CHEMISTRY AND LIFE
An Introduction to General, Organic, and Biological Chemistry 6th Ed

Chemistry and Life

An Introduction to General, Organic, and Biological Chemistry

Sixth Edition

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PERIODIC TABLE OF THE ELEMENTS

Main groups — Main groups

Metals

Metalloids

Nonmetals

Transition metals

	1A[a] 1												3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 **H** 1.00794	2A 2																2 **He** 4.002602
2	3 **Li** 6.941	4 **Be** 9.012182											5 **B** 10.811	6 **C** 12.0107	7 **N** 14.00674	8 **O** 15.9994	9 **F** 18.998403	10 **Ne** 20.1797
3	11 **Na** 22.989770	12 **Mg** 24.3050	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	13 **Al** 26.981538	14 **Si** 28.0855	15 **P** 30.973762	16 **S** 32.066	17 **Cl** 35.4527	18 **Ar** 39.948
4	19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.95591	22 **Ti** 47.867	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.938049	26 **Fe** 55.845	27 **Co** 58.933200	28 **Ni** 58.6934	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.92160	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
5	37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.90585	40 **Zr** 91.224	41 **Nb** 92.90638	42 **Mo** 95.94	43 **Tc** [98]	44 **Ru** 101.07	45 **Rh** 102.90550	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.411	49 **In** 114.818	50 **Sn** 118.710	51 **Sb** 121.760	52 **Te** 127.60	53 **I** 126.90447	54 **Xe** 131.29
6	55 **Cs** 132.90545	56 **Ba** 137.327	57 ***La** 138.9055	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.217	78 **Pt** 195.078	79 **Au** 196.96655	80 **Hg** 200.59	81 **Tl** 204.3833	82 **Pb** 207.2	83 **Bi** 208.98038	84 **Po** [210]	85 **At** [210]	86 **Rn** [222]
7	87 **Fr** [223]	88 **Ra** [226]	89 **Ac** [227]	104 **Rf** [261]	105 **Db** [262]	106 **Sg** [266]	107 **Bh** [264]	108 **Hs** [265]	109 **Mt** [268]	110 [269]	111 [272]	112 [277]	113	114 [285]	115	116 [289]	117	118 [293]

*Lanthanide series	58 **Ce** 140.116	59 **Pr** 140.90765	60 **Nd** 144.24	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.964	64 **Gd** 157.25	65 **Tb** 158.92534	66 **Dy** 162.50	67 **Ho** 164.93032	68 **Er** 167.26	69 **Tm** 168.93421	70 **Yb** 173.04	71 **Lu** 174.967
Actinide series	90 **Th** 232.0381	91 **Pa** 231.03588	92 **U** 238.0289	93 **Np** [237]	94 **Pu** [244]	95 **Am** [243]	96 **Cm** [247]	97 **Bk** [247]	98 **Cf** [251]	99 **Es** [252]	100 **Fm** [257]	101 **Md** [258]	102 **No** [259]	103 **Lr** [262]

[a] The labels on top (1A, 2A, etc.) are common American usage. The labels below these (1, 2, etc.) are those recommended by the International Union of Pure and Applied Chemistry.

The names and symbols for elements 110 and above have not yet been decided.

Atomic masses in brackets are the masses of the longest-lived or most important isotope of radioactive elements.

Further information is available at http://www.shef.ac.uk/chemistry/web-elements/

The production of elements 116 and 118 was reported in May 1999 by scientists at Lawrence Berkeley National Laboratory.

LIST OF ELEMENTS WITH THEIR SYMBOLS AND ATOMIC MASSES

Element	Symbol	Atomic number	Atomic Mass
Actinium	Ac	89	227[a]
Aluminum	Al	13	26.981538
Americium	Am	95	243[a]
Antimony	Sb	51	121.760
Argon	Ar	18	39.948
Arsenic	As	33	74.92160
Astatine	At	85	210[a]
Barium	Ba	56	137.327
Berkelium	Bk	97	247[a]
Beryllium	Be	4	9.012182
Bismuth	Bi	83	208.98038
Bohrium	Bh	107	264[a]
Boron	B	5	10.811
Bromine	Br	35	79.904
Cadmium	Cd	48	112.411
Calcium	Ca	20	40.078
Californium	Cf	98	251[a]
Carbon	C	6	12.0107
Cerium	Ce	58	140.116
Cesium	Cs	55	132.90545
Chlorine	Cl	17	35.4527
Chromium	Cr	24	51.9961
Cobalt	Co	27	58.933200
Copper	Cu	29	63.546
Curium	Cm	96	247[a]
Dubnium	Db	105	262[a]
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	252[a]
Erbium	Er	68	167.26
Europium	Eu	63	151.964
Fermium	Fm	100	257[a]
Fluorine	F	9	18.9984032
Francium	Fr	87	223[a]
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.723
Germanium	Ge	32	72.61
Gold	Au	79	196.96655
Hafnium	Hf	72	178.49
Hassium	Hs	108	265[a]
Helium	He	2	4.002602
Holmium	Ho	67	164.93032
Hydrogen	H	1	1.00794
Indium	In	49	114.818
Iodine	I	53	126.90447
Iridium	Ir	77	192.217
Iron	Fe	26	55.845
Krypton	Kr	36	83.80
Lanthanum	La	57	138.9055
Lawrencium	Lr	103	262[a]
Lead	Pb	82	207.2
Lithium	Li	3	6.941
Lutetium	Lu	71	174.967
Magnesium	Mg	12	24.3050
Manganese	Mn	25	54.938049
Meitnerium	Mt	109	268[a]
Mendelevium	Md	101	258[a]
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.1797
Neptunium	Np	93	237[a]
Nickel	Ni	28	58.6934
Niobium	Nb	41	92.90638
Nitrogen	N	7	14.00674
Nobelium	No	102	259[a]
Osmium	Os	76	190.23
Oxygen	O	8	15.9994
Palladium	Pd	46	106.42
Phosphorus	P	15	30.973762
Platinum	Pt	78	195.078
Plutonium	Pu	94	244[a]
Polonium	Po	84	210[a]
Potassium	K	19	39.0983
Praseodymium	Pr	59	140.90765
Promethium	Pm	61	145[a]
Protactinium	Pa	91	231.03588
Radium	Ra	88	226[a]
Radon	Rn	86	222[a]
Rhenium	Re	75	186.207
Rhodium	Rh	45	102.90550
Rubidium	Rb	37	85.4678
Ruthenium	Ru	44	101.07
Rutherfordium	Rf	104	261[a]
Samarium	Sm	62	150.36
Scandium	Sc	21	44.95591
Seaborgium	Sg	106	266[a]
Selenium	Se	34	78.96
Silicon	Si	14	28.0855
Silver	Ag	47	107.8682
Sodium	Na	11	22.98977
Strontium	Sr	38	87.62
Sulfur	S	16	32.066
Tantalum	Ta	73	180.9479
Technetium	Tc	43	98[a]
Tellurium	Te	52	127.60
Terbium	Tb	65	158.92534
Thallium	Tl	81	204.3833
Thorium	Th	90	232.0381
Thulium	Tm	69	168.93421
Tin	Sn	50	118.710
Titanium	Ti	22	47.867
Tungsten	W	74	183.84
Uranium	U	92	238.0289
Vanadium	V	23	50.9415
Xenon	Xe	54	131.29
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.90585
Zinc	Zn	30	65.39
Zirconium	Zr	40	91.224
*[b]		110	269[a]
*[b]		111	272[a]
*[b]		112	277[a]
*[b]		114	285[a]
*[b]		116	289[a]
*[b]		118	293[a]

[a]Mass of longest-lived or most important isotope.

[b]The names of elements 110 and above have not yet been decided.

Preface

Our world has been transformed by science and technology. The impact of science on the quality of human life is profound. To beginning students, the scientific disciplines that daily influence their lives often seem mysterious and incomprehensible. Those of us who enjoy the study of science, however, find it a fascinating and rewarding experience precisely because it can provide reasonable explanations for seemingly mysterious phenomena.

Chemistry and Life has been written in that spirit. We help explain apparently obscure phenomena in an informal, readable style. We assume that the student has little or no chemistry background, so we clearly explain each new concept as it is introduced. Chemical principles and biological applications are carefully integrated throughout the text, with liberal use of drawings, diagrams, and photographs.

For this new edition, the entire text has been updated to reflect the latest scientific knowledge. In addition, we have responded to suggestions of users and reviewers of the fifth edition and used our own writing and teaching experience to make some important improvements.

Effective, Flexible Organization

Our selection of topics and choice of examples make the text especially appropriate for students in health and life sciences, but it is also suitable for anyone seeking to become a better-informed citizen of our technological society. The text provides ample material for a full-year course. We consciously increase the sophistication of chemical understanding as the student progresses through the chapters.

Selected Topics Offer Flexibility to the Instructor

We have included in this edition, as in past editions, a number of Selected Topics that cover key optional material in additional detail. These are introduced at the appropriate times (for example, the Selected Topic on Vitamins, which discusses key coenzymes, follows immediately after the chapter on Enzymes), and each includes its own end-of-topic problems. These Selected Topics offer instructors maximal flexibility; they may be omitted or assigned as outside reading without loss of continuity.

New to this edition:

In this new edition, unit conversions and significant figures are now in Chapter 1. VSEPR theory and the shapes of molecules are in Chapter 3, with our discussion of chemical bonding. Nuclear chemistry is now Chapter 12, following the general chemistry part of the text and just before the organic chapters. The chapters dealing with metabolism (24–27) have been extensively reorganized and rewritten and include a more complete discussion of anabolic pathways. Chapter 24 is now an overview of metabolism, with a particular emphasis on digestion and energy production (Krebs cycle and cellular respiration). Chapter 25 is concerned with the metabolic pathways unique to the metabolism of carbohydrates; Chapter 26 discusses the unique metabolism of lipids; and Chapter 27 presents protein metabolism.

Many sections have undergone extensive rewriting, especially the Selected Topics and sections dealing with molecular biology (Chapter 23) and body fluids (Chapter 28).

Rich in Applications

Capturing students' attention and curiosity is critical in teaching this course. To aid in this effort, we have created a text rich in applied chemistry. We offer applications in three places:

- In a series of special boxed essays within each chapter (you can find a list of these on page iv)
- In marginal notes located throughout the text
- In the prose itself (where even those students who tend to skip boxes and marginal notes, thinking they "won't be on the exam," can see the importance of chemistry to their lives and future careers).

New to this edition:

Most of the health-related topics from the fifth edition have been retained, and in some cases expanded. For example, the essay on "Aspartame" in Chapter 19 has been expanded to include other artificial sweeteners. We have added several new essays, including Body Temperature, Hypothermia, and Hyperthermia; Sizes and Masses of Objects: Powers of Ten; Oxidation-Reduction: Bleaches and Stain Removal; Reducing Fat Intake; Prions; Human Genome Project; Polymerase Chain Reaction; Creatine Phosphate; Cyanide Poisoning; Obesity Genes; and Genetic Diseases of Amino Acid Catabolism.

Pedagogy to Help Students

Each chapter has a list of Key Terms and a chapter Summary. The Key Terms are boldfaced when they are introduced in the text, and all are defined in the Glossary (Appendix II).

At the end of each chapter we offer **two classes of end-of-chapter exercises:**

- **Problems arranged by topic** test mastery of the material and—where pertinent—of problem-solving techniques introduced in the chapter. These problems are usually arranged in matched pairs.
- The **Additional Problems** are not grouped by type. Some are intended to be a bit more challenging; they often require a synthesis of ideas from more than one chapter. Others, however, are not any more difficult than those arranged by topic. Rather, they pursue an idea further than is done in the text, or they introduce new ideas.

New to this edition:

New to this edition are **Learning Objectives/Study Questions,** given at the beginning of each chapter. These are in the form of questions that students should be able to answer after completing the chapter.

Most sections of each chapter are followed by new **Review Questions** intended to provide an immediate assessment of the student's understanding of the section's material. Many worked-out Examples and Practice Exercises are also interspersed in the body of each chapter. Where appropriate, we provide two Exercises, labeled **A** and **B,** after a worked Example. The A exercise is much like the Example it follows; the B exercise often requires incorporation of knowledge acquired previously. Many of the worked-out Examples have been revised to improve the pedagogy.

Supplements for the Student

- **Student Study Guide and Solutions Manual,** by Marvin L. Hackert of the University of Texas at Austin, Roger K. Sandwick of the State University of New York at Plattsburgh, Michael Pelter of Purdue University–Calumet, and Libbie Pelter. This student-friendly manual contains chapter summaries, additional examples and problems, and numerous self-tests (with answers). Solutions correspond to the odd-numbered problems in the text. (ISBN 0-13-085385-2)
- **Chemistry and Life Companion Website: http://www.prenhall.com/hill.** This student-oriented website features computer-graded quizzes with detailed, book-specific feedback, pre-built molecular models for students to view using Chime, downloadable animations, and up-to-date links to chemistry and career-oriented websites.
- **Chemistry on the Internet,** by Thomas Gardner of Tennessee State University. This brief review of the Internet is perfect for students using the Internet and World Wide Web for the first time. It focuses on using the Internet to study chemistry. Available free with new copies of the text. Ask your Prentice Hall representative for details.
- **Chemistry and Life in the Laboratory: Experiments in General, Organic, and Biological Chemistry,** by Victor L. Heasley and Val J. Christensen of Point Loma Nazarene College, and Gene E. Heasley of Southern Nazarene University. This Manual contains 36 experiments that cover the same general topics as the text. Laboratory instructions are clear and thorough and the experiments are well-written and imaginative. This revision includes expanded information on issues of safety and disposal. All experiments have been thoroughly class tested. (ISBN 0-13-085376-3)
- **Allied Health Chemistry: A Companion,** by Tim Smith and Diane Vukovich, both of the University of Akron. This student companion teaches students how to apply the basic mathematics needed for this course. The book features study tips, examples, and careful explanations. Chapters cover metric conversions, unit conversions, simple algebra, temperature conversions, mole conversions, and stoichiometry. (ISBN 0-13-470460-6)
- **Prentice Hall/*The New York Times* Themes of Times.** Through this unique program, adopters of *Chemistry and Life* are eligible to receive our *New York Times* supplement for their students. This newspaper-format resource uses current chemistry-related articles to emphasize the importance and relevance of chemistry in everyday life. (Free in quantity to qualified adopters through your local Prentice Hall representative.)

Supplements for the Instructor

- **Instructor's Solutions Manual with Test Bank,** by Sandwick, Pelter, Pelter, and Aninna Carter of Adirondack Community College. The Instructor's Manual contains solutions to all the problems in the text. The extensively reviewed Test Bank contains over 1100 multiple-choice questions. (ISBN 0-13-085377-1)
- **PH Custom Test for Windows** (ISBN 0-13-085379-8) and **PH Custom Test for Macintosh** (ISBN 0-13-085378-X). These electronic versions of the *Chemistry and Life* Test Bank allow you to customize tests and questions.
- **Transparencies:** 137 full-color transparency acetates selected by the text authors. (ISBN 0-13-085381-X)
- **GOB Presentation Manager** is designed for instructors who use a computer to present material in-class. This CD-ROM features most of the art from the text

as well as animations relevant to general, organic, and biological chemistry. All images can be shown using the Presentation Manager program on the CD-ROM or can be downloaded into other presentation programs (such as PowerPoint). (ISBN 0-13-0853836)

- **Instructor's Manual to the Laboratory Manual,** by Heasley, Christensen, and Heasley. This Manual features equipment lists, chemical lists, teaching suggestions, and precautions for instructors using the Lab Manual. It also includes answers to the pre- and post-lab questions posed in the Lab Manual. (ISBN 0-13-085370-4)

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No book—or other educational device—can replace a good teacher; thus we have designed this book as an aid to the classroom teacher. The only valid test of this or any text is in a classroom. We would greatly appreciate receiving comments and suggestions based on your experience with this book.

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A Guide to Using this Text

What is chemistry? Chemistry is such a broad, all-encompassing area of study that people almost despair in trying to define it. Indeed, some have taken a cop-out approach by defining chemistry as "what chemists do." But that won't do; it's much too narrow a view.

Chemistry is what we all do. We bathe, clean, and cook. We put chemicals on our faces, hands, and hair. Collectively, we use tens of thousands of consumer chemical products in our homes. Professionals in the health and life sciences use thousands of additional chemicals as drugs, antiseptics, or reagents for diagnostic tests.

Your body itself is a remarkable chemical factory. You eat and breathe, taking in raw materials for the factory. You convert these supplies into an unbelievable array of products, some incredibly complex. This chemical factory—your body—also generates its own energy. It detects its own malfunctions and can regenerate and repair some of its component parts. It senses changes in its environment and adapts to these changes. With the aid of a neighboring facility, this fabulous factory can create other factories much like itself.

Everything you do involves chemistry. As you read this sentence, light energy is converted to chemical energy. As you think, protein molecules are synthesized and stored in your brain. All of us do chemistry.

Chemistry affects society as well as individuals. Chemistry is the language—and the principal tool—of the biological sciences, the health sciences, and the agricultural and earth sciences.

Chemistry has illuminated all the natural world, from the tiny atomic nucleus to the immense cosmos. We believe that a knowledge of chemistry can help you. We have written this book in the firm belief that from the beginning, chemistry is related to problems and opportunities in the life and health sciences. And we believe that this can make the study of chemistry interesting and exciting, especially to nonchemists.

For example, an "ion" is more than a chemical abstraction. Enough mercury ions in the wrong place can kill you, but the right number of calcium ions in the right place can keep you from bleeding to death. "$PV = nRT$" is an equation, but it is also the basis for the respiratory therapy that has saved untold lives in hospitals. "Hydrogen bonding" is a chemical phenomenon, but it also helps to account for the fact that a dog has puppies while a cat has kittens and a human has human babies. There are hundreds of similar fundamental and interesting applications of chemistry to life.

A knowledge of chemistry has already had a profound effect on the quality of life. Its impact on the future will be even more dramatic. At present we can control diabetes, cure some forms of cancer, and prevent some forms of mental retardation because of our understanding of the chemistry of the body. We can't *cure* diabetes or cure *all* forms of cancer or *all* mental retardation, because our knowledge is still limited. So learn as much as you can. Your work will be enhanced and your life enriched by your greater understanding.

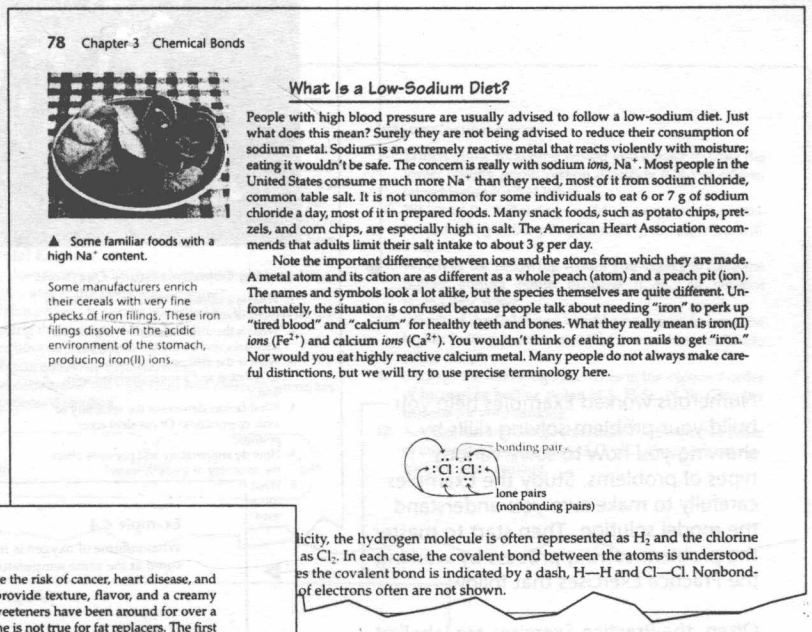
Be prepared. Something good might happen to you—and to others because of you.

You and your classmates come to this course with a variety of backgrounds and interests. Most of you plan to be professionals in a biological or allied health field. Knowledge of chemistry is essential to a true understanding of everything from DNA replication to drug discovery to nutrition. Indeed, the chemical properties and principles you learn in this course will pervade almost every aspect of your private and professional lives. In this text, we provide you with both the principles and applications of chemistry that will help you in your professional practice and enrich your everyday life as well.

This text is rich in pedagogical aids, both within and at the ends of the chapters. We present this "user's guide" to the text to help you get the most out of this book and your course.

Applications

Margin notes highlight the intriguing ways in which you can put your knowledge of chemistry to work. We touch on fields as diverse as medicine, engineering, agriculture, and consumer products.



78 Chapter 3 Chemical Bonds

What Is a Low-Sodium Diet?

People with high blood pressure are usually advised to follow a low-sodium diet. Just what does this mean? Surely they are not being advised to reduce their consumption of sodium metal. Sodium is an extremely reactive metal that reacts violently with moisture; eating it wouldn't be safe. The concern is really with sodium *ions*, Na^+. Most people in the United States consume much more Na^+ than they need, most of it from sodium chloride, common table salt. It is not uncommon for some individuals to eat 6 or 7 g of sodium chloride a day, most of it in prepared foods. Many snack foods, such as potato chips, pretzels, and corn chips, are especially high in salt. The American Heart Association recommends that adults limit their salt intake to about 3 g per day.

Note the important difference between ions and the atoms from which they are made. A metal atom and its cation are as different as a whole peach (atom) and a peach pit (ion). The names and symbols look a lot alike, but the species themselves are quite different. Unfortunately, the situation is confused because people talk about needing "iron" to perk up "tired blood" and "calcium" for healthy teeth and bones. What they really mean is iron(II) *ions* (Fe^{2+}) and calcium *ions* (Ca^{2+}). You wouldn't think of eating iron nails to get "iron." Nor would you eat highly reactive calcium metal. Many people do not always make careful distinctions, but we will try to use precise terminology here.

▲ Some familiar foods with a high Na^+ content.

Some manufacturers enrich their cereals with very fine specks of iron filings. These iron filings dissolve in the acidic environment of the stomach, producing iron(II) ions.

bonding pair
lone pairs (nonbonding pairs)

licity, the hydrogen molecule is often represented as H_2 and the chlorine as Cl_2. In each case, the covalent bond between the atoms is understood. es the covalent bond is indicated by a dash, H—H and Cl—Cl. Nonbond- of electrons often are not shown.

Reducing Fat Intake

We often hear of the need for a low fat diet to reduce the risk of cancer, heart disease, and other problems associated with obesity. But fats provide texture, flavor, and a creamy "mouthfeel" to foods. Artificial or high-intensity sweeteners have been around for over a century (see boxed essay in Chapter 19), but the same is not true for fat replacers. The first fat replacers, introduced in the 1960s, used carbohydrates as the primary ingredient. Carrageenan, a seaweed derivative approved for use in food in 1961, was initially used as an emulsifier, stabilizer, and thickener in food. In the early 1990s it was used as a fat replacer. Protein-based fat substitutes came along in the early 1990s. Unlike many of the initial carbohydrate-based products that were first used for other purposes, these were specifically designed to replace fat in foods. Microparticulated proteins, such as Simplesse®, are made from whey protein or milk and egg protein. The carbohydrate- and protein-based fat replacers can give the "mouthfeel," bulk, and texture of fats, but cannot be used for frying.

In January 1996 the first true fat-based fat replacer was approved—olestra (marketed as Olean® by Procter & Gamble). Olestra is composed of a sucrose core with six to eight fatty acids attached. Because olestra is a much larger molecule than a triglyceride, it is too large to be hydrolyzed by lipases and digested or absorbed by the body or metabolized by the microorganisms in the intestinal tract. Thus it adds no fat or calories to foods. Olestra is not broken down or degraded when it is exposed to high temperatures; thus it can be used for frying foods.

Olestra does have some drawbacks to its use. Clinical studies have shown that it may cause intestinal cramps and loose stools in some individuals. It also reduces the absorption of fat-soluble nutrients, such as vitamins A, D, E, and K and carotenoids, from foods eaten at the same time. Because of these concerns, the Food and Drug Administration (FDA) requires that foods containing olestra be fortified with vitamins A, D, E, and K and that the following statement appear on the package: "This product contains olestra. Olestra may cause abdominal cramping and loose stools. Olestra inhibits the absorption of some vitamins and other nutrients. Vitamins A, D, E, and K have been added."

◀ Molecular models of olestra and a trizglyceride. Olestra's core is sucrose with six to eight fatty acids attached.

Olestra

◀ There are many boxes in this text that focus on how we apply our chemical knowledge to solve real-life problems, and on historical topics of interest. These readings will help you see how chemistry affects everyday life and how we arrived at our current understanding of chemistry.

Learning Tools

At the start of each chapter you'll find a set of learning objectives in the form of study questions. Read these objectives before you start each chapter; they will help you identify key points in each section. They will also help you make sure you can answer each question when you finish the chapter. This is an excellent way to test your understanding of the material.

Solutions

CHAPTER

Fish, plants, and other marine organisms reside within a water solution that contains all the necessary ingredients to support life.

Learning Objectives/Study Questions

1. What is a solution? What are the different types of solutions?
2. What is the difference between a soluble substance and a miscible substance?
3. What is the difference between a saturated solution and a supersaturated solution?
4. What factors determine the solubility of ionic compounds? Of covalent compounds?
5. How do temperature and pressure affect the solubility of gases in water?
6. What
   concer
   used?
7. What is a colligative property? How do colligative properties explain the use of antifreeze in radiators or of salt to melt snow and ice?
8. What are osmosis and osmotic pressure? What is their relevance to human biology and to medicine?
9. What are colloids? How do the properties of a colloid compare to those of a solution or suspension? Give some examples of colloids.
10. What is dialysis? What is its relevance to

Numerous worked Examples help you build your problem-solving skills by showing you how to solve various types of problems. Study the Examples carefully to make sure you understand the model solution. Then start to master the problem-solving process by working the Practice Exercises that follow.

Often, the Practice Exercises are labelled A and B. Exercise A asks a question similar to that in the Example. Exercise B usually asks you to extend your understanding a bit further. For example, you may need to apply a problem-solving technique you learned earlier. These Exercises help prepare you for solving more complex problems, such as those you might face on an exam.

Example 4.4

What volume of oxygen is required to burn 0.556 L of propane, if both gases are measured at the same temperature and pressure?

$$C_3H_8(g) + 5\,O_2(g) \longrightarrow 3\,CO_2(g) + 4\,H_2O(g)$$

Solution

The equation indicates that *five* volumes of $O_2(g)$ are required for every volume of $C_3H_8(g)$. Thus, we use 5 L $O_2(g)$/ 1 L $C_3H_8(g)$ as the ratio to find the volume of oxygen required.

$$?\,L\,O_2(g) = 0.556\,L\,C_3H_8(g) \times \frac{5\,L\,O_2(g)}{1\,L\,C_3H_8(g)} = 2.78\,L\,O_2(g)$$

Practice Exercises

A. Using the equation in Example 4.4, calculate the volume of $CO_2(g)$ that is produced when 0.492 L of propane is burned if the two gases are compared at the same temperature and pressure.

B. Calculate the volume of $CO_2(g)$ that is produced when 5.42 L of butane, $C_4H_{10}(g)$, is burned if the two gases are compared at the same temperature and pressure. (Hint: First write a balanced chemical equation.)

Example 4.1

Balance the following equation.

$$Fe + O_2 \longrightarrow Fe_2O_3$$

Solution

Begin by balancing the oxygen atoms. The least common multiple of 2 and 3 is 6. We need *three* O_2 and *two* Fe_2O_3

3 × 2 = 6 O atoms | 2 × 3 = 6 O atoms

$$Fe + 3\,O_2 \longrightarrow 2\,Fe_2O_3 \quad (\textit{not balanced})$$

1 Fe atom | 2 × 2 = 4 Fe atoms

We now have *four* iron atoms on the right side. We can get four on the left by placing the coefficient 4 in front of Fe.

Voice balloons help you understand each step in the solution to a problem. Make sure you understand where each answer comes from; don't just memorize them.

Review questions conclude each section. Make sure you can answer these questions before you proceed. You can check your answers to the questions numbered in red at the back of the book in Appendix III.

...velop like charges. The brush develops an opposite charge, and the hairs are attracted to it.

✓ Review Questions

1.11 What is a force? How do charged particles exert a force? What sort of force is exerted by Earth on an object at its surface?

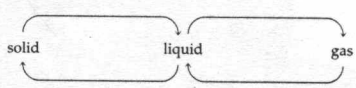
1.12 Describe what happens to two particles with like charges when they are brought close together. What happens to particles with unlike charges when they are brought close together?

End-of-chapter problems test your mastery of the problem-solving techniques and material presented in the chapter. They are arranged by topic and come in matched pairs (each odd- and even-numbered pair test the same concept). Problems may emphasize estimation skills or conceptual understanding. Work many of the Problems to develop the strong problem-solving skills that will help you succeed. Problems numbered in red are answered at the back of the book.

Problems

Some General Considerations

1. How do liquids and solids differ from gases in their compressibility, spacing of molecules, and intermolecular forces?
2. List four types of interactions between particles in the liquid and solid states. Give an example of each type.
3. Why does it take longer to boil an egg at high altitude than at sea level? Does it take longer to fry an egg at high altitude? Explain.
4. Why does steam at 100 °C cause more severe burns than liquid water at the same temperature?
5. In which process is energy absorbed by the material undergoing the change of state?
   a. melting or freezing
   b. condensation or vaporization
6. Label each arrow with the term that correctly identifies the process described.



Intermolecular Forces

7. Which of the following would you expect to have the lower boiling point: carbon disulfide (CS_2) or carbon tetrachloride (CCl_4)? Why?
8. Which of the following would you expect to have the lower boiling point: phosphine (PH_3) or arsine (AsH_3)? Why?
9. Which of the following would you expect to have the higher boiling point: propane (C_3H_8) or ethanol (C_2H_5OH)? Why?
10. Which of the following would you expect to have the higher boiling point: water (H_2O) or carbon monoxide (CO)? Why?
11. Arrange the following substances in the expected order of increasing boiling point: H_2S, H_2Se, H_2Te. Give the reasons for your ranking.
12. Arrange the following substances in the expected order of increasing boiling point: H_2O, HCl, CH_4. Give the reasons for your ranking.

Additional Problems

61. The speed limit in rural Ontario is 90 km/hr. What is this speed in miles per hour?
62. The speed of light is 186,000 mi/sec. What is this speed in meters per second?
63. If your heart beats at a rate of 72 times per minute and your lifetime will be 70 years, how many times will your heart beat during your lifetime?
64. How many 325-milligram aspirin tablets ca... from 875 grams of aspirin?
65. A doctor puts you on a diet of 5500 kilojoul... day. How many calories is that? How many kilocalories (food Calories)?
66. Milk costs $3.89 per gallon or $1.15 per liter. Which is cheaper?
67. What is the thickness of a 45.4 cm × 104.6 cm rectangular piece of cast iron (d = 7.76 g/cm^3) that has a mass of ...

Some of the Additional Problems are more challenging than the Problems, requiring a synthesis of concepts from multiple chapters. Others will help you to attain a stronger mastery of key concepts in this chapter. Additional Problems may also emphasize estimation skills or conceptual understanding.

... to 35.0 °C by the same quantity of heat that is capable of raising the temperature of 145 g H_2O from 22.5 °C to 35.0 °C?

71. Arrange the following in order of increasing length (shortest first): (1) a 1.21-m chain, (2) a 75-in. board, (3) a 3 ft 5-in. rattlesnake, (4) a yardstick.
72. Arrange the following in order of increasing mass (lightest first): (1) a 5-lb bag of potatoes, (2) a 1.65-kg cabbage, (3) 2500 g sugar.
73. One of the women pictured below has a mass of 38.5 kg and a height of 1.51 m. Which one is it likely to be?

... includes the air between the pieces of polystyrene foam.)

75. Which of the following items would be most difficult to lift into the bed of a pickup truck: (1) a 100-lb bag of potatoes, (2) a 15-gal plastic bottle filled with water, (3) a 3.0-L flask filled with mercury (d = 13.6 g/cm^3)?
76. A rectangular block of gold-colored material measures 3.00 cm × 1.25 cm × 1.50 cm and has a mass of 28.12 g. Can the material be gold?
77. An experiment calls for 8.65 grams of carbon tetrachloride (d = 1.59 g/mL). What is the volume of such a mass?
78. Adult male Hooker's sea lions are 250 to 350 cm long and weigh 300 to 450 kg. Convert these measurements to inches and pounds.
79. Pediatric drug dosages are usually based on infant weight and are expressed in units such as milligrams of drug per kilogram of body weight (mg/kg). If the recommended dosage of a particular drug is 5.0 mg/kg, what is the proper mass of drug for a 17-lb baby?
80. Each Tylenol chewable tablet contains 80 mg of acetaminophen. The recommended dosage for children is 10 mg/kg of body weight. How many tablets constitute the proper dosage for a 55 lb child?
81. In its nonstop, round-the-world trip, the aircraft Voyager traveled 25,102 mi in 9 days, 3 min, and 44 s. Calculate the average speed of Voyager in miles per hour.

... is a unit ... racing, and the unit ...

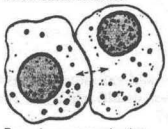
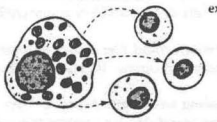
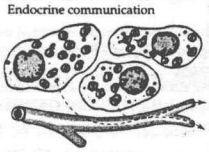
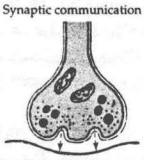
Selected Topics

SELECTED TOPIC **E**

Hormones

Humans and all other multicellular organisms must have a way for cells to communicate with each other—intercellular communication. Informational signals must be sent from one cell to adjacent cells or to cells or tissues at a greater distance. Table E.1 outlines the ways that cells and tissues communicate with each other. Selected Topic C discussed neurotransmitters, needed for synaptic communication. In this special topic we consider the molecules needed for paracrine and endocrine communication. A distinguishing characteristic of these compounds is their production of dramatic effects at very low concentrations. In **paracrine communication** the chemical messengers, known as **paracrine factors,** move from one cell to an-

Table E.1 Mechanisms of Intercellular Communication

Mechanism	Transmission	Chemical Mediators	Distribution of Effects
Direct communication 	Through gap junctions from cytoplasm to cytoplasm	Ions, small solutes, lipid-soluble materials	Limited to adjacent cells that are directly interconnected by interlocking membrane proteins
Paracrine communication 	Through extracellular fluid	Paracrine factors	Primarily limited to local area, where concentrations are relatively high; target cells must have appropriate receptors
Endocrine communication 	Through the circulatory system	Hormones	Target cells are primarily in other tissues and organs and must have appropriate receptors
Synaptic communication 	Across synaptic clefts	Neurotransmitters	Limited to very specific area; target cells must have appropriate receptors

557

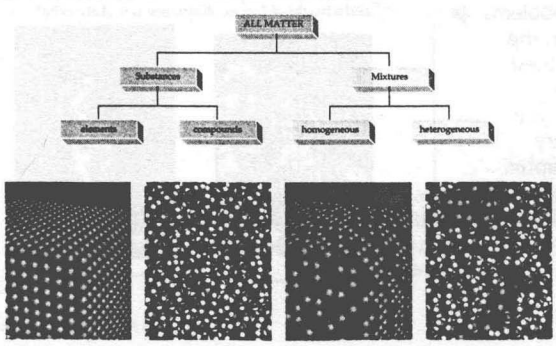
◀ Interspersed between chapters are seven Selected Topics. These mini-chapters treat selected subjects in more detail. Your instructor may assign these, or you may choose to read them on your own. In either case, each has end-of-topic problems you can use to test your understanding of the material.

Illustrations

Study the illustrations and graphics carefully. Chemistry is a visual science, and the art will help you to visualize atoms, molecules, and chemical processes that cannot be seen with the unaided eye. ▶

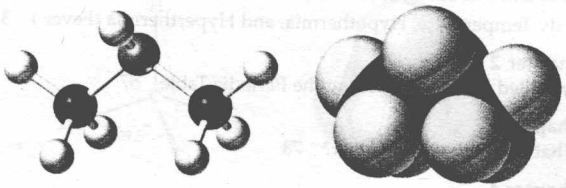
1.5 Elements, Compounds, and Mixtures

Figure 1.3 shows several other ways that chemists classify matter. A **substance** has a definite, or fixed, composition that does not vary from one sample to another. The composition of a **mixture** is variable. Pure gold (24-karat gold) consists entirely of



▲ **Figure 1.3**
Scheme for classifying matter, as explained in the text. The "molecular-level views" are of gold (an element), water (a compound), 12-karat gold (a *homogeneous mixture* of silver and gold), (a [illegible]).

Brief Contents



Application Boxes