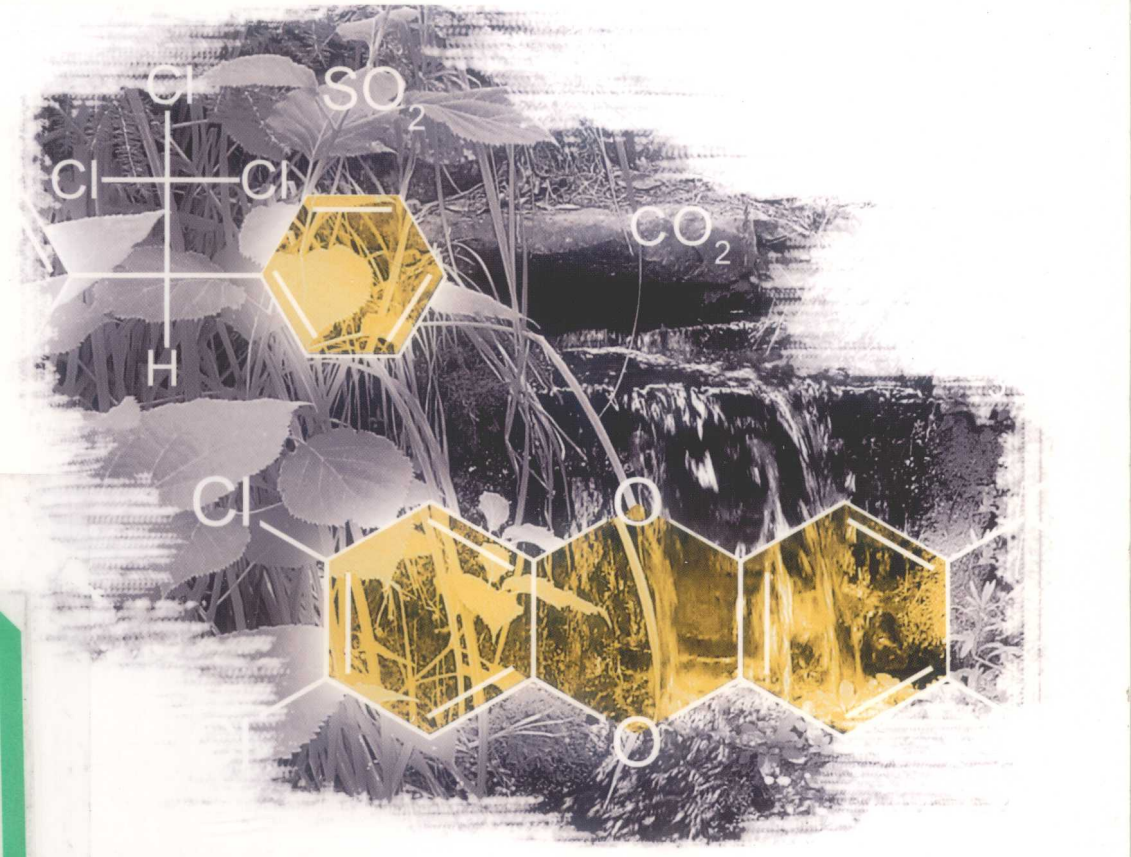
Second Edition

Environmental Chemistry in Society



James M. Beard

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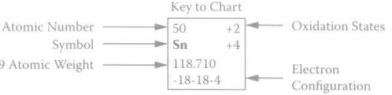
Periodic Table of The Elements

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Shell
1 +1 **H** −1 [1.00784; 1.00811] 1																	2 0 **He** 4.002602 2	K
3 +1 **Li** [6.938; 6.997] 2-1	4 +2 **Be** 9.012182 2-2											5 +3 **B** [10.806; 10.821] 2-3	6 +2 **C** +4 −4 [12.0096; 12.0116] 2-4	7 +1 **N** +2 +3 +4 +5 −1 −2 −3 [14.00643; 14.00728] 2-5	8 −2 **O** [15.99903; 15.99977] 2-6	9 −1 **F** 18.9984032 2-7	10 0 **Ne** 20.1797 2-8	K-L
11 +1 **Na** 22.989770 2-8-1	12 +2 **Mg** 24.3050 2-8-2											13 +3 **Al** 26.981538 2-8-3	14 +2 **Si** +4 −4 [28.084; 28.086] 2-8-4	15 +3 **P** +5 −3 30.973761 2-8-5	16 +4 **S** +6 −2 [32.059; 32.076] 2-8-6	17 +1 **Cl** +5 +7 −1 [35.446; 35.457] 2-8-7	18 0 **Ar** 39.948 2-8-8	K-L-M
19 +1 **K** 39.0983 -8-8-1	20 +2 **Ca** 40.078 -8-8-2	21 +3 **Sc** 44.955910 -8-9-2	22 +2 **Ti** +3 +4 47.867 -8-10-2	23 +2 **V** +3 +4 +5 50.9415 -8-11-2	24 +2 **Cr** +3 +6 51.9961 -8-13-1	25 +2 **Mn** +3 +4 +7 54.938049 -8-13-2	26 +2 **Fe** +3 55.845 -8-14-2	27 +2 **Co** +3 58.933200 -8-15-2	28 +2 **Ni** +3 58.6934 -8-16-2	29 +1 **Cu** +2 63.546 -8-18-1	30 +2 **Zn** 65.38 -8-18-2	31 +3 **Ga** 69.723 -8-18-3	32 +2 **Ge** +4 72.63 -8-18-4	33 +3 **As** +5 −3 74.92160 -8-18-5	34 +4 **Se** +6 −2 78.96 -8-18-6	35 +1 **Br** +5 −1 79.904 -8-18-7	36 0 **Kr** 83.798 -8-18-8	-L-M-N
37 +1 **Rb** 85.4678 -18-8-1	38 +2 **Sr** 87.62 -18-8-2	39 +3 **Y** 88.90585 -18-9-2	40 +4 **Zr** 91.224 -18-10-2	41 +3 **Nb** +5 92.90638 -18-12-1	42 +6 **Mo** 95.96 -18-13-1	43 +4 **Tc** +6 +7 (98) -18-13-2	44 +3 **Ru** 101.07 -18-15-1	45 +3 **Rh** 102.90550 -18-16-1	46 +2 **Pd** +3 106.42 -18-18-0	47 +1 **Ag** 107.8682 -18-18-1	48 +2 **Cd** 112.411 -18-18-2	49 +3 **In** 114.818 -18-18-3	50 +2 **Sn** +4 118.710 -18-18-4	51 +3 **Sb** +5 −3 121.760 -18-18-5	52 +4 **Te** +6 −2 127.60 -18-18-6	53 +1 **I** +5 +7 −1 126.90447 -18-18-7	54 0 **Xe** 131.293 -18-18-8	-M-N-O
55 +1 **Cs** 132.90545 -18-8-1	56 +2 **Ba** 137.327 -18-8-2	57-71 Lanthanoids	72 +4 **Hf** 178.49 -32-10-2	73 +5 **Ta** 180.9479 -32-11-2	74 +6 **W** 183.84 -32-12-2	75 +4 **Re** +6 +7 186.207 -32-13-2	76 +3 **Os** +4 190.23 -32-14-2	77 +3 **Ir** +4 192.217 -32-15-2	78 +2 **Pt** +4 195.078 -32-17-1	79 +1 **Au** +3 196.96655 -32-18-1	80 +1 **Hg** +2 200.59 -32-18-2	81 +1 **Tl** +3 [204.382; 204.385] -32-18-3	82 +2 **Pb** +4 207.2 -32-18-4	83 +3 **Bi** +5 208.98038 -32-18-5	84 +2 **Po** +4 (209) -32-18-6	85 **At** (210) -32-18-7	86 0 **Rn** (222) -32-18-8	-N-O-P
87 +1 **Fr** (223) -18-8-1	88 +2 **Ra** (226) -18-8-2	89-103 Actinoids	104 +4 **Rf** (261) -32-10-2	105 **Db** (262) -32-11-2	106 **Sg** (266) -32-12-2	107 **Bh** (272) -32-13-2	108 **Hs** (277) -32-14-2	109 **Mt** (276) -32-15-2	110 **Ds** (281) -32-16-2	111 **Rg** (280)	112 **Cn** (285)	113 **Uut** (284)	114 **Fl** (287)	115 **Uup** (288)	116 **Lv** (291)	117 **Uus** (294)	118 **Uuo** (294)	-O-P-Q

Lanthanoids	57 +3 **La** 138.9055 -18-9-2	58 +3 **Ce** +4 140.116 -19-9-2	59 +3 **Pr** 140.90765 -21-8-2	60 +3 **Nd** 144.24 -22-8-2	61 +3 **Pm** (145) -23-8-2	62 +2 **Sm** +3 150.36 -24-8-2	63 +2 **Eu** +3 151.964 -25-8-2	64 +3 **Gd** 157.25 -25-9-2	65 +3 **Tb** 158.92534 -27-8-2	66 +3 **Dy** 162.500 -28-8-2	67 +3 **Ho** 164.93032 -29-8-2	68 +3 **Er** 167.259 -30-8-2	69 +3 **Tm** 168.93421 -31-8-2	70 +2 **Yb** +3 173.054 -32-8-2	71 +3 **Lu** 174.9668 -32-9-2	-N-O-P
Actinoids	89 +3 **Ac** (227) -18-9-2	90 +4 **Th** 232.0381 -18-10-2	91 +5 **Pa** +4 231.03588 -20-9-2	92 +3 **U** +4 +5 +6 238.02891 -21-9-2	93 +3 **Np** +4 +5 +6 (237) -22-9-2	94 +3 **Pu** +4 +5 +6 (244) -24-8-2	95 +3 **Am** +4 +5 +6 (243) -25-8-2	96 +3 **Cm** (247) -25-9-2	97 +3 **Bk** +4 (247) -27-8-2	98 +3 **Cf** (251) -28-8-2	99 +3 **Es** (252) -29-8-2	100 +3 **Fm** (257) -30-8-2	101 +2 **Md** +3 (258) -31-8-2	102 +2 **No** +3 (259) -32-8-2	103 +3 **Lr** (262) -32-8-3	-O-P-Q

Key to Chart



Atomic weight values are from Wieser, M.E., and Coplen, T.B., *Pure Appl. Chem.* 83, 359, 2011. See "Standard Atomic Weights (2009)" in Sec. 1 for an explanation of the IUPAC notation for atomic weight ranges. For radioactive elements that do not occur in nature, the mass number of the most stable isotope currently known is given in parentheses. Isotopes of elements 113, 115, 117, and 118 have been reported, but element names have not been adopted.

Metallic solids | Non-metallic solids | Liquids | Gases

Second Edition

Environmental Chemistry in Society

This edition is dedicated to Susan, the love of my life; to my children: Kristin, Amy, Brian, Kelly, David, and Landon; and to all my grandchildren.

Preface

I wrote this book because of my belief that it is important for non-science-oriented students to understand the environment. It is, after all, these very individuals who will influence the course of public policy on the environment in any democracy. Many books present environmental science to the non-science student, but few look specifically into environmental chemistry. Among the numerous chemical issues that are important to any understanding of the environment around us, all of us need to have some understanding of global warming, ozone depletion, energy sources, air pollution, acid rain, water pollution, waste disposal, and hazardous waste.

To the students who will read this book, I would point out that, although this is a college text, there is no assumption of any background in chemistry. Within the text you will find all of the background information necessary to understand it. To the faculty who will use this book, I would like to note that this is a self-contained environmental chemistry text, in which students can find all of the background they need. The book is structured in such a way as to give students a background in science, chemistry, and toxicology before delving into such areas as energy in society, air quality, global atmospheric concerns, water quality, and solid waste management. The basic structure is given below:

Introduction	Chapter 1
Foundational material	Chapters 2, 3, 4, 5, 6, 7
Specific background material	Chapters 8 and 12
Environmental content chapters	Chapters 7, 9, 10, 11, 13, 14, 15

The intention is that all students cover Chapters 1 to 6, with Chapter 7 strongly encouraged but not essential. All other chapters could be covered in any order, provided Chapter 8 precedes Chapters 9 and 11, and Chapter 12 precedes Chapter 13. This arrangement of material allows instructors the freedom to cover the material in a manner that can be customized to the needs of their courses.

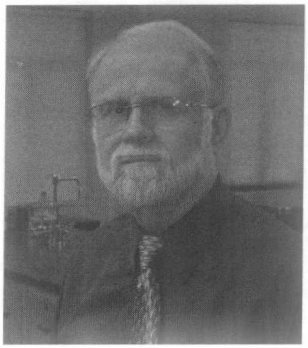
In the second edition the environmental data have been updated and material has been added concerning fracking, the Fukushima Daiichi power plant disaster, and the Deepwater Horizon oil rig blowout. Most of the homework questions have been rewritten to provide questions that require more critical thinking skills.

I have enjoyed writing this book and have tried to make it very readable for any college student. Any text, of course, can be made better. I would welcome any suggestions for improvement in or corrections to the text. I can be reached by email at jbeard@catawba.edu.

Acknowledgments

I would like to thank many people for their understanding and support during the writing of this book. A special thanks to my wife, Susan, for being tolerant while I wrote and wrote and wrote. Her continued support made this book possible. I would like to express my appreciation to Catawba College for their flexibility during this effort and for the sabbatical semester which accounted for a considerable amount of the writing time. My thanks to Delores Imblum, the biology–chemistry administrative assistant, who provided valuable help with the manuscript. I also thank Maegen Worley and Tracy Ratliff of Catawba College for providing the original artwork and layout for the book's cover. I would like to acknowledge my daughter Amy's contribution of some of the illustrations in the book; my colleague Dr. Carol Ann Miderski for helping me with the ins and outs of thermodynamics; the late Dr. Bruce Griffith, professor of history, for much of the background information used in Chapter 1; and Dr. Wayne E. Steinmetz, professor emeritus of chemistry at Pomona College, for numerous suggestions to improve the book. Finally, I would like to express my appreciation to the late Dr. Richard H. Eastman of Stanford University for important advice and encouragement when I started the book.

Author



James M. Beard, PhD, earned a BA in chemistry from Manchester College (now Manchester University) in 1965 and a PhD in organic chemistry from Stanford University in 1969. He then spent a year at Iowa State University as a postdoctoral research associate in organic photochemistry. After two years of teaching chemistry at Manchester College, he pursued a career as a clinical chemist. During the next 12 years, Dr. Beard worked as a product developer, quality control consultant, and administrator in both hospital and industry settings. In 1985, he returned to chemical education as an associate professor of chemistry at Pikeville College. Since 1988, Dr. Beard has been a member of the faculty at Catawba College in Salisbury, North Carolina, where he is a professor of chemistry. Dr. Beard's major interest at Catawba has been in environmental chemical education.

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