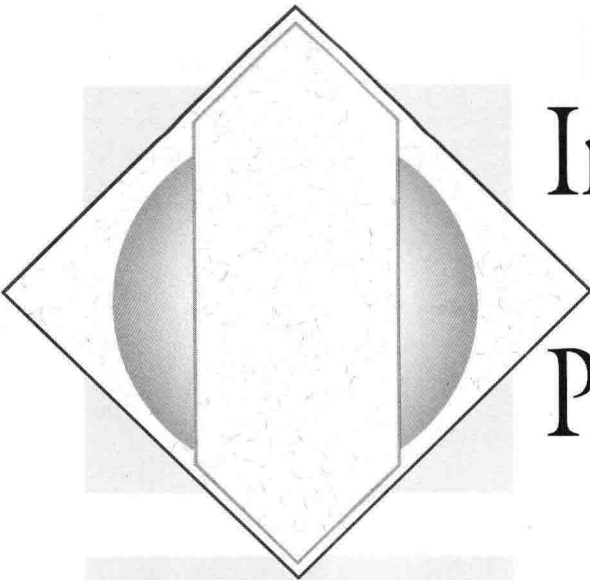


INTRODUCTION TO
**CHEMICAL
PRINCIPLES**
F I F T H E D I T I O N



H. Stephen Stoker



Introduction to Chemical Principles

H. Stephen Stoker Fifth Edition
Weber State University



PRENTICE HALL
Upper Saddle River, NJ 07458

Library of Congress Cataloging-Publication Data

Stoker, H. Stephen (Howard Stephen)

Introduction to chemical principles / H. Stephen Stoker—5th
ed.

p. cm.

Includes index.

ISBN 0-13-228438-3

1. Chemistry I. Title.

QD33.S86 1996

540—dc20

95-20146

CIP

Acquisitions Editor: Mary Hornby

Project Management: J. Carey Publishing Service

Manufacturing Manager: Trudy Piscioti

Art Director: Joseph Sengotta

Cover Designer: Thomas Nery

Interior Designer: Amy Rosen

Cover Image: Thermite Reaction, Richard Megna, Fundamental Photographs



© 1996 by Prentice-Hall, Inc.

Simon & Schuster/A Viacom Company

Upper Saddle River, New Jersey 07458

All rights reserved. No part of this book may be reproduced, in any form or by
any means, without permission in writing from the publisher.

Earlier editions copyright © 1993, 1990, 1986, and 1983 by Macmillan Publishing Company.

Printed in the United States of America

10 9 8 7 6 5 4 3

ISBN 0-13-228438-3

Prentice-Hall International (UK) Limited, *London*

Prentice-Hall of Australia Pty. Limited, *Sydney*

Prentice-Hall Canada, Inc., *Toronto*

Prentice-Hall Hispanoamericana, S.A., *Mexico*

Prentice-Hall of India Private Limited, *New Delhi*

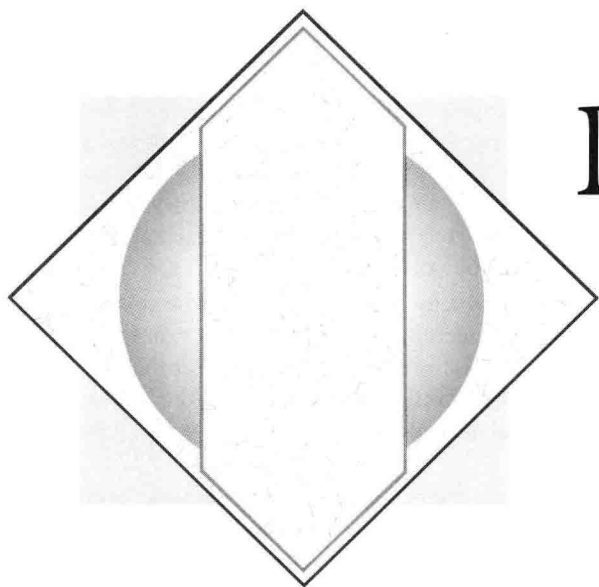
Prentice-Hall of Japan, Inc., *Tokyo*

Simon & Schuster Asia Pte. Ltd., *Singapore*

Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

Introduction to Chemical Principles





Preface


Introduction to Chemical Principles is a text for students who have had little or no previous instruction in chemistry or who had such instruction long enough ago that a thorough review is needed. The text's purpose is to give students the background (and confidence) needed for a subsequent successful encounter with a main sequence college level general chemistry course.

Many texts written for preparatory chemistry courses are simply "watered down" versions of general chemistry texts; they treat almost all topics found in the general chemistry course, but at a superficial level. *Introduction to Chemical Principles* does not fit this mold. The author's philosophy is that it is better to treat fewer topics extensively and have the student understand those topics in greater depth. The very real temptation to include "lots and lots" of additional concepts in this new edition of the text was resisted. Instead the focus for the revision was on rewriting selected portions to improve the clarity of presentation.

IMPORTANT FEATURES OF THIS TEXTBOOK

1. Because of the varied degrees of understanding of chemical principles possessed by students taking a preparatory chemistry course, development of each topic in this text starts at "ground level" and continues step by step until the level of sophistication required for a further chemistry course is attained.
2. Problem solving receives major emphasis. Nearly thirty years of teaching experience indicate to the author that student "troubles" in general chemistry courses are almost always centered in the inability to set up and solve problems. Whenever possible, dimensional analysis is used in problem solving. This method, which requires no mathematics beyond arithmetic and elementary algebra, is a powerful and widely applicable problem-solving tool. Most important, it is a method that an average student can master with an average amount of diligence. Mastering dimensional analysis also helps build the confidence that is so valuable for future chemistry courses.

3. Significant figure concepts are emphasized in all problem-solving situations. Routinely, electronic calculators display answers that contain more digits than are needed or acceptable. In all worked-out examples, students are reminded about these “unneeded digits” by the appearance of two answers to the example: the calculator answer (which does not take into account significant figures) and, in color, the correct answer (which is the calculator answer adjusted to the correct number of significant figures).
4. Numerous worked-out example problems are found within the textual material with detailed commentary accompanying each such example. In addition an unworked practice exercise is coupled to each example. It is intended that students will work this exercise immediately after “working through” the example. For immediate feedback, the answer to each practice exercise follows the exercise.
5. All end-of-chapter exercises occur in “matched pairs.” In essence, each chapter has two independent, but similar, problem sets. Counting subparts to problems, there are over 5000 questions and problems available for a student to use in his or her “struggle” to become proficient at problem solving. Answers to all of the odd-number problems are found at the end of the text. Thus, two problem sets exist, one with answers and one without answers.
6. Each end-of-chapter problem set, except for Chapters 1 and 2, is divided into three sections: (1) Practice Problems, (2) Additional Problems, and (3) Cumulative Problems. The practice problems are categorized by topic and are arranged in the same sequence as the chapter’s textual material. These problems, which are always single-concept, are “drill” problems which most students will find “routine.” The additional problem section contains problems that involve more than one concept from the chapter and are usually more difficult than the practice problems. The cumulative-skills section draws not only on materials from the current chapter but also on concepts discussed in previous chapters. The working of problems in this third group allows students to continue to use, rather than forget, problem-solving techniques presented earlier.



NEW FEATURES OF THE FIFTH EDITION

1. All 197 of the worked out examples in the text are new to this edition.
2. At least 50% of the end-of-chapter problems in each chapter are new. Overall, 1124 of the 1972 end-of-chapter problems and questions are new.
3. The sequence of presentation of the covalent bonding topics in Chapter 7 has been altered. The geometry of molecules (VSEPR theory) is now more closely tied to the concept of electron-dot structures.
4. Chapter 8, Chemical Nomenclature, has been extensively rewritten. An important new feature of this chapter is the introduction of nomenclature flow charts (“decision trees”).
5. Chapter 9 contains an expanded discussion of the calculation of empirical and molecular formulas.

6. The material in Chapter 15 dealing with balancing redox reactions using the half-reaction method has been simplified. A new procedure for balancing half-reactions in basic solution has been added.



SUPPLEMENTS

A *Student Solutions Manual* has been prepared by Dr. Garth L. Welch of Weber State University to accompany this text. There is also an appropriate lab manual, *Prentice Hall Laboratory Experiments for Introductory Chemistry* by Charles H. Corwin of American River College. A free supplement, *How to Study Chemistry*, stressing strategies for learning and achievement in chemistry, is available to students on request from the instructor.

Also available to adopters is an *Instructor's Solutions Manual* by Dr. Welch. A test bank compiled by Dr. Stoker is available as a manual or in computerized formats, both MAC and IBM. There is an *Instructor's Manual to the Laboratory Experiments* available to the instructor, and *The New York Times Themes of the Times*, a newsprint collection of timely topics relevant to chemistry in action in our world.

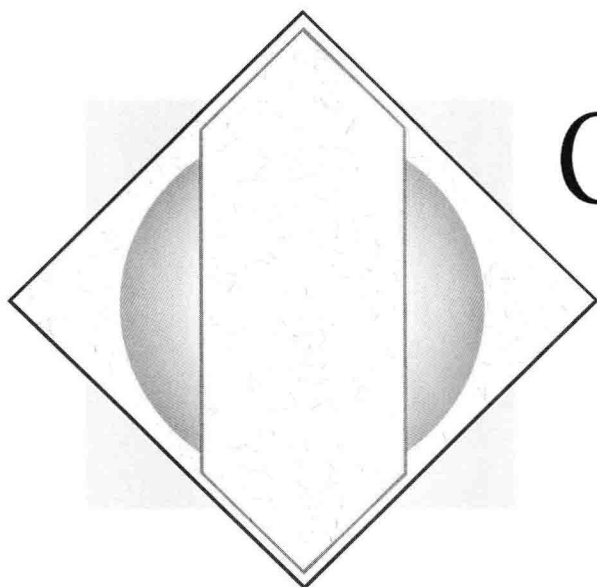


ACKNOWLEDGMENTS

As always, the valuable contributions of reviewers are gratefully acknowledged: Spencer Steinberg of University of Nevada Las Vegas; Gerard Nobiling, Monroe Community College; Thomas Mincs, St. Louis-Florissant Community College; Donald Langr, North Iowa Community College.

H.S.S.

Introduction to Chemical Principles



Contents

Preface xiii

Chapter 1 THE SCIENCE OF CHEMISTRY 1

- 1.1 Chemistry—A Scientific Discipline 1
- 1.2 Scientific Disciplines and Technology 2
- 1.3 The Scope of Chemistry and Chemical Technology 2
- 1.4 How Chemists Discover Things—The Scientific Method 3
 - Key Terms 8
 - Practice Problems 8

Chapter 2 NUMBERS FROM MEASUREMENTS 11

- 2.1 The Importance of Measurement 11
- 2.2 Accuracy, Precision, and Error 12
- 2.3 Significant Figures—A Method for Handling Uncertainty in Measurement 13
- 2.4 Significant Figures and Calculated Quantities 18
- 2.5 Scientific Notation 25
- 2.6 Scientific Notation and Mathematical Operations 31
 - Key Terms 38
 - Practice Problems 39

Chapter 3 UNIT SYSTEMS AND DIMENSIONAL ANALYSIS 45

- 3.1 The Metric System of Units 45
- 3.2 Metric Units of Length 47

- 3.3 Metric Units of Mass 47
- 3.4 Metric Units of Volume 51
- 3.5 Units in Mathematical Operations 53
- 3.6 Conversion Factors 55
- 3.7 Dimensional Analysis 58
- 3.8 Density 69
- 3.9 Percentage 73
- 3.10 Temperature Scales 76
- 3.11 Types and Forms of Energy 80
- 3.12 Heat Energy and Specific Heat 82
- Key Terms 87
- Practice Problems 88
- Additional Problems 93
- Cumulative Problems 94

Chapter 4 BASIC CONCEPTS ABOUT MATTER 95

- 4.1 Chemistry—The Study of Matter 95
- 4.2 Physical States of Matter 96
- 4.3 Properties of Matter 96
- 4.4 Changes in Matter 98
- 4.5 Mixtures and Pure Substances 101
- 4.6 Types of Mixtures: Heterogeneous and Homogeneous 103
- 4.7 Types of Pure Substances: Elements and Compounds 105
- 4.8 Discovery and Abundance of the Elements 107
- 4.9 Names and Symbols of the Elements 109
- Key Terms 112
- Practice Problems 112
- Additional Problems 116
- Cumulative Problems 116

Chapter 5 ATOMS, MOLECULES, FORMULAS, AND SUBATOMIC PARTICLES 118

- 5.1 The Atom 118
- 5.2 The Molecule 120
- 5.3 Natural and Synthetic Compounds 122
- 5.4 Chemical Formulas 123
- 5.5 Subatomic Particles: Protons, Neutrons, and Electrons 125
- 5.6 Evidence Supporting the Existence and Arrangement of Subatomic Particles 128
- 5.7 Atomic Number and Mass Number 131
- 5.8 Isotopes 134
- 5.9 Atomic Masses 137
- Key Terms 144
- Practice Problems 145

Additional Problems	149
Cumulative Problems	151

Chapter 6

ELECTRONIC STRUCTURE AND CHEMICAL PERIODICITY 152

6.1	The Periodic Law	152
6.2	The Periodic Table	153
6.3	The Energy of an Electron	156
6.4	Electron Shells	157
6.5	Electron Subshells	159
6.6	Electron Orbitals	160
6.7	Writing Electron Configurations	162
6.8	Orbital Diagrams	167
6.9	Electron Configurations and the Periodic Law	169
6.10	Electron Configurations and the Periodic Table	170
6.11	Classification Systems for the Elements	176
6.12	Chemical Periodicity	178
	Key Terms	181
	Practice Problems	182
	Additional Problems	185
	Cumulative Problems	187

Chapter 7

CHEMICAL BONDS 188

7.1	Chemical Bonds	188
7.2	Valence Electrons and Electron-Dot Structures	189
7.3	The Octet Rule	191
7.4	The Ionic Bond Model	192
7.5	Ionic Compound Formation	194
7.6	Formulas for Ionic Compounds	198
7.7	Structure of Ionic Compounds	200
7.8	Polyatomic Ions	201
7.9	The Covalent Bond Model	202
7.10	Electron-Dot Structures for Molecular Compounds	204
7.11	Single, Double, and Triple Covalent Bonds	206
7.12	Coordinate Covalent Bonds	208
7.13	Resonance Structures	209
7.14	A Systematic Method for Determining Electron-Dot Structures	211
7.15	The Shapes of Molecules: Molecular Geometry	215
7.16	Electronegativity	221
7.17	The Polarity of Chemical Bonds	223
7.18	Molecular Polarity	226
	Key Terms	229
	Practice Problems	230

Additional Problems	236
Cumulative Problems	237

Chapter 8 **CHEMICAL NOMENCLATURE 239**

8.1	Classification of Compounds for Nomenclature Purposes	239
8.2	Types of Binary Ionic Compounds	240
8.3	Nomenclature for Binary Ionic Compounds	242
8.4	Nomenclature for Ionic Compounds Containing Polyatomic Ions	247
8.5	Nomenclature for Binary Molecular Compounds	250
8.6	Nomenclature for Acids	254
8.7	Nomenclature Rules—A Summary	258
	Key Terms	261
	Practice Problems	261
	Additional Problems	264
	Cumulative Problems	266

Chapter 9 **CHEMICAL CALCULATIONS: THE MOLE CONCEPT AND CHEMICAL FORMULAS 269**

9.1	The Law of Definite Proportions	269
9.2	Calculation of Formula Masses	271
9.3	Percent Composition	273
9.4	The Mole: The Chemist's Counting Unit	275
9.5	The Mass of a Mole	279
9.6	Counting Particles by Weighing	284
9.7	The Mole and Chemical Formulas	287
9.8	The Mole and Chemical Calculations	289
9.9	Empirical and Molecular Formulas	294
9.10	Determination of Empirical Formulas	296
9.11	Determination of Molecular Formulas	303
	Key Terms	308
	Practice Problems	308
	Additional Problems	314
	Cumulative Problems	315

Chapter 10 **CHEMICAL CALCULATIONS INVOLVING CHEMICAL EQUATIONS 317**

10.1	The Law of Conservation of Mass	317
10.2	Writing Chemical Equations	319
10.3	Balancing Chemical Equations	320
10.4	Special Symbols Used in Equations	325
10.5	Patterns in Chemical Reactivity	326

- 10.6** Classes of Chemical Reactions 327
- 10.7** Chemical Equations and the Mole Concept 330
- 10.8** Calculations Based on Chemical Equations—Stoichiometry 333
- 10.9** The Limiting Reactant Concept 338
- 10.10** Yields: Theoretical, Actual, and Percent 343
- 10.11** Simultaneous and Consecutive Reactions 345
 - Key Terms 347
 - Practice Problems 348
 - Additional Problems 354
 - Cumulative Problems 355

Chapter 11 STATES OF MATTER 357

- 11.1** Physical States of Matter 357
- 11.2** Property Differences of Physical States 359
- 11.3** The Kinetic Molecular Theory 359
- 11.4** The Solid State 361
- 11.5** The Liquid State 362
- 11.6** The Gaseous State 362
- 11.7** A Comparison of Solids, Liquids, and Gases 363
- 11.8** Endothermic and Exothermic Changes of State 364
- 11.9** Temperature Changes as a Substance Is Heated 365
- 11.10** Energy and Changes of State 366
- 11.11** Heat Energy Calculations 368
- 11.12** Evaporation of Liquids 372
- 11.13** Vapor Pressure of Liquids 375
- 11.14** Boiling and Boiling Points 376
- 11.15** Intermolecular Forces in Liquids 378
- 11.16** Water—A Most Unusual (Unique) Substance 381
- 11.17** Types of Solids 387
 - Key Terms 389
 - Practice Problems 390
 - Additional Problems 395
 - Cumulative Problems 396

Chapter 12 GAS LAWS 397

- 12.1** Properties of Some Common Gases 397
- 12.2** Gas Law Variables 397
- 12.3** Boyle's Law: A Pressure–Volume Relationship 402
- 12.4** Charles's Law: A Temperature–Volume Relationship 407
- 12.5** Gay-Lussac's Law: A Temperature–Pressure Relationship 410
- 12.6** The Combined Gas Law 411
- 12.7** Standard Conditions for Temperature and Pressure 415
- 12.8** Gay-Lussac's Law of Combining Volumes 416

- 12.9** Avogadro's Law: A Volume–Quantity Relationship 418
- 12.10** Molar Volume of a Gas 420
- 12.11** The Ideal Gas Law 425
- 12.12** Equations Derived from the Ideal Gas Law 428
- 12.13** Gas Laws and Chemical Equations 431
- 12.14** Dalton's Law of Partial Pressures 434
 - Key Terms 442
 - Practice Problems 443
 - Additional Problems 450
 - Cumulative Problems 451

Chapter 13 **SOLUTIONS 453**

- 13.1** Types of Solutions 453
- 13.2** Terminology Used in Describing Solutions 454
- 13.3** Solution Formation 456
- 13.4** Solubility Rules 458
- 13.5** Solution Concentrations 459
- 13.6** Concentration: Percentage of Solute 460
- 13.7** Concentration: Parts per Million and Parts per Billion 464
- 13.8** Concentration: Molarity 466
- 13.9** Concentration: Molality 472
- 13.10** Dilution 476
- 13.11** Molarity and Chemical Equations 479
 - Key Terms 483
 - Practice Problems 483
 - Additional Problems 489
 - Cumulative Problems 490

Chapter 14 **ACIDS, BASES, AND SALTS 492**

- 14.1** Arrhenius Acid–Base Theory 492
- 14.2** Brønsted–Lowry Acid–Base Theory 493
- 14.3** Conjugate Acids and Bases 495
- 14.4** Polyprotic Acids 497
- 14.5** Strengths of Acids and Bases 499
- 14.6** Salts 502
- 14.7** Ionic and Net Ionic Equations 503
- 14.8** Reactions of Acids 507
- 14.9** Reactions of Bases 509
- 14.10** Reactions of Salts 510
- 14.11** Dissociation of Water 513
- 14.12** The pH Scale 515
- 14.13** Hydrolysis of Salts 521
- 14.14** Buffer Solutions 525

- 14.15 Buffers in the Human Body 526
- 14.16 Acid–Base Titrations 528
- 14.17 Acid–Base Titration Calculations Using Normality 529
- 14.18 Acid and Base Stock Solutions 535
 - Key Terms 536
 - Practice Problems 537
 - Additional Problems 543
 - Cumulative Problems 544

Chapter 15 OXIDATION AND REDUCTION 545

- 15.1 Oxidation–Reduction Terminology 545
- 15.2 Oxidation Numbers 547
- 15.3 Types of Chemical Reactions 552
- 15.4 Balancing Oxidation–Reduction Equations 554
- 15.5 Oxidation-Number Method for Balancing Redox Equations 554
- 15.6 Half-Reaction Method for Balancing Redox Equations 560
- 15.7 Disproportionation Reactions 567
- 15.8 Some Important Oxidation–Reduction Reactions 570
 - Key Terms 578
 - Practice Problems 578
 - Additional Problems 582
 - Cumulative Problems 583

Chapter 16 REACTION RATES AND CHEMICAL EQUILIBRIUM 585

- 16.1 Theory of Reaction Rates 585
- 16.2 Potential Energy Diagrams for Chemical Reactions 587
- 16.3 Factors That Influence Reaction Rates 589
- 16.4 Chemical Equilibrium 592
- 16.5 Equilibrium Mixture Stoichiometry 593
- 16.6 Equilibrium Constants 595
- 16.7 Le Châtelier’s Principle 600
- 16.8 Forcing Reactions to Completion 604
 - Key Terms 605
 - Practice Problems 605
 - Additional Problems 608
 - Cumulative Problems 609

Chapter 17 NUCLEAR CHEMISTRY 611

- 17.1 Atomic Nuclei 611
- 17.2 Discovery of Radioactivity 612
- 17.3 Nature of Natural Radioactive Emissions 613

- 17.4 Equations for Nuclear Reactions 614
- 17.5 Rate of Radioactive Decay 617
- 17.6 Induced Radioactivity: Bombardment Reactions 621
- 17.7 Positron Emission and Electron Capture 623
- 17.8 Nuclear Stability 625
- 17.9 Radioactive Decay Series 627
- 17.10 Ionizing Effects of Radiation 629
- 17.11 Biological Effects of Various Types of Radiation 630
- 17.12 Detection of Radiation 631
- 17.13 Sources of Radiation Exposure 633
- 17.14 Nuclear Medicine 634
- 17.15 Nuclear Fission and Nuclear Fusion 636
- 17.16 A Comparison of Nuclear and Chemical Reactions 638
 - Key Terms 639
 - Practice Problems 639
 - Additional Problems 643
 - Cumulative Problems 644

Chapter 18

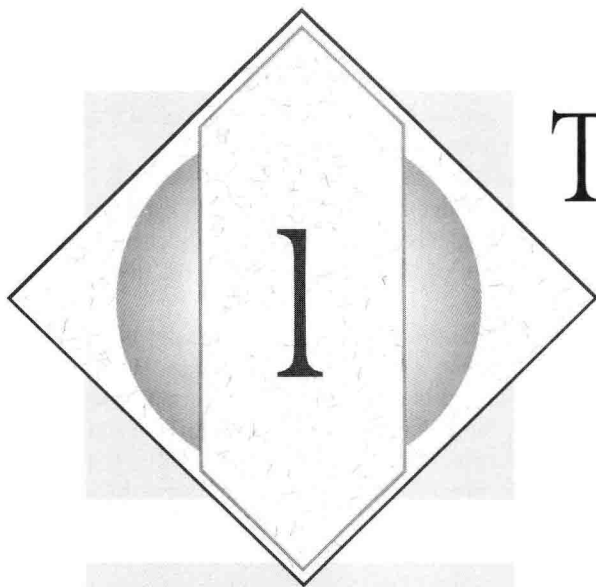
♦ HYDROCARBONS AND HYDROCARBON DERIVATIVES 645

- 18.1 Organic Chemistry—A Historical Perspective 645
- 18.2 Hydrocarbons 647
- 18.3 Alkanes 647
- 18.4 Structural Isomerism of Hydrocarbons 648
- 18.5 IUPAC Nomenclature for Noncyclic Alkanes 651
- 18.6 Structure and Nomenclature of Cycloalkanes 657
- 18.7 Structure and Nomenclature of Alkenes and Alkynes 658
- 18.8 Aromatic Hydrocarbons 662
- 18.9 Sources and Uses of Hydrocarbons 666
- 18.10 Derivatives of Hydrocarbons 667
- 18.11 Halogenated Hydrocarbons (Organic Halides) 669
- 18.12 Alcohols 671
- 18.13 Ethers 673
- 18.14 Carboxylic Acids 675
- 18.15 Esters 677
 - Key Terms 679
 - Practice Problems 680
 - Additional Problems 686
 - Cumulative Problems 687

Appendix A 689

Answers to Odd-Numbered Problems 699

Index 715



The Science of Chemistry

- 1.1** Chemistry—A Scientific Discipline
- 1.2** Scientific Disciplines and Technology
- 1.3** The Scope of Chemistry and Chemical Technology
- 1.4** How Chemists Discover Things—The Scientific Method

1.1 CHEMISTRY—A SCIENTIFIC DISCIPLINE

Students who are required to take two years, one year, or just one course of chemistry all often ask the same question prior to beginning their “chemistry experience.” That question is: Why must I take chemistry? The answer to this simple five-word question, which involves an appreciation for the relationships between various branches of scientific knowledge, serves as our entry point into the “realm” of chemistry.

Chemistry is part of a larger body of knowledge called *science*. *Science is the study in which humans attempt to organize and explain, in a systematic and logical manner, knowledge about themselves and their surroundings.*

Because of the enormous scope of science, the sheer amount of accumulated knowledge, and the limitations of human mental capacity to master such a large and diverse body of knowledge, science is divided into smaller subdivisions called *scientific disciplines*. A **scientific discipline** is a branch of science limited in size and scope to make it more manageable. Examples of scientific disciplines are chemistry, astronomy, botany, geology, physics, and zoology.

Figure 1.1 shows an organization chart, with emphasis on chemistry, for the various scientific disciplines. These disciplines can be grouped into *physical sciences* (the study of matter and energy) and *biological sciences* (the study of living organisms). Chemistry is a physical science.

Rigid boundaries between scientific disciplines *do not exist*. All scientific disciplines borrow information and methods from each other. No scientific discipline is totally independent. “Environmental problems” that scientists have encountered in the last two decades particularly show the interdependence of the various scientific disciplines. For example, chemists attempting to solve the problems of chemical contamination of the environment find that they need some knowledge of