture courses on environmental chemistry principles.

Part Two is concerned with analytical measurements. A new chapter has been added on statistical analysis of analytical data. All analytical procedures are subject to errors. There is a critical need for students to learn how to evaluate the uncertainties such errors present. This chapter discusses basic methods for evaluating and reporting uncertainties in measurements that are essential for analytical chemists, regulatory agencies, and environmental professionals who use analytical data to make important decisions.

The next several chapters contain general information on quantitative, qualitative, and instrumental methods of analysis, useful as background material for the subsequent chapters concerned with water and wastewater analyses of particular interest to environmental engineers and scientists. These chapters are written to stress the basic chemistry of each analysis and show their environmental significance. They should be particularly useful when used with "Standard Methods for the Examination of Water and Wastewater," published jointly by the American Public Health Association, American Water Works Association, and Water Environment Federation, and giving the details for carrying out each analytical determination. The final chapter stresses trace contaminants, many of which are determined analytically with instrumental procedures discussed in earlier chapters. A listing of U.S. Environmental Protection Agency drinking water standards and World Health Organization drinking water quality guidelines for various trace contaminants are also contained in this chapter. Part Two is considered to be most useful as lecture material to accompany a laboratory course in environmental chemistry. Revisions have been made in other chapters to reflect the many changes in "Standard Methods" that have occurred since the last edition of this text.

Problems are included at the end of most chapters to stress fundamentals and increase the usefulness of this book as a classroom text. Example problems throughout the text help increase the students' understanding of the principles outlined. In Part One of the book, where the emphasis is on chemical fundamentals, answers are included after many homework problems, allowing students to evaluate independently their understanding of the principles emphasized.

To meet textbook requirements, brevity has been an important consideration throughout. For those who believe that we have been too brief, we can only beg their indulgence and recommend that they seek further information in standard references on the subject. Important references are listed at the end of each chapter.

It is inevitable that we have made errors in producing this textbook. For this we apologize. Hopefully they are not so numerous that they impede the student's ability to learn the material. Fortunately, for this new edition, McGraw-Hill is providing a website where we can list errata that can be readily downloaded with no charge to students and faculty. A solution manual for text problems can also be obtained at this website, but by faculty members only. We hope also to use this website to post more example problems and their solutions. There was a request for such by reviewers, and this is one way that we can provide additional material without expanding the number of pages and costs for the text. The website for this textbook can be found at http://www.mhhe.com/sawyer. We would appreciate hearing from students and faculty when errors are found so that we can enter them in a timely manner on the website. Our e-mail addresses are included in the errata section of the website.

Special thanks are due colleagues at the University of Iowa—Michelle Scherer for specific suggestions to improve the text and generous help with new homework problems, and Pedro Alvarez, Keri Hornbuckle, Craig Just, Jerry Schnoor, and Richard Valentine for helpful discussions. Thanks also to Mark Benjamin of the University of Washington for e-mail discussions of activity corrections and other weighty matters. Finally, we wish to express our gratitude to William Burgos, Pennsylvania State University; Cindy Lee, Clemson University; Howard Liljestrand, University of Texas, Austin; John Pardue, Louisiana State University; and Andrew Randall, University of Central Florida, as well as the anonymous reviewers, all of whom were selected by the publisher to provide comments about the textbook and to provide recommendations for change. We appreciate the many thoughtful and detailed comments that were offered and used them extensively in preparing this revision. We hope that the reviewers and other faculty find the changes to be beneficial to them and to their students.

Perry L. McCarty
Gene F. Parkin

ABOUT THE AUTHORS

The late **Clair N. Sawyer** was active in the field of sanitary chemistry for over 30 years. He received a Ph.D. from the University of Wisconsin. As Professor of Sanitary Chemistry at the Massachusetts Institute of Technology, he taught and directed research until 1958. He then was appointed Vice President and Director of Research at Metcalf and Eddy, Inc., and served as consultant on numerous water and wastewater treatment projects in the United States and many foreign countries. After retiring, he served as an environmental consultant for several years. He passed away in 1992. He was the originator and sole author of the first edition, which was published in 1960.

Perry L. McCarty is the Silas H. Palmer Professor Emeritus of civil and environmental engineering at Stanford University. He received a B.S. degree in civil engineering from Wayne State University and S.M. and Sc.D. degrees in sanitary engineering from the Massachusetts Institute of Technology, where he taught for four years. In 1962 he joined the faculty at Stanford University. His research has been directed towards the application of biological processes for the solution of environmental problems. He is an honorary member of the American Water Works Association and the Water Environment Federation, and Fellow in the American Academy of Arts and Sciences, the American Association for the Advancement of Science, and the American Academy of Microbiology. He was elected to the National Academy of Engineering in 1977. He received the Tyler Prize for environmental achievement in 1992 and the Clarke Prize for outstanding achievement in water science and technology in 1997.

Gene F. Parkin is a Professor of Civil and Environmental Engineering at the University of Iowa, and Director of the Center for Health Effects of Environmental Contamination. He received a B.S. degree in civil engineering and an M.S. degree in sanitary engineering from the University of Iowa and a Ph.D. degree in environmental engineering from Stanford University. He taught at Drexel University for eight years before joining the faculty at the University of Iowa in 1986. His teaching interests have been in biological treatment processes and environmental chemistry. His research has been directed toward anaerobic biological processes and bioremediation of waters contaminated with organic chemicals. He has received the J. James R. Croes Medal from the American Society of Civil Engineers and the Harrison Prescott Eddy Medal from the Water Environment Federation. In 1989 he received the Hancher-Finkbine Medallion from the University of Iowa for outstanding teaching and leadership and in 1999 he received a state of Iowa Board of Regents Award for Faculty Excellence.

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PART 1

Fundamentals of Chemistry for Environmental Engineering and Science