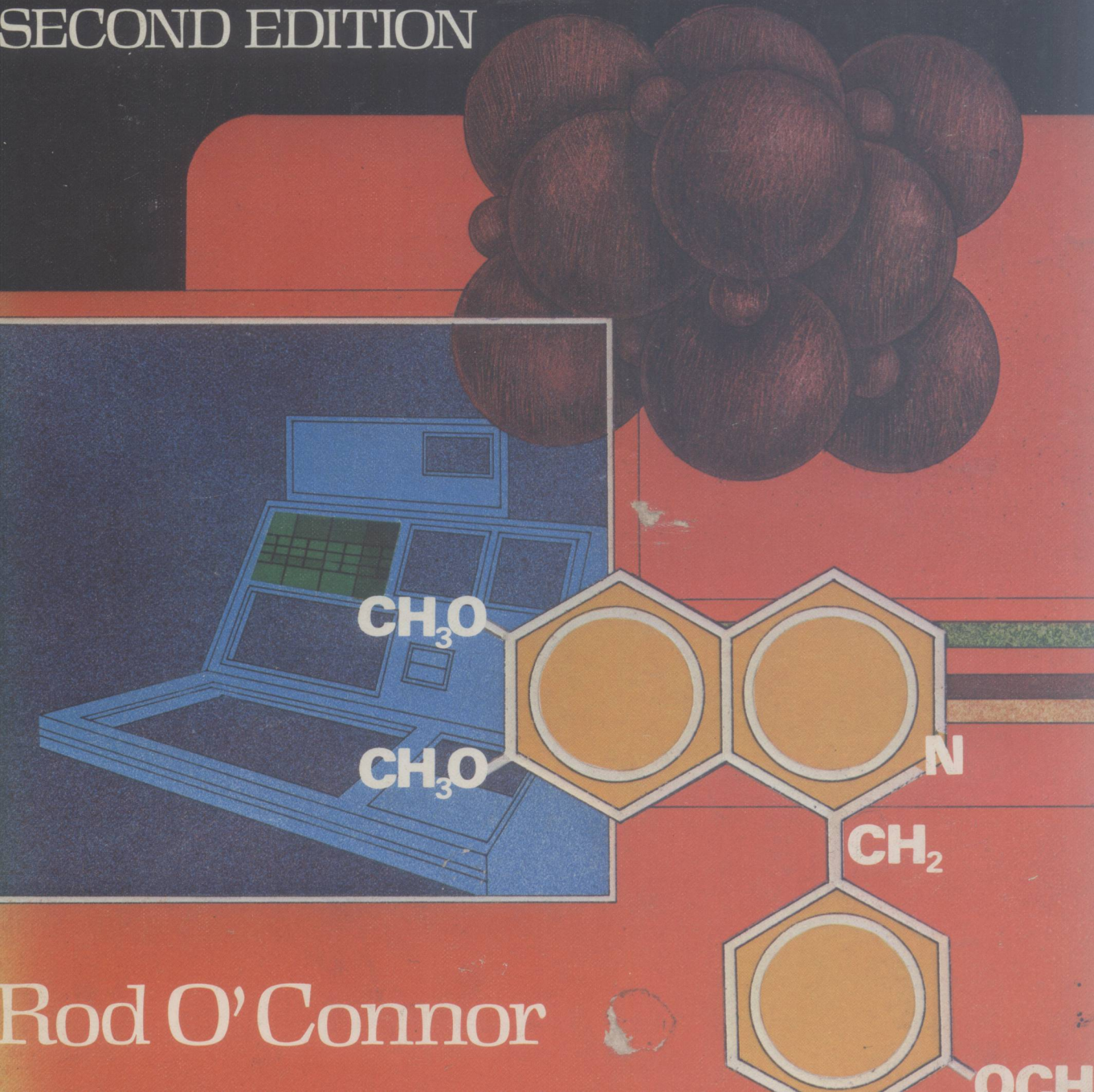
FUNDAMENTALS OF CHEMISTRY

SECOND EDITION



Rod O'Connor

FUNDAMENTALS OF CHEMISTRY

SECOND EDITION

ROD O'CONNOR
TEXAS A&M UNIVERSITY

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New York Hagerstown San Francisco London

Dedicated to my wife, Shirley, and to Mark, Kara, Shanna, and Timothy Patrick; to my parents, Jay H. and Flora O'Connor; to my favorite teachers, Jim Cason, Shirley Gaddis, H. A. Mangan, Leroy Mason, and Bob Smith; and to my students in freshman chemistry.

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Periodic Table of the Elements

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	Zero (VIIIA)
e 1 H 1.0080																	2 He 4.0026
3 Li 6.94	4 Be 9.012											e 5 B 10.811	e 6 C 12.0115	e 7 N 14.0067	e 8 O 15.9994	e 9 F 18.9984	10 Ne 20.18
e 11 Na 22.9898	e 12 Mg 24.31											13 Al 26.9815	e 14 Si 28.086	e 15 P 30.974	e 16 S 32.06	e 17 Cl 35.453	18 Ar 39.948
e 19 K 39.102	e 20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	e 23 V 50.94	e 24 Cr 51.996	e 25 Mn 54.938	e 26 Fe 55.847	e 27 Co 58.933	28 Ni 58.71	e 29 Cu 63.546	e 30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	e 34 Se 78.96	35 Br 79.909	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	e 42 Mo 95.94	m 43 Tc (99)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.868	48 Cd 112.40	49 In 114.82	e 50 Sn 118.69	51 Sb 121.75	52 Te 127.60	e 53 I 126.904	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	57 *La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.98	84 Po (210)	m 85 At (210)	86 Rn (222)
m 87 Fr (223)	88 Ra (226)	89 †Ac (227)	m 104 ‡Rf (261)	m 105 ‡Ha (260)	m 106 ‡ ?												

Key to Families of Elements

Group	Family	Group	Family	Group	Family	Group	Family
IA	Alkali	VA	Nitrogen	IB	Copper	VB	Vanadium
IIA	Alkaline earth	VIA	Chalcogen	IIB	Zinc	VIB	Chromium
IIIA	Aluminum	VIIA	Halogen	IIIB	Scandium	VIIB	Manganese
IVA	Germanium	Zero (VIIIA)	Noble gas	IVB	Titanium	VIIIB	Iron/Platinum

*Lanthanoid series													
58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	m 61 Pm (147)	62 Sm 150.4	63 Eu 151.96	64 Gd 157.25	65 Tb 158.9	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
†Actinoid series													
90 Th 232.0	91 Pa 231.0	92 U 238.03	m 93 Np 237.0	m 94 Pu (244)	m 95 Am (243)	m 96 Cm (247)	m 97 Bk (247)	m 98 Cf (251)	m 99 Es (254)	m 100 Fm (257)	m 101 Md (258)	m 102 No (255)	m 103 Lr (258)

‡ Involved in disputed discovery claims (U.S.-U.S.S.R.).

= liquid = solid = gas Reflects a normal temperature range of 15-30° C. Note that Cs, Fr, and Ga melt around 30° C.

e = elements essential to living organisms

m = man-made elements

Preface to the Student

"Chemistry, to me, is the most fascinating field of study in all the sciences. Not only is it an area of stimulating intellectual exercise, but . . . ."

That's how I started to write the preface for this book, when I realized that if any of my former students ever read it, they'd think the old man had lost his marbles. Let's be honest. Chemistry is *not* "fascinating," except to chemists, and even then it's mostly a job with only a few really great experiences—when something just goes beautifully. For everybody else it's usually something they *have* to take to get where they want to go.

I guess what I try to do in my classes is to present chemistry in such a way that students are sometimes surprised to find themselves *interested* and are usually surprised that the subject isn't as "impossible" as they thought it would be. That's what I've tried to do with this book, and it's a lot harder to write that way, than to do it "live." I would much rather sit down with you and talk about chemistry—that's when things sparkle—than to write about it, but I hope the book will have some of that flavor.

You may find that this book alone is not sufficient for your learning needs, although, hopefully, it can play a significant role. Many concepts and problem situations require more extensive discussion than any textbook can realistically provide. The extent to which additional discussion is necessary depends, to a large extent, on your own background, interests, and study patterns. Books can't really "teach," because teaching requires some give-and-take communication. This book was designed to be part of a total *learning system* that includes alternative resources, not the least of which is the interaction with an instructor. What this book *can* do is to facilitate your study of chemistry by helping you to identify and to assimilate important information, concepts, and approaches to problem solving. In addition, by means of short introductions and special topic sections in each unit, we can illustrate some of the applications of chemistry to other fields, showing that chemistry can be worth knowing even if you aren't going to be a professional chemist.

The content and level of this book have been designed for the student in science or a science-related field. While presenting an overview of chemistry for those students who will not take additional courses in the field, careful attention has been given to providing important background for additional studies in chemistry. Many students have commented that they have found the previous edition to be useful as a reference during subsequent courses and for review in preparing for various professional school admission exams.

Each unit begins with a set of *objectives* to direct your primary attention to the kinds of things you should learn and be able to do. There is more information in each unit than is required to satisfy these objectives so that you may see some of the background and applications associated with various topics. On the other hand, a

single unit does not usually complete the development of a topic. Unless there is some later expansion and reinforcement of early ideas, these ideas tend to "slip away." You will, therefore, see many of the unit topics considered again and again in subsequent units, as they apply to and are amplified by later information. For those areas in which you find special interest or a need for additional study, supplementary readings are suggested at the end of each unit.

Each unit also concludes with a set of exercises designed to offer practice in recalling and applying the information presented in the unit, as identified by the objectives. For those wishing or needing additional practice, an extensive set of problems, *practice for proficiency,* is provided as well. Answers are given in Appendix I so that you can check your work. You may need to refer back to the information in the unit while working the exercises; you should do so freely.

Finally, a *self-test* is provided to permit you to evaluate your progress in satisfying the objectives and to pinpoint areas requiring further study or discussion with your instructor. Self-tests should be taken without referring to any information other than that indicated in the test heading. Answers to self-tests are also given in Appendix I.

The text is divided into *sections,* each containing two or more related *units.* At the end of each *section* is a *section overview test* designed to help you evaluate your comprehension of the broad area covered by the complete set of *units* in that *section.* Answers to these tests are given in Appendix J.

Your own instructor may wish to modify or expand on the objectives, exercises, and self-tests as dictated by the particular goals of your class.

The most efficient procedure for using this text may be summarized as follows:

(1) Read the unit objectives to determine the areas for study emphasis.
(2) Read through the unit once in its entirety.
(3) Participate in lectures, audiovisual programs, or discussions of the topic involved.
(4) Refer back to the objectives and study carefully the information and examples that apply to these guidelines.
(5) Work the exercises, referring back to unit information as often as necessary. Check your answers, then work as many of the problems in the practice for proficiency section as necessary. Discuss any difficulties with your instructor.
(6) Take the self-test without referring to unit information. If you miss any questions, review the appropriate topics carefully and consult with your instructor for additional help.
(7) When you have completed all *units* in a *section,* try the *section overview test* to evaluate your progress and to identify topics still requiring review.

I've been teaching chemistry for a long time. I've had more than 20,000 students. One former student is a well-known professional football player; hundreds are doctors or dentists, nurses or engineers; some are legislators, mechanics, or housewives; others are chemists and teachers. For most of them, chemistry was a set of hurdles to jump in the race for their own particular goal. A teacher can lower the hurdles by covering only the "easy stuff," or a teacher can make the hurdles so high that not many can jump them at all. Neither route appeals to me very much. I like to think that a teacher has the chance to help with a boost over the tougher hurdles. I've tried to do that in my teaching, and I think *Fundamentals of Chemistry, Second Edition,* can remain true to this intention.

This book is the result of working with students as colleagues in learning. It reflects hundreds of their suggestions. I would be most pleased to hear yours.

Rod O'Connor

Preface to the Instructor

Fundamentals of Chemistry, Second Edition, reflects my own experience in teaching chemistry to more than 20,000 students, and, to a large extent, it reflects student opinion on what a textbook of chemistry should offer. In earlier editions it has been class tested with many thousands of students and more than a hundred different faculty members. The major modifications made in this edition reflect the suggestions of students, other teachers who have used the book, and several special reviewers.

At the time that I wrote the preliminary version and the first edition, I was the only one using the text and I designed it to fit within my own particular needs, recognizing the extent to which it would be supplemented by lectures, audiovisual programs, and other resources. Now that I am directing a multisection program serving about 5000 students per semester, it is easy to see the need for the textbook to contain a more extensive treatment of many areas and thus to be more useful to other teachers whose approaches differ from my own.

This edition is much more than a minor revision. It is essentially a new book in which I have tried to preserve the better features of the first edition, while rewriting and expanding the more important sections, such as bonding and structure, and reducing the coverage of some areas of lesser importance. The text now contains more material than anyone would probably want to cover in a one-year course, but this is a deliberate effort to provide flexibility of coverage. In our own case, for example, we can now provide some of our sections (such as those serving certain engineering majors) with a fairly extensive coverage of appropriate topics in inorganic chemistry, while spending more time on organic and biochemistry topics with sections serving students in agriculture and other biology-related fields.

The emphasis on objectives and self-tests is in direct response to the obvious need for some way of helping students use their study time more efficiently without the frequent "wheel-spinning" of trying to guess what to study. If you want your students to use these, you will probably need to restrict examination questions to those related to specifications provided by objectives and self-tests. Should you wish to modify the text's learning specifications, you may wish to provide your students with suitable exercises and self-tests to correlate with the new objectives you define for them.

We have had a considerable success with the *learning systems approach* in our own program. More than half of our students now receive A's (90% or better achievement of objectives) or B's, and of these students, the ones going on to further courses in chemistry have demonstrated a superior comprehension of background

material. Our program is the first on campus to receive a "commendation for excellence" from the University's Academic Council and student evaluations reflect the growing popularity of the program, while noting that it requires a great deal of work.

Because *Fundamentals of Chemistry, Second Edition,* places a major responsibility on the student, I find that my lectures play a somewhat different role in the learning process than they used to. I spend about the first third of "lecture" time working out exercises and answering questions on the preceding unit, and the remaining time on the development of selected new unit concepts and problem situations—in particular those best illustrated by demonstrations or audiovisual aids. Since the text's approach generates a desire for the student to talk with an instructor periodically, the staff at Texas A&M provides students with a *professor-tutorial* system whereby regular office hours are reserved for students in freshman chemistry. Students can therefore locate a senior faculty member at any hour of the academic day to discuss concepts or problems. The chemistry department also provides an *autotutorial center* with access to the supplementary readings suggested in the text as well as to a variety of audiovisual aids for remedial and enrichment needs.

Although many of the units are interrelated, others are essentially independent and may be omitted easily if not important to the goals of a particular course.

I would like to acknowledge all those of my students and colleagues who have made useful suggestions for this text, but the entire list would need a book of its own. Among the students, I particularly appreciate the suggestions for revisions of objectives, glossary, and appendixes made by Allen Zchiesche and the extensive help in manuscript preparation and proofreading by Mark and Kara O'Connor, both of whom have "suffered" through their father's course. For faculty comments, I am most grateful to Darell Axtell, Barry Barnhart, Ray Bogucki, Roy Caton, Bill Hutton, Paul Javora, Neil Kestner, Stanley Marcus, Ed Mercer, Bill Mooney, Don Nyberg, Larry Peck, Tim Rose, Jerry Sarquis, Spencer Seager, Jacob Seaton, Leonard Spicer, Yi-Noo Tang, Dave Torgerson, Catherine Travaglini, and Harry Zeitlin. In addition, John Woods, Chemistry Editor, and Lois Lombardo, Project Editor, of Harper & Row were of immense help on this project.

Finally, a very special thanks goes to the faculty, staff, and students in the first-year chemistry programs at Texas A&M University. They are, indeed, "the salt of the earth."

If you plan to use this text and would be interested in any of the details of our program, or if you have suggestions for improvement, I would be most pleased to hear from you.

Rod O'Connor

The Elements

Symbols/Names/Atomic Numbers and Weights

SYMBOL	NAME*	ATOMIC NUMBER	ATOMIC WEIGHT†
Ac	actinium	89	(227)
Al	aluminum	13	26.9815
Am	americium	95	(243)
Sb	antimony (stibium)	51	121.75
Ar	argon	18	39.948
As	arsenic	33	74.9216
At	astatine	85	(210)
Ba	barium	56	137.34
Bk	berkelium	97	(247)
Be	beryllium	4	9.012
Bi	bismuth	83	208.98
B	boron	5	10.811
Br	bromine	35	79.909
Cd	cadmium	48	112.40
Ca	calcium	20	40.08
Cf	californium	98	(251)
C	carbon	6	12.0115
Ce	cerium	58	140.12
Cs	cesium	55	132.91
Cl	chlorine	17	35.453
Cr	chromium	24	51.996
Co	cobalt	27	58.933
Cu	copper (cuprum)	29	63.546
Cm	curium	96	(247)
Dy	dysprosium	66	162.50
Es	einsteinium	99	(254)
Er	erbium	68	167.26
Eu	europium	63	151.96
Fm	fermium	100	(257)
F	fluorine	9	18.9984
Fr	francium	87	(223)
Gd	gadolinium	64	157.25
Ga	gallium	31	69.72
Ge	germanium	32	72.59
Au	gold (aurum)	79	196.97
Hf	hafnium	72	178.49
Ha	hahnium‡	105	(260)
He	helium	2	4.0026
Ho	holmium	67	164.93
H	hydrogen	1	1.0080
In	indium	49	114.82
I	iodine	53	126.904
Ir	iridium	77	192.22
Fe	iron (ferrum)	26	55.847
Kr	krypton	36	83.80
La	lanthanum	57	138.91
Lr	lawrencium	103	(256)
Pb	lead (plumbum)	82	207.2
Li	lithium	3	6.94
Lu	lutetium	71	174.97
Mg	magnesium	12	24.31
Mn	manganese	25	54.938
Md	mendelevium	101	(258)
Hg	mercury (hydrargyrum)	80	200.59
Mo	molybdenum	42	95.94
Nd	neodymium	60	144.24
Ne	neon	10	20.18
Np	neptunium	93	237.0
Ni	nickel	28	58.71
Nb	niobium	41	92.91
N	nitrogen	7	14.0067
No	nobelium§	102	(255)
Os	osmium	76	190.2
O	oxygen	8	15.9994
Pd	palladium	46	106.4
P	phosphorus	15	30.974
Pt	platinum	78	195.09
Pu	plutonium	94	(244)
Po	polonium	84	(210)
K	potassium (kalium)	19	39.102
Pr	praseodymium	59	140.91
Pm	promethium	61	(147)
Pa	protactinium	91	231.0
Ra	radium	88	(226)
Rn	radon	86	(222)
Re	rhenium	75	186.2
Rh	rhodium	45	102.91
Rb	rubidium	37	85.47
Ru	ruthenium	44	101.07
Rf	rutherfordium**	104	(261)
Sm	samarium	62	150.4
Sc	scandium	21	44.96
Se	selenium	34	78.96
Si	silicon	14	28.086
Ag	silver (argentum)	47	107.868
Na	sodium (natrium)	11	22.9898
Sr	strontium	38	87.62
S	sulfur	16	32.06
Ta	tantalum	73	180.95
Tc	technetium	43	(99)
Te	tellurium	52	127.60
Tb	terbium	65	158.9
Tl	thallium	81	204.37
Th	thorium	90	232.0
Tm	thulium	69	168.93
Sn	tin (stannum)	50	118.69
Ti	titanium	22	47.90
W	tungsten (wolfram)	74	183.85
U	uranium	92	238.03
V	vanadium	23	50.94
Xe	xenon	54	131.30
Yb	ytterbium	70	173.04
Y	yttrium	39	88.91
Zn	zinc	30	65.37
Zr	zirconium	40	91.22

*The names in parentheses are the Latin forms used in complex formation; e.g., gold (*aurum*); $[AuCl_4]^-$ is tetrachloroaurate(III). (Exception is wolfram, which has a German derivation.)

†"Atomic weights" in parentheses are mass numbers of the most stable radioisotope.

‡This name has been suggested by American researchers. Russian researchers have suggested the name *nielsbohrium*.

§Although the name nobelium has official IUPAC sanction, some Russian researchers use the name *joliotium*.

**This name has been suggested by American researchers. Russian researchers have suggested the name *kurchatovium*.

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