BRADY / HOLUM

FUNDAMENTALS OF CHEMISTRY

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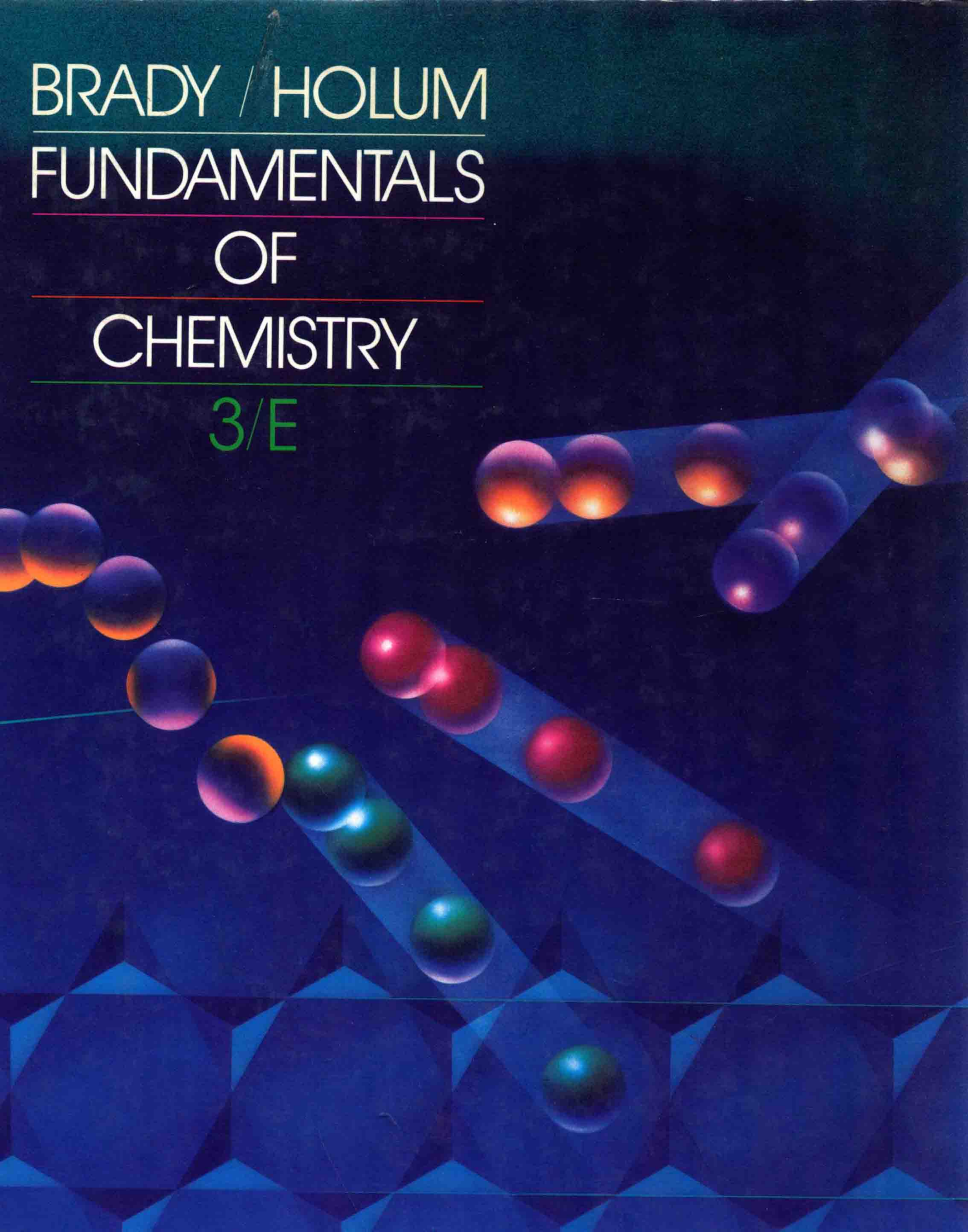

FUNDAMENTALS OF CHEMISTRY

Third Edition

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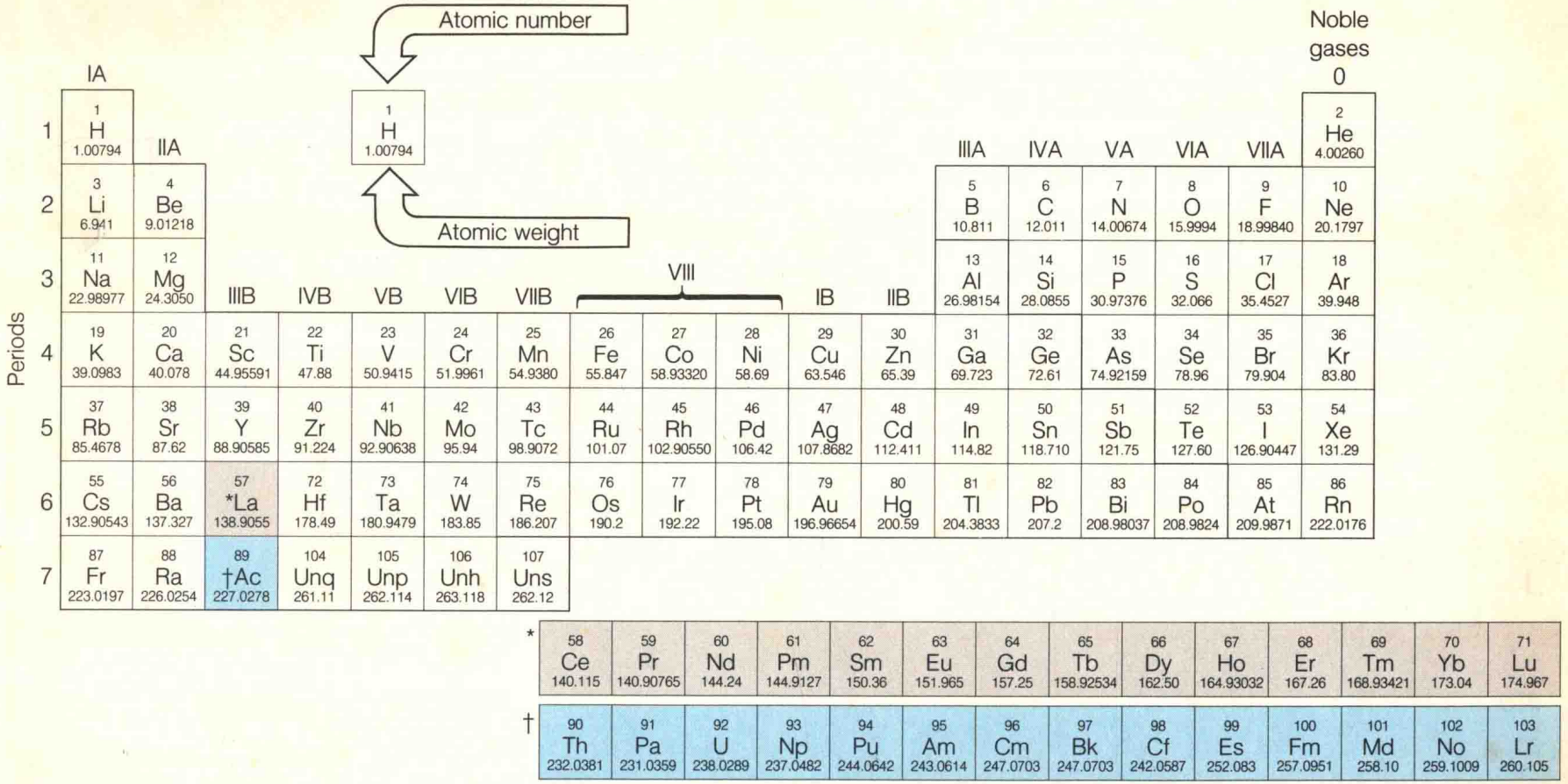

[a] Atomic weights are the 1985 values given in the Table of Atomic Weights and Numbers (opposite) but rounded, where appropriate to the fifth decimal place.

TABLE OF ATOMIC WEIGHTS AND NUMBERS

Based on the 1985 Report of the Commission on Atomic Weights of the International Union of Pure and Applied Chemistry and for the elements as they exist naturally on earth. Scaled to the relative atomic mass of carbon-12. The estimated uncertainties in values, between ±1 and ±9 units in the last digit of an atomic weight, are in parentheses after the atomic weight. (From *Pure and Applied Chemistry*, Vol. 58 (1986), pp. 1677–1692. Copyright © 1986 IUPAC)

Element	Symbol	Atomic Number	Atomic Weight	
Actinium	Ac	89	227.0278	(L)
Aluminum	Al	13	26.981539(5)	
Americium	Am	95	243.0614	(L)
Antimony	Sb	51	121.75(3)	
Argon	Ar	18	39.948(1)	(g, r)
Arsenic	As	33	74.92159(2)	
Astatine	At	85	209.9871	(L)
Barium	Ba	56	137.327(7)	
Berkelium	Bk	97	247.0703	(L)
Beryllium	Be	4	9.012182(3)	
Bismuth	Bi	83	208.98037(3)	
Boron	B	5	10.811(5)	(g, m, r)
Bromine	Br	35	79.904(1)	
Cadmium	Cd	48	112.411(8)	(g)
Calcium	Ca	20	40.078(4)	(g)
Californium	Cf	98	242.0587	(L)
Carbon	C	6	12.011(1)	(r)
Cerium	Ce	58	140.115(4)	(g)
Cesium	Cs	55	132.90543(5)	
Chlorine	Cl	17	35.4527(9)	
Chromium	Cr	24	51.9961(6)	
Cobalt	Co	27	58.93320(1)	
Copper	Cu	29	63.546(3)	(r)
Curium	Cm	96	247.0703	(L)
Dysprosium	Dy	66	162.50(3)	(g)
Einsteinium	Es	99	252.083	(L)
Erbium	Er	68	167.26(3)	(g)
Europium	Eu	63	151.965(9)	(g)
Fermium	Fm	100	257.0951	(L)
Fluorine	F	9	18.9984032(9)	
Francium	Fr	87	223.0197	(L)
Gadolinium	Gd	64	157.25(3)	(g)
Gallium	Ga	31	69.723(4)	
Germanium	Ge	32	72.61(2)	
Gold	Au	79	196.96654(3)	
Hafnium	Hf	72	178.49(2)	
Helium	He	2	4.002602(2)	(g, r)
Holmium	Ho	67	164.93032(3)	
Hydrogen	H	1	1.00794(7)	(g, m, r)
Indium	In	49	114.82(1)	
Iodine	I	53	126.90447(3)	
Iridium	Ir	77	192.22(3)	
Iron	Fe	26	55.847(3)	
Krypton	Kr	36	83.80(1)	(g, m)
Lanthanum	La	57	138.9055(2)	(g)
Lawrencium	Lr	103	260.105	(L)
Lead	Pb	82	207.2(1)	(g, r)
Lithium	Li	3	6.941(2)	(g, m, r)
Lutetium	Lu	71	174.967(1)	(g)
Magnesium	Mg	12	24.3050(6)	
Manganese	Mn	25	54.93805(1)	
Mendelevium	Md	101	258.10	(L)
Mercury	Hg	80	200.59(3)	
Molybdenum	Mo	42	95.94(1)	
Neodymium	Nd	60	144.24(3)	(g)
Neon	Ne	10	20.1797(6)	(g, m)
Neptunium	Np	93	237.0482	(L)
Nickel	Ni	28	58.69(1)	
Niobium	Nb	41	92.90638(2)	
Nitrogen	N	7	14.00674(7)	(g, r)
Nobelium	No	102	259.1009	(L)
Osmium	Os	76	190.2(1)	(g)
Oxygen	O	8	15.9994(3)	(g, r)
Palladium	Pd	46	106.42(1)	(g)
Phosphorus	P	15	30.973762(4)	
Platinum	Pt	78	195.08(3)	
Plutonium	Pu	94	244.0642	(L)
Polonium	Po	84	208.9824	(L)
Potassium	K	19	39.0983(1)	
Praseodymium	Pr	59	140.90765(3)	
Promethium	Pm	61	144.9127	(L)
Protactinium	Pa	91	231.03588(2)	(Z)
Radium	Ra	88	226.0254	(L)
Radon	Rn	86	222.0176	(L)
Rhenium	Re	75	186.207(1)	
Rhodium	Rh	45	102.90550(3)	
Rubidium	Rb	37	85.4678(3)	(g)
Ruthenium	Ru	44	101.07(2)	(g)
Samarium	Sm	62	150.36(3)	(g)
Scandium	Sc	21	44.955910(9)	
Selenium	Se	34	78.96(3)	
Silicon	Si	14	28.0855(3)	
Silver	Ag	47	107.8682(2)	(g)
Sodium	Na	11	22.989768(6)	
Strontium	Sr	38	87.62(1)	(g, r)
Sulfur	S	16	32.066(6)	(r)
Tantalum	Ta	73	180.9479(1)	
Technetium	Tc	43	98.9072	(L)
Tellurium	Te	52	127.60(3)	(g)
Terbium	Tb	65	158.92534(3)	
Thallium	Tl	81	204.3833(2)	
Thorium	Th	90	232.0381(1)	(g, r, Z)
Thulium	Tm	69	168.93421(3)	
Tin	Sn	50	118.710(7)	(g)
Titanium	Ti	22	47.88(3)	
Tungsten	W	74	183.85(3)	
(Unnilhexium)	(Unh)	106	263.118	(L, n)
(Unnilpentium)	(Unp)	105	262.114	(L, n)
(Unnilquadium)	(Unq)	104	266.11	(L, n)
(Unnilseptium)	(Uns)	107	262.12	(L, n)
Uranium	U	92	238.0289(1)	(g, m, Z)
Vanadium	V	23	50.9415(1)	
Xenon	Xe	54	131.29(2)	(g, m)
Ytterbium	Yb	70	173.04(3)	(g)
Yttrium	Y	39	88.90585(2)	
Zinc	Zn	30	65.39(2)	
Zirconium	Zr	40	91.224(2)	(g)

(g) Geologically exceptional specimens of this element are known that have different isotopic compositions. For such samples, the atomic weight given here may not apply as precisely as indicated.

(L) This atomic weight is for the relative mass of the isotope of longest half-life. The element has no stable isotopes.

(m) Modified isotopic compositions can occur in commercially available materials that have been processed in undisclosed ways, and the atomic weight given here might be quite different for such samples.

(n) Name and symbol are assigned according to systematic rules developed by the IUPAC.

(r) Ranges in isotopic compositions of normal samples obtained on earth do not permit a more precise atomic weight for this element, but the tabulated value should apply to any normal sample of the element.

(Z) Despite having no stable isotopes, the terrestrial compositions of samples of the long-lived isotopes allow a meaningful atomic weight.

FUNDAMENTALS OF CHEMISTRY

Preface

Since the first edition of this text was published, the emphasis in teaching the first year course in chemistry for science majors has shifted from a predominantly "principles" approach to one that places more emphasis on descriptive chemistry — chemical reactions and properties. This transformation blends well with the basic philosophy that we brought to this book from the very beginning, that chemistry is fundamentally an experimental science, and that observed facts must form the foundation for theory and explanations. Therefore, when we approached this revision we welcomed the opportunity to incorporate more of the flavor of descriptive chemistry while continuing to maintain a solid treatment of chemical principles. At the same time, we wished to preserve the character of the previous edition, which has a relaxed, nonthreatening writing style, pedagogical aids designed to assist students in acquiring problem-solving skills, and many examples that illustrate how chemistry relates to the world in which we live.

Features in Organization and Content

In realizing our goals, we have combined our own thoughts with input from users of previous editions as well as suggestions by reviewers. The result has been some major changes in the flow of topics. For example, those familiar with the previous edition will note that much of the material about the periodic table that had appeared in Chapter 5 now occurs much earlier in Chapter 2. In addition, we have changed the sequence of topics dealing with thermodynamics, kinetics, and equilibrium. The first chapter on equilibrium now occurs at a location that places it approximately at the beginning of the second semester; thermodynamics logically precedes the chapter on electrochemistry; and kinetics is placed after thermodynamics and immediately before chapters dealing with the chemistry of the elements.

Throughout the revision special care was taken to present accurate, up-to-date treatments of important and current topics. Examples are discussions of the bonding in the water molecule (page 282) and of sulfide precipitations (page 650). New to this edition is an Appendix of tables of data that will be helpful to the instructor in preparing additional exercises and exam questions.

Although there have been organizational changes in the text, it continues to provide a logical development of concepts. In a broad sense, the text can be divided into a number of major units as follows:

Introduction to the Science and Structure of Chemistry (Chapters 1 and 2). Students are introduced to the concept of chemical change, the tools of science and measurement, the periodic table and some properties of the elements and their compounds, and the basics of chemical nomenclature. Chapter 1 has been extensively revised to introduce students to chemical reactions and chemical properties more quickly. Much of former Chapter 5 is now incorporated in Chapter 2. Together, these chapters give students a core of chemical facts that serve as a foundation for future chapters.

Quantitative Aspects of Chemistry (Chapters 3 to 5). These chapters include the stoichiometry of compounds and chemical reactions as well as thermochemistry. Additional material has been included on the stoichiometry of reactions in solution in Chapter 4, which should aid in integrating the text with the laboratory. In thermochemistry, the emphasis is now almost entirely on joules as an energy unit.

Atomic Structure and Bonding (Chapters 6 to 8). In this unit we begin by examining the electronic structures of atoms and some atomic properties that vary systematically in the periodic table. The basic features of ionic and covalent bonding are now presented together in one chapter along with the shapes of molecules and their influence on molecular polarity. A thermochemical discussion of bond energies complements treatments of valence bond and molecular orbital theories.

Properties of Pure Substances (Chapters 9 and 10). The emphasis is on the physical properties of gases, liquids, and solids, and the influence of intermolecular forces in determining these properties. The nature of intermolecular forces is now discussed early in Chapter 10, which makes subsequent discussions of the properties of liquids and solids more meaningful.

Chemical Reactions in Mixtures (Chapters 11 and 12). Acid-base and metathesis reactions are discussed first along with the Brønsted and Lewis approaches, followed by an entire chapter devoted to redox reactions. A new section on periodic trends in acid-base strengths has been added, as well as a discussion of metal complexes as an illustration of Lewis acid-base chemistry. Solution stoichiometry and titrations are treated; and normality and equivalents are discussed in separate sections for those who may choose to omit these topics.

Physical Properties of Mixtures (Chapter 13). This chapter is devoted to the physical properties of colloids and solutions. The discussion of the dissolution process has been completely rewritten and examines the interplay between intermolecular forces and the tendency toward randomness.

Equilibrium (Chapters 14 and 15). The phenomenon of chemical equilibrium is examined first for gaseous systems and then for heterogeneous reactions, including solubility equilibria. The effect of complex ion formation on equilibrium is discussed. The unit concludes with acid-base equilibria. The section on hydrolysis now focuses on the acid-base properties of ions.

Factors that Control the Outcomes of Reactions (Chapters 16 to 18). Having studied *what* happens in reactions, we now explore the reasons *why*. The interplay between energy and entropy in determining the spontaneity of events is studied, followed by the relationship between thermodynamics and equilibrium. Electrochemistry, in its ability to predict the outcome of reactions, can be seen as a practical extension of thermodynamics. Rates of reactions determine whether we ever get to see reactions that are thermodynamically possible.

Inorganic Chemicals and Reactions (Chapters 19 to 22). The focus is on important chemicals and reactions. These chapters have been enlarged considerably in this edition, with an emphasis on applying chemical principles learned in earlier chapters. The material is presented so that instructors can easily choose to cover topics they consider to be most important to their students.

Nuclear Chemistry and the Chemistry of Carbon (Chapters 23 and 24). The origin of nuclear energy and stability is explored along with applications of nuclear phenomena to chemistry and an up-to-date discussion of nuclear energy production. Organic chemistry and biochemistry serve as a bridge to the second-year course in chemistry.

Although the order of topics presented here follows a logical development of the course material, we recognize that other equally valid organizations are possible, and the chapters have been carefully written to permit alternative orders of coverage. Some are suggested in the Instructor's Guide.

Descriptive Inorganic Chemistry

A question that many teachers have been asking themselves is "How shall I bring more descriptive chemistry into my course?" There is probably no single best answer to this, so in organizing this book our aim has been to provide the maximum degree of flexibility and effectiveness. First, we have sought to make descriptive chemistry interesting by illustrating many important reactions with really useful photographs. Second, we interweave a large amount of descriptive chemistry in discussions related to principles.

For example, Chapter 1 has been reorganized to provide an early introduction to chemical reactions and chemical properties as well as an introduction to the tools of measurement. Chapter 2 incorporates discussions of the basic structure of matter with the periodic table and properties of the elements and some of their compounds. And in Chapter 11 we discuss metal complexes to illustrate Lewis acid-base chemistry. Third, we have included 16 interchapter units called *Chemicals in Use* that focus on important chemicals and chemical processes. In making this revision, we have added some, deleted others, and revised many. Each now includes a set of questions, but their basic goal is the same: to provide interesting glimpses of how chemistry impacts on our lives. Fourth, new to this edition are three "interchapters" called *Qual Topics* that each illustrate how chemical principles discussed in the preceding chapter are brought to bear on the separation and identification of cations in solution. They illustrate practical applications of principles and so are valuable even for students who will not be preforming qualitative analyses in the laboratory. They will be especially useful, however, for courses that place a heavy emphasis on qualitative analysis in their lab components, and they supplement material discussed in the "Qual version" of this text. Finally, we have expanded considerably Chapters 19 through 22, which are devoted entirely to the chemistry of the nonmetals and metals. By having this flexible approach available, teachers can choose a presentation best suited to their course.

Features in Problem Solving

In this edition we continue our commitment toward developing problem-solving skills through a planned program of review and reinforcement. Within chapters there are numerous **worked examples,** many of which have been rewritten to improve clarity. Each begins with a brief statement identifying the type of problem being solved. Worked examples are usually followed by **Practice Exercises** that encourage students to test their understanding. At the ends of chapters there are extensive sets of **Review Exercises,** sorted by category. Answers to all the Practice Exercises and to a representative sampling of the Review Exercises are given in Appendix C. Finally, there are additional sets of exercises called **Tests of Facts and Concepts** that occur after groups of related chapters. These exercises review concepts covered in sets of two or more chapters, and their answers are only to be found in the Instructor's Guide.

Features That Enhance Student Interest

A goal of this text throughout all its editions has been to make chemistry as interesting as possible. We continue to be careful to maintain a conversational writing style and we use common chemicals whenever possible as examples in both theoretical discussions and in problems and exercises. To help students appreciate the importance of chemistry to other disciplines and to their lives in general, we have opened each chapter with a photograph that, in most instances shows how the chapter contents relate to some familiar aspect of the world around us. We also continue to employ numerous **Special Topics** placed strategically within chapters throughout the text. As noted earlier, the interchapter **Chemicals in Use** focus on common and important chemicals and have been deliberately written in a light and interesting style.

Features in Learning Aids

Each chapter incorporates a variety of learning aids to improve student understanding and performance. A chapter begins with a brief table of contents so students can see at a glance what topics will be covered. Each section then begins with a brief title followed by a statement that summarizes the key lesson to be learned. This gives students a brief preview of the section content and serves as an aid later during review. Throughout the text there are frequent margin comments, figures, and photographs that supplement discussions. New terms are presented in blue boldface type when they are introduced and defined, and important equations and definitions are boxed in red to set them apart. All of the boldface terms are also located in a Glossary at the end of the book where each term is accompanied by a reference to one or more principal sections where the term is discussed. (A glossary by chapter is also provided in the **Study Guide.**) Another review aid is the **chapter summaries** that provide an overview of important concepts.

James E. Brady

John R. Holum

Acknowledgments

We begin by paying special tribute to our wives, Mary Holum and June Brady, and to our children Liz, Ann, and Kathryn Holum and to Mark and Karen Brady for their constant support and encouragement. Our appreciation is also extended to our colleagues Earl Alton of Augsburg College and to Ernest Birnbaum, Neil Jespersen, Eugene Holleran, and William Pasfield of St. John's University for their helpful discussions and stimulating ideas. We also recognize the support of our colleagues at the administrative level — Dean Ryan LaHurd and President Charles S. Anderson of Augsburg College and Rev. Joseph Breen, C. M. of St. John's University. It is with particular pleasure that we thank the staff at Wiley for their careful work, encouragement, and sense of humor, particularly our editor Dennis Sawicki, our picture editor Safra Nimrod, our designer Kevin Murphy, our illustrator John Balbalis, our production supervisors Lucille Buonocore and Dawn Reitz and their delightful boss Linda Indig. We also extend our most sincere appreciation to Dr. Donald W. Murphy of AT & T Bell Laboratories for providing us with a photograph of a magnet levitated over one of the newly discovered superconducting ceramics, to Dr. Harry Allcock of Penn State University for a photograph of a polyphosphazene polymer, to Sandra Olmstead for her valuable suggestions passed along during her help with the proofreading, and to the colleagues listed below whose, careful reviews, helpful suggestions, and thoughtful criticisms of the manuscript have been of such great value to us in developing this book. And finally, we are especially grateful to Dr. Jo Beran of Texas A & I University for the use of some of the specifics of his qual analysis procedures in Chapter 25 of the Qual Version of this text.

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Supplementary Material for Students and Teachers

A complete package of supplements has been assembled to aid the teacher in presenting the course and to help students accomplish problem solving and other study assignments.

Study Guide for Fundamentals of Chemistry Third edition by James E. Brady and John R. Holum. This softcover book has been carefully structured to assist students in mastering the important subjects in the text. For each section there is a brief statement of objectives, followed by a brief review that highlights major topics, sometimes with additional worked-out examples. Most sections have a brief "Self-Test," with answers provided, that supplements the text exercises. Each chapter concludes with a glossary of key terms introduced in the chapter.

Laboratory Manual for Fundamentals of Chemistry Third edition by Jo A. Beran. This manual includes a thorough techniques section covering 19 basic lab techniques, photographs of important manipulations, and 46 carefully planned experiments geared to topic development in the main text.

Solutions Manual for Fundamentals of Chemistry Third edition by Ernest R. Birnbaum and Paul Gaus. This softcover supplement provides detailed solutions to all of the numerical problems and answers to all the nonnumerical questions that appear in Practice Exercises and end-of-chapter Review Exercises.

Teachers Manual for Fundamentals of Chemistry This manual, available only to instructors, contains suggestions for alternate topic sequences, detailed chapter objectives and chapter rationales, answers to the *Tests of Facts and Concepts* questions, and assistance with qualitative analysis.

Teachers Manual for the Laboratory Manual This supplement for instructors provides outlines of every experiment, lab suggestions and cautions, expected experimental data, chemicals and equipment to be used, and details on reagent solution preparation.

Test Bank/Microtest Available in both hard copy and software (Apple®, Macintosh®, and IBM® compatible) versions, this carefully prepared test resource contains 1800 questions in all.

Transparencies Instructors who adopt this book may obtain from Wiley, without charge, a set of one hundred $8\frac{1}{2}$ in. $\times$ 11 in. transparencies that duplicate key illustrations from the text.

Video Package Developed at the University of Illinois, and available from Wiley, this package features a range of 2 to 3 minute video lecture demonstrations showing chemical reactions and applications and single topic sequences on subjects such as thermodynamics.

J. E. B.

J. R. H.

Contents