

Chemistry and the Environment

From the origin of the Earth to climate change, this textbook presents the chemistry of the environment using the full strength of physical, inorganic, and organic chemistry, in addition to the necessary mathematics and physics, using modern notation and terminology. It provides a broad yet thorough description of the environment and the environmental impact of human activity using scientific principles.

Chemistry and the Environment describes the chemistry of Earth's atmosphere, hydrosphere, and lithosphere (including soils) and the biogeochemical cycles. The book presents a variety of industrial processes, from paper and steel to energy and pesticide production, focusing discussion on the environmental impact of these processes and showing how increasing environmental awareness has led to improved methods. The text provides an accessible account of environmental chemistry while paying attention to the fundamental basis of the science, showing derivations of formulas and giving primary references and historical insight. The authors make consistent use of professionally accepted nomenclature (IUPAC and SI), allowing transparent access to the material by students and scientists from other fields.

The authors created this textbook primarily for their own courses, and it has been developed through many years of feedback from students and colleagues. The book will be invaluable for advanced undergraduate and graduate students in environmental chemistry courses, and for professionals in chemistry and allied fields.

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Advance praise for *Chemistry and the Environment*

“This outstanding text brings together fundamental information about the natural chemistry of the Earth and its atmosphere and the environmental impacts of anthropogenic chemicals. It is well suited for upper-level undergraduate and graduate students and researchers in chemistry, Earth sciences, and atmospheric science.”

– Mark Jacobson, Department of Civil and Environmental Engineering, Stanford University, author of *Air Pollution and Global Warming*

“Both authors have excellent scientific standing and complementary backgrounds. They have combined well on this excellent textbook, based on their long experience of teaching environmental chemistry to undergraduate students at the University of Copenhagen. There are many textbooks on environmental chemistry aimed at undergraduate and graduate courses, but this is one of the best that I have come across. It will be adopted for courses in every university for the next decade and beyond due to its logical and comprehensive content. I strongly recommend this excellent textbook for environmental chemistry and related courses at the graduate and undergraduate levels.”

– Naohiro Yoshida, Department of Environmental Chemistry & Engineering, Tokyo Institute of Technology

“Harnung and Johnson have produced a textbook on environmental chemistry that is firmly rooted in physical and chemical principles and follows a strict quantitative and analytical approach. Nevertheless, the accessible style and informative footnotes make it a joy to read and explore for graduate students and professionals alike. It perfectly fills the gap left by more phenomenological introductions to the field.”

– Jan Kaiser, Department of Environmental Sciences, University of East Anglia

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Contents

<i>Preface</i>	<i>page xi</i>
<i>Acknowledgments</i>	<i>xiii</i>
Introduction	1
1 The Earth	4
1.1 Origin of the Earth	4
a. Big Bang	4
b. The solar system	7
c. The Earth	10
1.2 Structure of the Earth	14
a. Classical measurements	14
b. Internal structure of the Earth	17
1.3 Geological periods and dating	21
a. Geological periods	21
b. Radioactive dating	23
c. Isotopic fractionation	26
1.4 Features of the Earth’s development	31
a. Plate tectonics	31
b. Chemistry mediated by water and biota	34
c. Global chemistry of life	35
2 Environmental dynamics	37
2.1 Introduction	37
a. Basic concepts	37
b. Time dependence of concentration	40
c. Field	43
d. Transport	44
2.2 Fluid dynamics	45
a. Basic properties of the flux density	45
b. Open physicochemical systems	49
c. Continuity equations	51
d. Equations of motion	54
e. Applications of the equations of motion	56
f. Applications of the continuity equation	65
2.3 Chemical thermodynamics	69
a. Basic concepts	70
b. Phase equilibria	81

2.4 Chemical kinetics	91
a. Basic concepts	92
b. Description of elementary reactions	92
c. Temperature dependence of reaction rates	94
3 The Spheres	98
3.1 The lithosphere	99
a. Abundance of the elements	100
b. The rock-forming minerals	102
c. Igneous rocks	109
d. Sedimentary rocks	112
e. Metamorphic rocks	114
3.2 The hydrosphere	115
a. Chemical composition of natural waters	116
b. Analytical characteristics of environmental waters	117
c. Physicochemical properties of water	121
3.3 The atmosphere	124
a. Chemical composition	124
b. Hydrosphere-atmosphere equilibria	126
c. The physics of the atmosphere	128
3.4 Biota	131
a. Chemical composition of biota	131
b. The cell	135
4 Chemistry of the atmosphere	140
4.1 Tropospheric chemistry	142
a. The hydroxyl radical	142
b. Nonmethane hydrocarbons	151
c. Tropospheric aerosols	154
d. Henry's law and deposition	155
4.2 Stratospheric chemistry	156
a. The Chapman mechanism: O_x	157
b. The radicals HO_x	159
c. The radicals NO_x	160
d. The radicals ClO_x and coupling of the cycles	161
e. The ozone hole	163
f. Midlatitude ozone depletion	166
5 Chemistry of the hydrosphere	169
5.1 Acid-base chemistry	170
a. Acid-base properties of water	171
b. An acid and its conjugate base	172
c. Oligovalent acids	178
d. Polyvalent acids	187

5.2 Coordination chemistry	189
a. Complex formation	190
b. Lewis acids and bases	194
c. Coordination chemistry of natural waters	196
5.3 Electrolytic properties	200
a. Redox chemistry of natural waters	201
b. Aqueous solutions of electrolytes	206
6 Chemistry of the pedosphere	217
6.1 Structure of soil	218
a. Soil profile	218
b. Regolith and groundwater	220
6.2 Physics of soil water	222
a. The saturated zone	222
b. The vadose zone	224
c. Flowing groundwater	226
6.3 Chemistry of soils	228
a. Structure of soil minerals	230
b. The soil solution	236
c. Soil adsorption phenomena	238
d. Soil colloid phenomena	246
e. Soil organic matter	248
7 Global cycles of the elements	250
7.1 Biogeochemical cycles	250
7.2 Carbon	251
a. Reservoirs of carbon	251
b. Fluxes of carbon dioxide	253
c. Fluxes of methane	255
d. Anthropogenic sources of atmospheric carbon dioxide	255
7.3 Nitrogen	256
a. Natural nitrogen fixation	256
b. Industrial nitrogen fixation	261
7.4 Phosphorus	263
7.5 Sulfur	265
a. Natural sulfur cycles	266
b. Anthropogenic sulfur cycles	267
7.6 Chlorine	270
7.7 Aluminium and silicon	272
8 The chemicals industry	273
8.1 Introduction	273
a. Energy	274
b. A survey of the chemicals industry	275

c. The agriculture and food industries	277
d. Chemical production	279
8.2 Heavy industry	282
a. Cement	282
b. Coal and steel	285
c. Metals	289
d. Pulp and paper	292
8.3 The inorganic chemicals industry	294
a. The electrolytic cell	296
b. Sodium hydroxide	299
c. Sodium carbonate	299
d. Chlorine	302
8.4 The biotechnology industry	304
8.5 Sustainable synthetic chemistry: Green chemistry	304
9 Environmental impact of selected chemicals	310
9.1 Pesticides	310
a. Insecticides	312
b. Herbicides	315
c. Fungicides	318
d. Enantiomeric xenobiotics	320
9.2 Organochlorine compounds	323
a. Dioxins and (polychloro)biphenyls	323
b. Hexachlorocyclohexane, HCH, and pentachlorocyclohexene, PCCH	326
c. Bromocyclenes	328
9.3 Metal compounds	328
9.4 Detergents	330
a. Soaps	331
b. Syndets	332
c. The Gibbs isotherm	334
9.5 Water treatment	335
a. Domestic water	336
b. Industrial water	338
c. General methods	339
10 The chemistry of climate change	343
10.1 The physics of thermal radiation	344
a. Quantitative expressions	344
b. Radiation theory	345
c. Application to the Sun-Earth system	348
10.2 Astronomical forcing	352
a. The insolation formula	353
b. Time dependence of insolation	355
c. Climate recorded in sediments and glacial ice	358

10.3 Modern climate	360
a. Causes of climate change	361
b. Energy flux densities in the atmosphere	361
c. Radiant forcing	362
d. Global warming potential	365
e. Climate sensitivity	365
f. Climate change	367
Appendix 1	371
A1.1 Symbols of the elements	371
A1.2 Atomic weights of the elements	372
A1.3 The international system of units, SI	375
A1.4 Nonstandard units and suffixes	376
A1.5 Transport properties	377
A1.6 Electricity	377
A1.7 General chemistry	378
A1.8 Fundamental constants	379
A1.9 α -Amino acids of proteins	379
A1.10 The Greek alphabet	380
Appendix 2	381
A2.1 Polyvalent acids	381
A2.2 Mononuclear complexes	385
a. Polynuclear complexes	387
Appendix 3	389
A3.1 The activity of electrolytes	389
a. The Debye-Hückel limiting law	389
Appendix 4	393
A4.1 Convection	393
Appendix 5	396
A5.1 Parameters of the insolation formula, Equation 10.29	396
a. The 24-h mean insolation at a geographical latitude φ	396
b. The ecliptic	398
<i>References</i>	401
<i>Name index</i>	415
<i>Subject index</i>	417

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Sven E. Harnung and Matthew S. Johnson
Frontmatter
[More information](#)

Preface

Chemical species made by humans affect many naturally occurring processes and organisms. The observation of an anthropogenic substance in Nature raises a series of questions: Where did it come from? How and why was it produced and released? How does it move around within the environment? What is its chemistry, including the reaction rate, mechanism, and products, and how does it influence living organisms and the Earth system? More generally, and perhaps not within the focus of scientific chemistry, there are questions such as: Who is entitled to make use of Nature and to what extent? Are there limits to growth? A rational discussion of these questions involves the scientific method and results from the physical sciences, as well as law, economy, and the humanities.

Turning to chemistry: there is no doubt that success in the field of environmental chemistry requires mastering fundamental disciplines such as analytical chemistry, thermodynamics, and modern experimental and theoretical chemistry. The important role of environmental chemistry as a field in its own right is recognized internationally: the International Union of Pure and Applied Chemistry, IUPAC,^{a,233} has organized scientific investigations of the environmental impact of chemistry for many years; examples include its series of reports on pesticides,¹⁷⁹ starting long before environmental issues were of political and public interest, and the White Book on chlorine.¹⁹¹ Recognition of the importance of the subject has driven IUPAC to rename its Applied Chemistry Division the Chemistry and the Environment Division. The significance of this change is underlined by the fact that the word *Applied* is part of the very name of the Union.

Despite the central role of environmental chemistry in sustainable development, we have often wished that there was a textbook that would address the subject using the full strength of physical, inorganic, and organic chemistry, in addition to the necessary mathematics and physics. The target audience for this book is interested professionals and advanced undergraduate and graduate students in chemistry and allied fields.

Scientists with very different backgrounds have contributed to environmental sciences, and various traditions regarding nomenclature are found in the literature. Accordingly, much time and effort are sometimes required in order to interpret scientific papers. For this reason we have emphasized the use of standard ISO-IUPAC nomenclature throughout. The overall objective of a nomenclature is the safe exchange of scientific and technical information among people in different disciplines

^a The international organizations are discussed in the Introduction.

and between nations.^a For example, public safety demands that chemists and nonexperts (e.g., customs authorities, emergency and health services) be able to communicate clearly concerning the identities of chemical species involved.

Environmental chemistry is driven by specific examples such as detection of pesticide residues and characterization of the ozone hole. The background knowledge needed to understand these subjects in depth has been put into a separate chapter on environmental dynamics, which includes derivations and formulas related to fluid dynamics, thermodynamics, and reaction kinetics. The intention is that this material not be taught from start to finish, but rather taken up when it is relevant. Similarly, teachers are encouraged to choose the specific sections of the book that are most relevant to their educational programs. The purpose of the forward references in the text is to help the reader during the final reading of the book; they may not be helpful in the first reading. We have included dates of significant events in the history of chemistry and the environment. Dates prior to 1950, mainly of chemical history, may be found in the treatise *A History of Chemistry*,^{73a,b} while more recent events are referenced directly. Dates of historical interest for other disciplines are provided without explicit references.

Together we have taught environmental chemistry at the University of Copenhagen for more than 30 years, and this book has grown out of our classes. We are indebted to the many gifted students it has been an honor to teach and who have helped us refine our methods and the material.

^a The loss of the Mars Climate Orbiter on September 23, 1999, because of confusion of the nonstandard pound force (lbf) with the SI newton (N), illustrates the point.

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