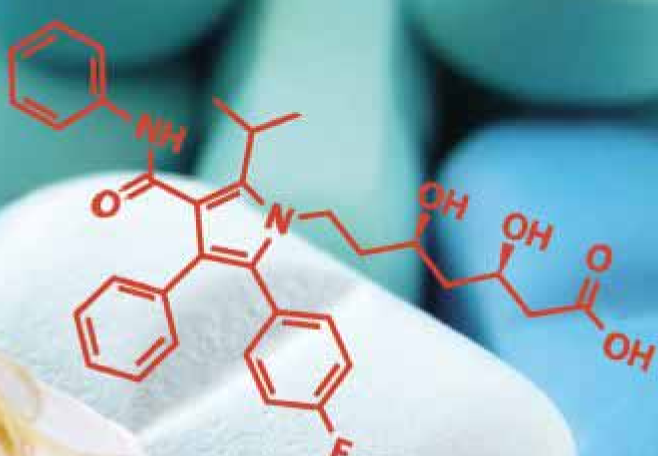
Spencer L. Seager / Michael R. Slabaugh

8e

Organic and Biochemistry for Today



Ask an Expert:

Melina B. Jampolis, MD

Do foods, medications, and supplements interact? See answer inside!

Chemistry and Your Health: The 10 Best Foods for Your Health.

At the Counter: Buying Prescription Drugs Online: Do's and Don'ts.

PERIODIC TABLE OF THE ELEMENTS

KEY

79 **Au** Gold 197.0	Atomic number Symbol Name Atomic weight (rounded to four significant figures)

- Metals
- Metalloids
- Nonmetals, noble gases

Group number, IUPAC system — (1)
Group number, U.S. system — IA
Period number
Group designation

Period	(1) IA	(2) IIA	(3) IIIB	(4) IVB	(5) VB	(6) VIB	(7) VIIB	(8) VIIIB	(9) VIIIB	(10) VIIIB	(11) IB	(12) IIB	(13) IIIA	(14) IVA	(15) VA	(16) VIA	(17) VIIA	Noble Gases (18) VIIIA	Period
1	1 **H** Hydrogen 1.008																	2 **He** Helium 4.003	1
2	3 **Li** Lithium 6.94	4 **Be** Beryllium 9.012											5 **B** Boron 10.81	6 **C** Carbon 12.01	7 **N** Nitrogen 14.01	8 **O** Oxygen 16.00	9 **F** Fluorine 19.00	10 **Ne** Neon 20.18	2
3	11 **Na** Sodium 22.99	12 **Mg** Magnesium 24.31											13 **Al** Aluminum 26.98	14 **Si** Silicon 28.09	15 **P** Phosphorus 30.97	16 **S** Sulfur 32.06	17 **Cl** Chlorine 35.45	18 **Ar** Argon 39.95	3
4	19 **K** Potassium 39.10	20 **Ca** Calcium 40.08	21 **Sc** Scandium 44.96	22 **Ti** Titanium 47.87	23 **V** Vanadium 50.94	24 **Cr** Chromium 52.00	25 **Mn** Manganese 54.94	26 **Fe** Iron 55.85	27 **Co** Cobalt 58.93	28 **Ni** Nickel 58.69	29 **Cu** Copper 63.55	30 **Zn** Zinc 65.38	31 **Ga** Gallium 69.72	32 **Ge** Germanium 72.63	33 **As** Arsenic 74.92	34 **Se** Selenium 78.96	35 **Br** Bromine 79.90	36 **Kr** Krypton 83.80	4
5	37 **Rb** Rubidium 85.47	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.91	40 **Zr** Zirconium 91.22	41 **Nb** Niobium 92.91	42 **Mo** Molybdenum 95.96	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3	5
6	55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)	6
7	87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (265)	105 **Db** Dubnium (268)	106 **Sg** Seaborgium (271)	107 **Bh** Bohrium (270)	108 **Hs** Hassium (277)	109 **Mt** Meitnerium (276)	110 **Ds** Darmstadtium (281)	111 **Rg** Roentgenium (280)	112 **Cn** Copernicium (285)	113 **—** — (284)	114 **Fl** Flerovium (289)	115 **—** — (288)	116 **Lv** Livermorium (293)	117 **—** — (294)	118 **—** — (294)	7

Mass numbers in parentheses are the most stable radioactive isotope.

Period															Period
6	58 **Ce** Cerium 140.1	59 **Pr** Praseodymium 140.9	60 **Nd** Neodymium 144.2	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.4	63 **Eu** Europium 152.0	64 **Gd** Gadolium 157.3	65 **Tb** Terbium 158.9	66 **Dy** Dysprosium 162.5	67 **Ho** Holmium 164.9	68 **Er** Erbium 167.3	69 **Tm** Thulium 168.9	70 **Yb** Ytterbium 173.0	71 **Lu** Lutetium 175.0	6
7	90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)	7

EIGHTH EDITION

Organic and Biochemistry for Today

Spencer L. Seager

Weber State University

Michael R. Slabaugh

Weber State University

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Spencer L. Seager, Michael R. Slabaugh

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To our grandchildren:

Nate and Braden Barlow, Megan and Bradley Seager, and Andrew Gardner

Alexander, Annie, Christian, Elyse, Foster, Megan, and Mia Slabaugh, Addison and Hadyn Hansen

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Spencer L. Seager

Spencer L. Seager is a professor of chemistry at Weber State University, where he served as chemistry department chairman from 1969 until 1993. He teaches general chemistry at the university and is also active in projects to help improve chemistry and other science education in local elementary schools. He received his B.S. degree in chemistry and Ph.D. degree in physical chemistry from the University of Utah. Other interests include making minor home repairs, reading history of science and technology, listening to classical music, and walking for exercise.

Michael R. Slabaugh

Michael R. Slabaugh is a senior fellow at Weber State University, where he teaches the year-long sequence of general chemistry, organic chemistry, and biochemistry. He received his B.S. degree in chemistry from Purdue University and his Ph.D. degree in organic chemistry from Iowa State University. His interest in plant alkaloids led to a year of postdoctoral study in biochemistry at Texas A&M University. His current professional interests are chemistry education and community involvement in science activities, particularly the State Science and Engineering Fair in Utah. He also enjoys the company of family, hiking in the mountains, and fishing the local streams.

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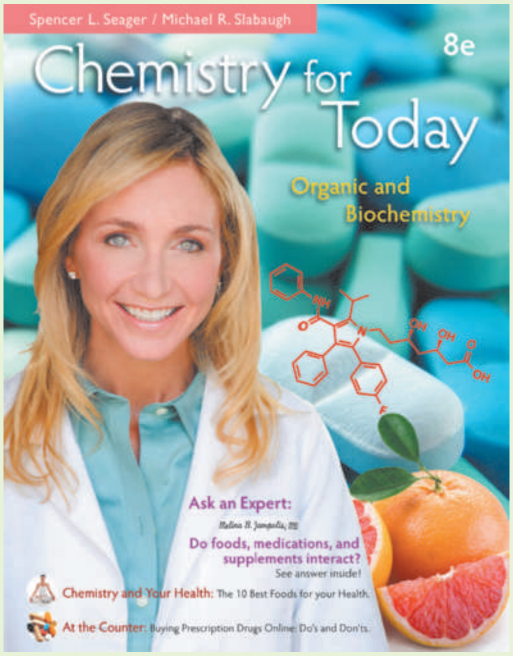

Dr. Melina B. Jampolis, M.D. is an internist and board-certified Physician Nutrition Specialist (one of only several hundred in the country). She specializes exclusively in nutrition for weight loss and disease prevention and treatment.

A graduate of Tufts University as well as Tufts School of Medicine, she completed her residency in internal medicine at Santa Clara Valley Medical Center, a Stanford University teaching hospital. In 2005, Dr. Jampolis hosted a program on the Discovery Network's FIT TV titled *Fit TV's Diet Doctor,* and she currently serves as the diet and fitness expert for CNNHealth.com. She serves as a member of the medical advisory board of *Better Homes and Gardens* and VivMag.com.

Her first book, *The No-Time-to-Lose Diet,* was released in January 2007, and the paperback version, *The Busy Person's Guide to Permanent Weight Loss,* was released in May 2008. Her latest book, *The Calendar Diet,* was released in March 2012.

Dr. Jampolis lectures throughout the country on nutrition for weight loss and optimal health. She has been interviewed on nutrition and weight loss–related topics by *USA Today, USA Weekend, New York Post, The Washington Post, Family Circle, Better Homes and Gardens,* Glamour.com, *Ladies' Home Journal, First for Women, Women's World, Alternative Medicine, Women's Health, SanFrancisco Magazine, Clean Eating, Baby Talk,* and more. She has appeared numerous times on *Live with Regis & Kelly,* CNN, FOX News Channel, FOX Business Network, as well as on *The Dr. Oz Show, Dr. Drew's Lifechangers,* and local television and radio stations, including ABC, NBC, FOX, KGO radio, and KRON-4 news.

Dr. Jampolis lives in Los Angeles with her husband and two-year-old son. She maintains a small private practice in San Francisco and Los Angeles.

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DR. MELINA B. JAMPOLIS, M.D.

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Dr. Melina B. Jampolis, M.D. is a Los Angeles, California, Physician Nutrition Specialist—a specialty practiced by only a few hundred physicians in the United States. She focuses exclusively on nutrition for weight loss and disease prevention and treatment.

Ask an Expert

Q: Do foods, medications, and supplements interact?

A: Most people are aware that medications can interact with one another, but many may not be aware of the interaction of certain foods and supplements with medications. These interactions generally result from either impaired absorption or altered metabolism.

Iron, present in food and supplements, has numerous clinically relevant interactions. Absorption of heme iron from meat protein is very efficient and differs from the absorption of non-heme iron such as that found in plant foods and supplements. Non-heme iron must be digested and converted to a soluble and ionized form in order to be absorbed in the intestine. This process is enhanced by gastric acid which improves the solubility of iron and reduces it to ferrous iron (2 + oxidation state) for better absorption. Acid reducing medications such as proton pump inhibitors and antacids reduce the absorption of non-heme iron by decreasing the acidity in the stomach and upper duodenum. Tannins found in tea and phytates found in legumes and wheat bran may also impair iron absorption by chelating iron, preventing its absorption. Ascorbic acid (vitamin C) enhances absorption by reducing ferric to ferrous iron and chelating ferrous iron, improving its absorption at the higher pH of the regions of the small intestine located farthest from the stomach. Calcium supplements and dairy foods also impair iron absorption. Ferrous iron can also interact with several types of medications including the antibiotics ciprofloxacin and tetracycline, and thyroid medication. It impairs their absorption and thereby potentially reduces their effectiveness as medications.

Calcium, also found in both dairy foods and some supplements, has several food and drug interactions. Like iron, calcium is only absorbed in ionic form. It too requires an acidic environment for optimal absorption, particularly when it is in the calcium carbonate form. This form is best taken with meals. Unlike iron, more calcium is absorbed in the parts of the small intestine located farthest from the acidic stomach. As a result, acid blocking medications are not as detrimental to absorption as they are for iron.

But calcium citrate, which is more soluble at a neutral pH, may still be the preferable form for those with compromised levels of stomach acid. Phytates and oxalic acid, found in spinach, rhubarb, collard greens, sweet potatoes and beans bind calcium, creating insoluble complexes that cannot be absorbed. Calcium can also decrease the absorption of several medications including quinolone antibiotics, tetracycline, and thyroid replacement medication.

Unlike iron and calcium which interact with medications by preventing their absorption, grapefruit interacts with numerous medications through its effect on drug metabolism. A flavonoid compound in grapefruit inhibits an enzyme, cytochrome P450 3A4, that is important for the degradation of numerous drugs. Since less of the drug is broken down when consumed with grapefruit or grapefruit juice, more of the drug is bioavailable, which can potentially lead to toxic levels in some cases. In addition to several of the cholesterol reducing statin medications, other drugs affected this way include several blood pressure lowering medications, the anti-retroviral medication saquinavir, and the immunosuppressive medication cyclosporine.

St. John's wort, a popular herbal supplement often used for the treatment of mild depression, may enhance rather than suppress the cytochrome P450 34A system in a clinically relevant manner, potentially reducing the effectiveness of several HIV medications, immunosuppressive medications, and even cancer treatment drugs.

There are numerous other food, drug and supplement interactions. While not all of them may be clinically relevant, their presence underscore the importance of discussing both supplementation and diet with appropriate health care provider. This is especially true if you are taking prescription medication or supplements to treat a deficiency or medical condition.

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PREFACE

The Image of Chemistry

We, as authors, are pleased that the acceptance of the previous seven editions of this textbook by students and their teachers has made it possible to publish this eighth edition. In the earlier editions, we expressed our concern about the negative image of chemistry held by many of our students, and their genuine fear of working with chemicals in the laboratory. Unfortunately, this negative image not only persists, but seems to be intensifying. Reports in the media related to chemicals or to chemistry continue to be primarily negative, and in many cases seem to be designed to increase the fear and concern of the general public. With this edition, we continue to hope that those who use this book will gain a more positive understanding and appreciation of the important contributions that chemistry makes in their lives.

Theme and Organization

This edition continues the theme of the positive and useful contributions made by chemistry in our world.

This text is designed to be used in either a two-semester or three-quarter course of study that provides an introduction to general chemistry, organic chemistry, and biochemistry. Most students who take such courses are majoring in nursing, other health professions, or the life sciences, and consider biochemistry to be the most relevant part of the course of study. However, an understanding of biochemistry depends upon a sound background in organic chemistry, which in turn depends upon a good foundation in general chemistry. We have attempted to present the general and organic chemistry in sufficient depth and breadth to make the biochemistry understandable.

As with previous editions, this textbook is published in a complete hardcover form and a two-volume paperback edition. One volume of the paperback edition contains all the general chemistry and the first two chapters of organic chemistry from the hardcover text. The second volume of the paperback edition contains all the organic chemistry and biochemistry of the hardcover edition. The availability of the textbook in these various forms has been a very popular feature among those who use the text because of the flexibility it affords them.

The decisions about what to include and what to omit from the text were based on our combined 75-plus years of teaching, input from numerous reviewers and adopters, and our philosophy that a textbook functions as a personal tutor to each student. In the role of a personal tutor, a text must be more than just a collection of facts, data, and exercises. It should also help students relate to the material they are studying, carefully guide them through more difficult material, provide them with interesting and relevant examples of chemistry in their lives, and become a reference and a resource that they can use in other courses or their professions.

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New to This Edition

In this eighth edition of the text, we have some exciting new features, including Case Studies, which begin each chapter, and Ask an Expert boxes written by CNN health expert Dr. Melina B. Jampolis. We have also retained features that received a positive reception from our own students, the students of other adopters, other teachers, and reviewers. The retained features are 23 *Study Skills* boxes that include 5 reaction maps; 4 *How Reactions Occur* boxes; 45 *Chemistry Around Us* boxes, including 14 new to this edition. The 13 *At The Counter* boxes reflect coverage of both prescription and non-prescription health-related products. There are 25 *Chemistry and Your Health* boxes, with 5 new to this edition. A greatly expanded feature of this eighth edition is the *Allied Health Exam Connection* that follows the exercises at the end of each chapter. This feature consists of examples of chemistry questions found on typical entrance examinations used to screen applicants to allied health professional programs. In addition, approximately 20% of the end-of-chapter exercises have been changed.

Allied Health Exam Connection

The following questions are from these sources:

1. *Nursing School Entrance Exam* © 2005, Learning Express, LLC.
2. *McGraw-Hill's Nursing School Entrance Exams* by Thomas A. Evangelist, Tamara B. Orr and Judy Unrein © 2009, The McGraw-Hill Companies, Inc.
3. *NSEE Nursing School Entrance Exams,* 3rd Edition © 2009, Kaplan Publishing.
4. *Cliffs Test Prep: Nursing School Entrance Exams* by Fred N. Grayson © 2004, Wiley Publishing, Inc.
5. *Peterson's Master the Nursing School and Allied Health Entrance Exams,* 18th Edition by Marion F. Gooding © 2008, Peterson's, a Nelnet Company.

9.126 An acid is a substance that dissociates in water into one or more _______ ions and one or more _______.

a. hydrogen . . . anions
b. hydrogen . . . cations
c. hydroxide . . . anions
d. hydroxide . . . cations

a. sulfate ions
b. water ions
c. hydrogen ions
d. oxygen ions

9.133 When a solution has a pH of 7, it is:

a. a strong base
b. a strong acid
c. a weak base
d. neutral

9.134 A common detergent has a pH of 11.0, so the detergent is:

a. neutral
b. acidic
c. alkaline
d. none of the above

9.135 In a 0.001 M solution of HCl, the pH is:

a. 2
b. −3
c. 1

Also new to this edition are many new photographs and updated art to further enhance student comprehension of key concepts, processes, and preparation.

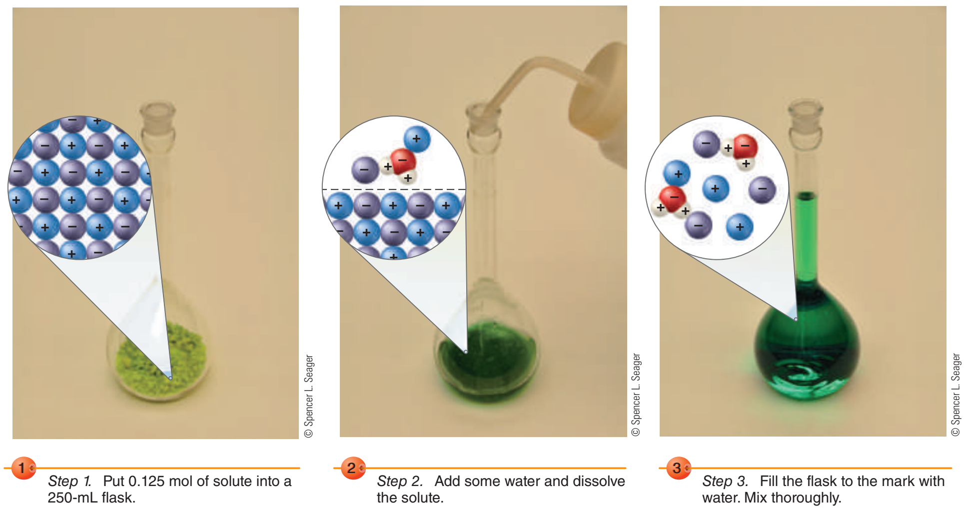

Figure 7.8 Preparation of a 0.500 M solution. Use the data given in the figure and show by a calculation that the resulting solution is 0.500 M.

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Revision Summary of Eighth Edition:

Chapter 1:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Ask an Expert: *Is Organic Food Worth the Price?*
- New Chemistry Around Us: *Oil Production from Wells and Sands*
- 20% new Exercises

Chapter 2:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- 20% new Exercises

Chapter 3:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Chemistry Around Us: *Alcohol and Antidepressants Don't Mix*
- New Chemistry And Your Health: *Why Do Teens Drink?*
- New Ask an Expert: *What Are Polyphenols?*
- 20% new Exercises

Chapter 4:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- 20% new Exercises

Chapter 5:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- 20% new Exercises

Chapter 6:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Ask an Expert: *Does Caffeine Help with Weight Loss?*
- 20% new Exercises

Chapter 7:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Ask an Expert: *Is High-Fructose Corn Syrup Worse for Your Health than Table Sugar?*
- 20% new Exercises

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Chapter 8:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Ask an Expert: *How Significantly Can Diet Really Lower Cholesterol?*
- New Chemistry and Your Health: *Performance Enhancing Steroids*
- New Chemistry Around Us: *Algae in Your Fuel Tank*
- New Chemistry Around Us: *Olive Oil: A Heart-Healthy Lipid*
- 20% new Exercises

Chapter 9:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Ask an Expert: *Can a Higher Protein Diet Help Me Lose Weight?*
- 20% new Exercises

Chapter 10:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- 20% new Exercises

Chapter 11:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Chemistry Around Us: *Is There a DNA Checkup in Your Future?*
- 20% new Exercises

Chapter 12:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Choose My Plate Nutrition Guide
- New Chemistry and Your Health: *Vitamin Water: Beneficial or Not?*
- New Ask an Expert: *Is It Better to Take a Fiber Supplement or to Eat Fiber-Fortified Foods?*
- 20% new Exercises

Chapter 13:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Ask an Expert: *How can we Avoid Energy Crashes?*
- New Chemistry Around Us: *What Is the Best Weight-Loss Strategy?*
- 20% new Exercises

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Chapter 14:

- New Case Study
- New Case Study Follow-up
- New photography
- New Chemistry Around Us: *Phenylalanine and Diet Foods*
- New Ask an Expert: *Are Certain Foods Better for the Brain?*
- 20% new Exercises

Chapter 15:

- New Case Study
- New Case Study Follow-up
- New photography
- 20% new Exercises

Features

Each chapter has features especially designed to help students study effectively, as well as organize, understand, and enjoy the material in the course.

Case Studies. These scenarios introduce you the students, to diverse situations a health-care professional might encounter. The purpose of the case studies is to stimulate inquiry; for that reason, we've placed them at the beginning of each chapter of the book. Vocabulary and scenarios may be unfamiliar to you who are studying these course materials, but our intent is to raise questions, and pique your curiosity. Medicine has long been described as an art. The questions raised by these case studies rarely have a single correct answer. With the knowledge that you gain from this text and your future training, acceptable answers to the questions raised in our scenarios will become apparent. A Case Study Follow-up to each Case Study can be found at the end of each chapter before the Concept Summary.

Case Study

Raju, a 15-year-old high-school student, was small for his age. Perhaps he took after his mother, who was quite petite. In the middle of his school year, Raju began having severe headaches, feeling them mostly behind his eyes. Over-the-counter remedies didn't seem to help much. Raju's mother had suffered from migraine headaches for some time. His doctor was inclined to diagnose migraine disorder, but Raju's symptoms didn't seem to completely support that diagnosis. Motivated by intuition, the doctor ordered an MRI scan. An MRI scan produces clear images of soft tissues such as the brain. Raju's scan revealed a golf ball–sized tumor impinging on the pituitary gland, located close to the hypothalamus, at the base of the brain. The tumor was likely the cause of Raju's growth issues as well as the headaches, because the pituitary gland regulates hormones related to growth. Fortunately, Raju's tumor was operable. He is now leading a normal life and annual MRI tests have shown no recurrence of the tumor.

How does an MRI scan work? What element in the body does an MRI scan detect? How important is it for health professionals to consider unlikely explanations for seemingly straightforward symptoms?

Chapter Outlines and Learning Objectives. At the beginning of each chapter, a list of learning objectives provides students with a convenient overview of what they should gain by studying the chapter. In order to help students navigate through each chapter and focus on key concepts, these objectives are repeated at the beginning of the section in which the applicable information is discussed. The objectives are referred to again in the concept summary at the end of each chapter along with one or two suggested end-of-chapter exercises. By working the suggested exercises, students get a quick indication of how well they have met the stated learning objectives. Thus, students begin each chapter with a set of objectives and end with an indication of how well they satisfied the objectives.

Key Terms. Identified within the text by the use of bold type, key terms are defined in the margin near the place where they are introduced. Students reviewing a chapter can quickly identify the important concepts on each page with this marginal glossary. A full glossary of key terms and concepts appears at the end of the text.

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At the Counter. These boxed features contain useful information about health-related products that are readily available to consumers with or without a prescription. The information in each box provides a connection between the chemical behavior of the product and its effect on the body.

AT THE COUNTER 2.1

Smoking: It's Quitting Time

Smoking is a difficult habit to break, especially if the attempt is made by stopping abruptly—going "cold turkey." Mark Twain described the more reasonable gradual approach when he said, "Habit is habit, and not to be flung out of the window by any man, but coaxed downstairs a step at a time." Smokers do not have to go "cold turkey" because there are several OTC aids available, as well as some new prescription products to help them gradually overcome the strong urge to smoke—and eventually quit.

The transdermal (absorbed through the skin) nicotine patch is available over the counter in doses of 7–22 mg. When used as

The Nicotrol nicotine inhalation system has also received FDA approval. This inhaler, available only by prescription, consists of a plastic cylinder about the size of a cigarette that encloses a cartridge containing nicotine. When a smoker "puffs" on the device, nicotine vapors are absorbed through the lining of the mouth and throat. It takes about 80 puffs to deliver the amount of nicotine obtained from a single cigarette. An advantage of using the system is that a smoker still mimics the hand-to-mouth behavior of smoking, a part of the smoking habit that will be easier to break once nicotine withdrawal symptoms subside.

One of the newest prescription products designed to help break the smoking habit does not contain any nicotine. It is an antidepressant called bupropion that has been shown to be ef-

Chemistry Around Us. These boxed features present everyday applications of chemistry that emphasize in a real way the important role of chemistry in our lives. Forty percent of these are new to this edition and emphasize health-related applications of chemistry.

Chemistry and Your Health. These boxed features contain current chemistry-related health issues such as "The Importance of Color in Your Diet," and questions about topics such as safety concerns surrounding genetically modified foods and the relationship between C-reactive protein and heart disease.

CHEMISTRY AND YOUR HEALTH 10.1

Is Irradiated Food Safe?

In 1993, four deaths and hundreds of illnesses were linked to the eating of undercooked ground beef that was contaminated with *E. coli* bacteria. In 1997 the largest recall of meat products in U.S. history up to that time took place when a producer voluntarily recalled 25 million pounds of ground beef suspected of being contaminated with the same type of bacteria. In 2002, a new meat product recall record was established when 27.4 million pounds of poultry products was recalled because of possible contamination by *Listeria*, a potentially deadly type of bacteria.

purchase and use them. Some irradiated foods are used unintentionally as a result of the labeling rules. For example, irradiated spices or fresh strawberries sold in a grocery store must have labels that indicate they have been irradiated. However, when such irradiated foods are used as ingredients in other foods, the other foods are not required to have irradiation labels. Also, irradiation labeling does not apply to foods served in restaurants.

Two factors that currently contribute to low consumer acceptance of irradiated food are continuing misconceptions about the effects of radiation on food and the low availability of irradiated foods for sale. Some misconceptions that are difficult to eliminate despite reassuring results from

Ask an Expert. Boxes written by Dr. Melina B. Jampolis engage students by presenting questions and answers about nutrition and health, as related to chemistry, that are relevant and important in today's world.

DR. MELINA B. JAMPOLIS, M.D.

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Dr. Melina B. Jampolis, M.D. is a Los Angeles, California, Physician Nutrition Specialist—a specialty

Ask an Expert 1.1

Q: Does food density matter when you're trying to lose weight?

A: When it comes to losing weight, it seems like there is a new fad diet out every month. Low fat, low carb, high protein, vegan, vegetarian low carb—the choices are endless. What really works for weight loss? The answer varies among individuals and likely depends on a combination of genes, food preferences, and lifestyle. But one of the most important concepts for achieving permanent weight loss is the energy density of the food you consume. Energy density refers to the number of calories per gram in a given type of food. Eating foods that have a lower energy density allows you to eat larger, more satisfying, portions while consuming fewer calories. Research has shown that this is important both mentally and physically when it comes to weight

Examples. To reinforce students in their problem-solving skill development, complete step-by-step solutions for numerous examples are included in each chapter.

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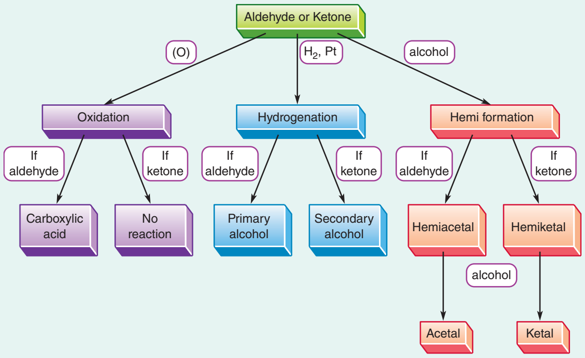
Learning Checks. Short self-check exercises follow examples and discussions of key or difficult concepts. A complete set of solutions is included in Appendix C. These allow students to measure immediately their understanding and progress.

Study Skills. Most chapters contain a *Study Skills* feature in which a challenging topic, skill, or concept of the chapter is addressed. Study suggestions, analogies, and approaches are provided to help students master these ideas.

Study Skills 4.1

A Reaction Map for Aldehydes and Ketones

This reaction map is designed to help you master organic reactions. Whenever you are trying to complete an organic reaction, use these two basic steps: (1) Identify the functional group that is to react, and (2) identify the reagent that is to react with the functional group. If the reacting functional group is an aldehyde or a ketone, find the reagent in the summary diagram, and use the diagram to predict the correct products.



How Reactions Occur. The mechanisms of representative organic reactions are presented in four boxed inserts to help students dispel the mystery of how these reactions take place.

Concept Summary. Located at the end of each chapter, this feature provides a concise review of the concepts and includes suggested exercises to check achievement of the learning objectives related to the concepts.

Concept Summary

Symbols and Formulas

Symbols based on names have been assigned to every element. Most consist of a single capital letter followed by a lowercase letter. A few consist of a single capital letter. Compounds are represented by formulas made up of elemental symbols. The number of atoms of each element in a molecule is shown by subscripts.

Objective 1, Exercise 2.4

Relative Masses of Atoms and Molecules

Relative masses called atomic weights have been assigned to each element and are tabulated in the periodic table. The units used are atomic mass units, abbreviated u. Relative masses for molecules, called molecular weights, are determined by adding the atomic weights of the atoms making up the molecules.

Objective 4, Exercise 2.32

Inside the Atom

Atoms are made up of numerous smaller particles of which the most important to chemical studies are the proton, neutron, and electron. Positively charged protons and neutral neutrons have a relative mass of 1 u each and

Isotopes and Atomic Weights

The atomic weights measured for elements are average weights that depend on the percentages and masses of the isotopes in the naturally occurring element. If the isotope percent abundances and isotope masses are known for an

Key Terms and Concepts. These are listed at the end of the chapter for easy review, with a reference to the chapter section in which they are presented.

Key Equations. This feature provides a useful summary of general equations and reactions from the chapter. This feature is particularly helpful to students in the organic chemistry chapters.

Exercises. Nearly 1,700 end-of-chapter exercises are arranged by section. Approximately half of the exercises are answered in the back of the text. Complete solutions to these answered exercises are included in the Student Study Guide. Solutions and answers

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to the remaining exercises are provided in the Instructor's Manual. We have included a significant number of clinical and other familiar applications of chemistry in the exercises.

Allied Health Exam Connection. These examples of chemistry questions from typical entrance exams used to screen applicants to allied health professional programs help students focus their attention on the type of chemical concepts considered important in such programs.

Chemistry for Thought. Included at the end of each chapter are special questions designed to encourage students to expand their reasoning skills. Some of these exercises are based on photographs found in the chapter, while others emphasize clinical or other useful applications of chemistry.

Possible Course Outlines

This text may be used effectively in either a two-semester or three-quarter course of study:

First semester: Chapters 1–13 (general chemistry and three chapters of organic chemistry)

Second semester: Chapters 14–25 (organic chemistry and biochemistry)

First semester: Chapters 1–10 (general chemistry)

Second semester: Chapters 11–21 (organic chemistry and some biochemistry)

First quarter: Chapters 1–10 (general chemistry)

Second quarter: Chapters 11–18 (organic chemistry)

Third quarter: Chapters 19–25 (biochemistry)

Supporting Materials

Please visit **www.cengage.com/chemistry/seager/gob8e** for information about student and instructor resources for this text.

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Organic and Biochemistry for Today

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1 Organic Compounds: Alkanes

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Case Study

Christi was at the end of her rope—she felt as if she had tried everything. Her daughter Mellissa was 4 years old, would start kindergarten in less than a year, and still wasn't able to control bowel movements. Nearly every day, Mellissa soiled her pants. Christi tried rewarding her with candy and even resorted to spanking, and the condescending advice of her mother-in-law didn't help. Mellissa would urinate in the toilet, but she seemed too busy playing or too stubborn to use it for anything else. Finally, in desperation and embarrassment, Christi consulted a pediatrician. He quickly diagnosed Mellissa with encopresis due to constipation. The doctor assured Christi it was neither poor parenting on her part nor bad behavior from her daughter that was causing the problem, but a medical condition. In addition to dietary changes, the doctor prescribed laxatives and 3 tablespoons of mineral oil daily. Mellissa disliked the mineral oil.

What behavioral techniques could Christi use to encourage her daughter to cooperate with the treatment? Should she punish Mellissa if she has an "accident"?

Follow-up to this Case Study appears at the end the chapter before the Concept Summary.

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Learning Objectives

When you have completed your study of this chapter, you should be able to:

1. Show that you understand the general importance of organic chemical compounds. **(Section 1.1)**
2. Recognize the molecular formulas of organic and inorganic compounds. **(Section 1.1)**
3. Explain some general differences between inorganic and organic compounds. **(Section 1.2)**
4. Use structural formulas to identify compounds that are isomers of each other. **(Section 1.3)**
5. Write condensed or expanded structural formulas for compounds. **(Section 1.4)**
6. Classify alkanes as normal or branched. **(Section 1.5)**
7. Use structural formulas to determine whether compounds are structural isomers. **(Section 1.6)**
8. Assign IUPAC names and draw structural formulas for alkanes. **(Section 1.7)**
9. Assign IUPAC names and draw structural formulas for cycloalkanes. **(Section 1.8)**
10. Name and draw structural formulas for geometric isomers of cycloalkanes. **(Section 1.9)**
11. Describe the key physical properties of alkanes. **(Section 1.10)**
12. Write alkane combustion reactions. **(Section 1.11)**

The word *organic* is used in several different contexts. Scientists of the 18th and 19th centuries studied compounds extracted from plants and animals and labeled them "organic" because they had been obtained from organized (living) systems. Organic fertilizer is organic in the original sense that it comes from a living organism. There is no universal definition of organic foods, but the term is generally taken to mean foods grown without the application of pesticides or synthetic fertilizers. When referring to organic chemistry, however, we mean the chemistry of carbon-containing compounds.

1.1 Carbon: The Element of Organic Compounds

Learning Objectives

1. Show that you understand the general importance of organic chemical compounds.
2. Be able to recognize the molecular formulas of organic and inorganic compounds.

Early chemists thought organic compounds could be produced only through the action of a "vital force," a special force active only in living organisms. This idea was central to the study of organic chemistry until 1828, because up to that time, no one had been able to synthesize an organic compound from its elements or from naturally occurring

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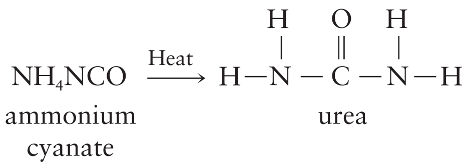
minerals. In that year, Friedrich Wöhler, a German chemist, heated an inorganic salt called ammonium cyanate and produced urea. This compound, normally found in blood and urine, was unquestionably organic, and it had come from an inorganic source. The reaction is



(1.1)

Wöhler's urea synthesis discredited the "vital force" theory, and his success prompted other chemists to attempt to synthesize organic compounds. Today, organic compounds are being synthesized in thousands of laboratories, and most of the synthetics have never been isolated from natural sources.

organic compound A compound that contains the element carbon.

organic chemistry The study of carbon-containing compounds.

inorganic chemistry The study of the elements and all noncarbon compounds.

Organic compounds share one unique feature: They all contain carbon. Therefore, **organic chemistry** is defined as the study of carbon-containing compounds. There are a few exceptions to this definition; a small number of carbon compounds—such as CO, CO_2, carbonates, and cyanides—were studied before Wöhler's urea synthesis. These were classified as inorganic because they were obtained from nonliving systems, and even though they contain carbon, we still consider them to be a part of **inorganic chemistry.**

The importance of carbon compounds to life on Earth cannot be overemphasized. If all carbon compounds were removed from Earth, its surface would be somewhat like the barren surface of the moon (see Figure 1.1). There would be no animals, plants, or any other form of life. If carbon-containing compounds were removed from the human body, all that would remain would be water, a very brittle skeleton, and a small residue of minerals. Many of the essential constituents of living matter—such as carbohydrates, fats, proteins, nucleic acids, enzymes, and hormones—are organic chemicals.

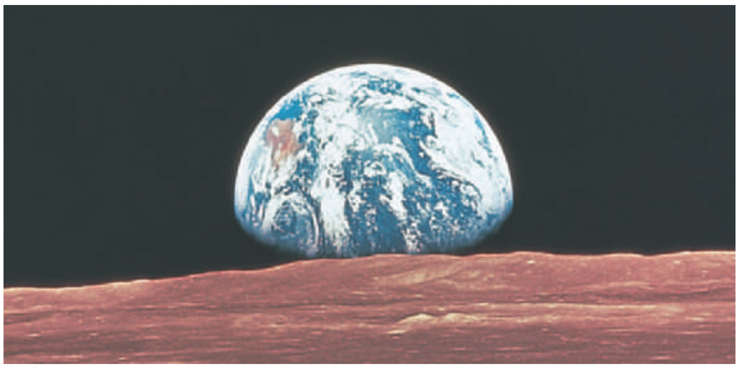


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Figure 1.1 Organic chemistry makes a tremendous difference when comparing the physical makeup of the Earth and the moon.

The essential needs of daily human life are food, fuel, shelter, and clothing. The principal components of food (with the exception of water) are organic. The fuels we use (e.g., wood, coal, petroleum, and natural gas) are mixtures of organic compounds. Our homes typically incorporate wood construction, and our clothing, whether made of natural or synthetic fibers, is organic.

Besides the major essentials, many of the smaller everyday things often taken for granted are also derived from carbon and its compounds. Consider an ordinary pencil. The "lead" (actually graphite), the wood, the rubber eraser, and the paint on the surface are all either carbon or carbon compounds. The paper in this book, the ink on its pages, and the glue holding it all together are also made of carbon compounds.

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1.2 Organic and Inorganic Compounds Compared

Learning Objective

3. Explain some general differences between inorganic and organic compounds.

It is interesting that the subdivision of chemistry into its organic and inorganic branches results in one branch that deals with compounds composed mainly of one element and another branch that deals with compounds formed by the more than 100 remaining elements. However, this classification seems more reasonable when we recognize that known organic compounds are much more numerous than inorganic compounds. An estimated 500,000 inorganic compounds have been identified, but more than 9 million organic compounds are known, and thousands of new ones are synthesized or isolated each year.

One of the reasons for the large number of organic compounds is the unique ability of carbon atoms to form stable covalent bonds with other carbon atoms and with atoms of other elements. The resulting covalently bonded molecules may contain as few as one or more than a million carbon atoms.

In contrast, inorganic compounds are often characterized by the presence of ionic bonding. Covalent bonding also may be present, but it is less common. These differences generally cause organic and inorganic compounds to differ physically (see Figure 1.2) and chemically, as shown in Table 1.1.

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Figure 1.2 Many organic compounds, such as ski wax, have relatively low melting points. What does this fact reveal about the forces between organic molecules?

TABLE 1.1 Properties of Typical Organic and Inorganic Compounds

Property	Organic Compounds	Inorganic Compounds
Bonding within molecules	Covalent	Often ionic
Forces between molecules	Generally weak	Quite strong
Normal physical state	Gases, liquids, or low-melting-point solids	Usually high-melting-point solids
Flammability	Often flammable	Usually nonflammable
Solubility in water	Often low	Often high
Conductivity of water solutions	Nonconductor	Conductor
Rate of chemical reactions	Usually slow	Usually fast

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Study Skills 1.1

Changing Gears for Organic Chemistry

You will find that organic chemistry is very different from general or inorganic chemistry. By quickly picking up on the changes, you will help yourself prepare for quizzes and exams.

There is almost no math in these next five chapters or in the biochemistry section. Very few mathematical formulas need to be memorized. The problems you will encounter fall mainly into four categories: naming compounds and drawing structures, describing physical properties of substances, writing reactions, and identifying typical uses of compounds. This pattern holds true for all six of the organic chemistry chapters.

The naming of compounds is introduced in this chapter, and the rules developed here will serve as a starting point in the next five chapters. Therefore, it is important to master naming in this chapter. A well-developed skill in naming will help you do well on exams covering the coming chapters.

Only a few reactions are introduced in this chapter, but many more will be in future chapters. Writing organic reactions is just as important (and challenging) as naming structures, and Study Skills 2.1 will help you learn this skill. Identifying the uses of compounds can best be handled by making a list as you read the chapter or by highlighting compounds and their uses so that they are easy to review. All four categories of problems are covered by numerous end-of-chapter exercises to give you practice.

LEARNING CHECK 1.1 Classify each of the following compounds as organic or inorganic:

a. NaCl
b. CH_4
c. C_6H_6
d. NaOH
e. CH_3OH
f. $Mg(NO_3)_2$

LEARNING CHECK 1.2 Decide whether each of the following characteristics most likely describes an organic or inorganic compound:

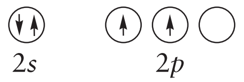
a. Flammable **b.** Low boiling point **c.** Soluble in water

1.3 Bonding Characteristics and Isomerism

Learning Objective

4. Be able to use structural formulas to identify compounds that are isomers of each other.

There are two major reasons for the astonishing number of organic compounds: the bonding characteristics of carbon atoms, and the isomerism of carbon-containing molecules. As a group IVA(14) element, a carbon atom has four valence electrons. Two of these outermost-shell electrons are in an *s* orbital, and two are in *p* orbitals:



With only two unpaired electrons, we might predict that carbon would form just two covalent bonds with other atoms. Yet, we know from the formula of methane (CH_4) that carbon forms four bonds.

Linus Pauling (1901–1994), winner of the Nobel Prize in chemistry (1954) and Nobel Peace Prize (1963), developed a useful model to explain the bonding characteristics of carbon. Pauling found that a mathematical mixing of the 2*s* and three 2*p* orbitals could produce four new, equivalent orbitals (see Figure 1.3). Each of these **hybrid orbitals** has the same energy and is designated sp^3. An sp^3 orbital has a two-lobed shape, similar to the

hybrid orbital An orbital produced from the combination of two or more nonequivalent orbitals of an atom.

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shape of a *p* orbital but with different-sized lobes (see Figure 1.4). Each of the four sp^3 hybrid orbitals contains a single unpaired electron available for covalent bond formation. Thus, carbon forms four bonds.

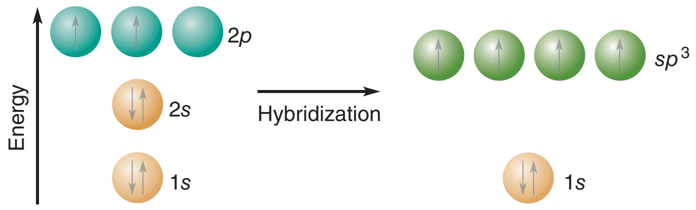

Figure 1.3 The mixing of 2*s* and three 2*p* orbitals of a carbon atom to generate four sp^3 carbon orbitals, each with energy intermediate between 2*s* and 2*p* orbitals.

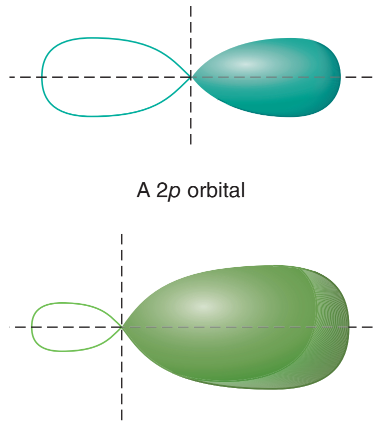

Figure 1.4 A comparison of unhybridized *p* and sp^3 hybridized orbital shapes. The atomic nucleus is at the junction of the lobes in each case.

Each carbon–hydrogen bond in methane arises from an overlap of a C (sp^3) and an H (1*s*) orbital. The sharing of two electrons in this overlap region creates a sigma (σ) bond. The four equivalent sp^3 orbitals point toward the corners of a regular tetrahedron (see Figure 1.5).

Carbon atoms also have the ability to bond covalently to other carbon atoms to form chains and networks. This means that two carbon atoms can join by sharing two electrons to form a single covalent bond:

$$\cdot\dot{\underset{\cdot}{C}}\cdot + \cdot\dot{\underset{\cdot}{C}}\cdot \longrightarrow \cdot\dot{\underset{\cdot}{C}}:\dot{\underset{\cdot}{C}}\cdot \qquad \text{or} \qquad \cdot\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}\cdot \tag{1.2}$$

A third carbon atom can join the end of this chain:

$$\cdot\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}\cdot + \cdot\dot{\underset{\cdot}{C}}\cdot \longrightarrow \cdot\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}\cdot \tag{1.3}$$

This process can continue and form carbon chains of almost any length, such as

$$\cdot\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}-\dot{\underset{\cdot}{C}}\cdot$$

The electrons not involved in forming the chain can be shared with electrons of other carbon atoms (to form chain branches) or with electrons of other elements such as hydrogen, oxygen, or nitrogen. Carbon atoms may also share more than one pair of electrons to form multiple bonds:

$$\cdot\dot{\underset{\cdot}{C}}-\dot{C}=\dot{C}-\dot{\underset{\cdot}{C}}\cdot \qquad \cdot\dot{\underset{\cdot}{C}}-C\equiv C-\dot{\underset{\cdot}{C}}\cdot$$

Chain with double bond   Chain with triple bond

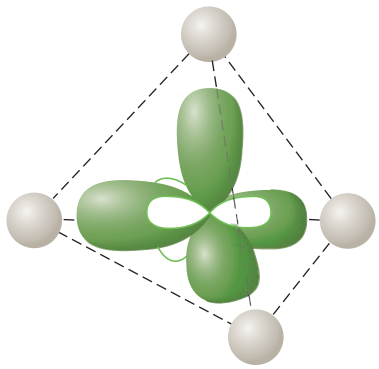

Figure 1.5 Directional characteristics of sp^3 hybrid orbitals of carbon and the formation of C—H bonds in methane (CH_4). The hybrid orbitals point toward the corners of a regular tetrahedron. Hydrogen 1*s* orbitals are illustrated in position to form bonds by overlap with the major lobes of the hybrid orbitals.

In principle, there is no limit to the number of carbon atoms that can bond covalently. Thus, organic molecules range from the simple molecules such as methane (CH_4) to very complicated molecules containing over a million carbon atoms.

The variety of possible carbon atom arrangements is even more important than the size range of the resulting molecules. The carbon atoms in all but the very simplest organic molecules can bond in more than one arrangement, giving rise to different compounds with different structures and properties. This property, called **isomerism,** is characterized by compounds that have identical molecular formulas but different arrangements of atoms. One type of isomerism is characterized by compounds called **structural isomers.** Another type of isomerism is introduced in Section 1.9.

isomerism A property in which two or more compounds have the same molecular formula but different arrangements of atoms.

structural isomers Compounds that have the same molecular formula but in which the atoms bond in different patterns.

Example 1.1

Use the usual rules for covalent bonding to show that a compound with the molecular formula C_2H_6O demonstrates the property of isomerism. Draw formulas for the isomers, showing all covalent bonds.

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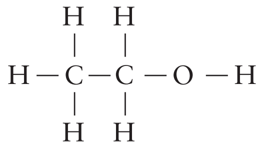
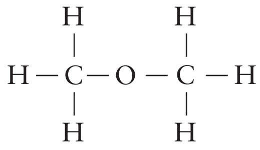
Solution

Carbon forms four covalent bonds by sharing its four valence-shell electrons. Similarly, oxygen should form two covalent bonds, and hydrogen a single bond. On the basis of these bonding relationships, two structural isomers are possible:

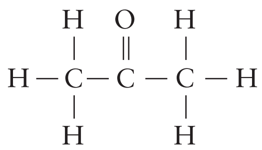


ethyl alcohol

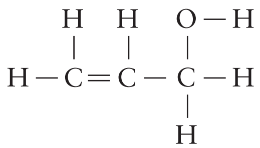


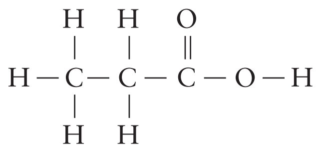
dimethyl ether

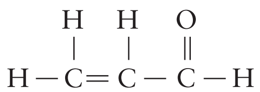
LEARNING CHECK 1.3 Which one of the structures below represents a structural isomer of



?

a. 

c. 

b. 

The two isomers of Example 1.1 are quite different. Ethyl alcohol (grain alcohol) is a liquid at room temperature, whereas dimethyl ether is a gas. As we've seen before, the structural differences exert a significant influence on properties. From this example, we can see that molecular formulas such as C_2H_6O provide much less information about a compound than do structural formulas. Figure 1.6 shows ball-and-stick models of these two molecules.

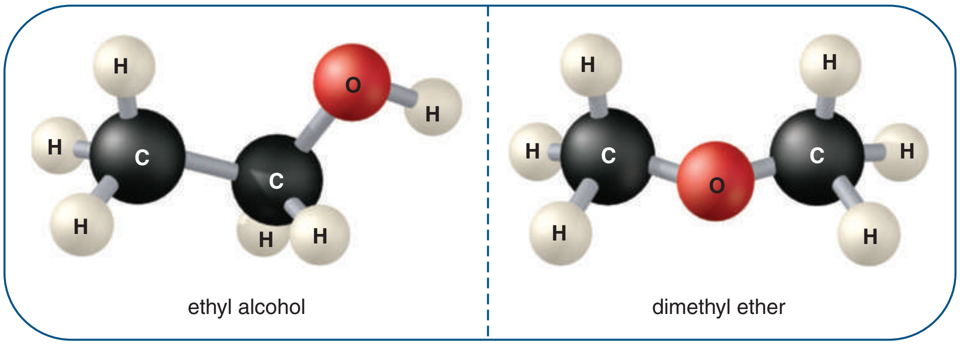


Figure 1.6 Ball-and-stick models of the isomers of C_2H_6O. Ethyl alcohol is a liquid at room temperature and completely soluble in water, whereas dimethyl ether is a gas at room temperature and only partially soluble in water.

As the number of carbon atoms in the molecular formula increases, the number of possible isomers increases dramatically. For example, 366,319 different isomers are possible for a molecular formula of $C_{20}H_{42}$. No one has prepared all these isomers or even drawn their structural formulas, but the number helps us understand why so many organic compounds have been either isolated from natural sources or synthesized.

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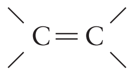
1.4 Functional Groups: The Organization of Organic Chemistry

Learning Objective

5. Write condensed or expanded structural formulas for compounds.

Because of the enormous number of possible compounds, the study of organic chemistry might appear to be hopelessly difficult. However, the arrangement of organic compounds into a relatively small number of classes can simplify the study a great deal. This organization is done on the basis of characteristic structural features called **functional groups.** For example, compounds with a carbon–carbon double bond



are classified as alkenes. The major classes and functional groups are given in Table 1.2. Notice that each functional group in Table 1.2 (except for alkanes) contains a multiple bond or at least one oxygen or nitrogen atom.

functional group A unique reactive combination of atoms that differentiates molecules of organic compounds of one class from those of another.

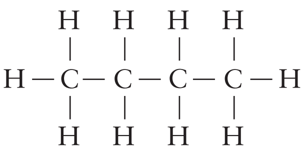
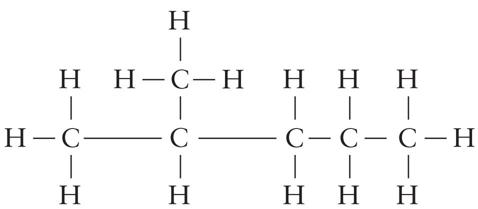
In Table 1.2, we have used both expanded and condensed structural formulas for the compounds. **Expanded structural formulas** show all covalent bonds, whereas **condensed structural formulas** show only specific bonds. You should become familiar with both types, but especially with condensed formulas because they will be used often.

expanded structural formula A structural molecular formula showing all the covalent bonds.

condensed structural formula A structural molecular formula showing the general arrangement of atoms but without showing all the covalent bonds.

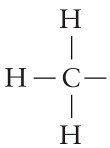
Example 1.2

Write a condensed structural formula for each of the following compounds:

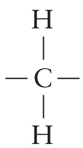
a.  **b.** 

Solution

a. Usually the hydrogens belonging to a carbon are grouped to the right. Thus, the group



condenses to CH_3—, and



condenses to —CH_2—. Thus, the formula condenses to

$$CH_3—CH_2—CH_2—CH_3$$

Other acceptable condensations are

$$CH_3CH_2CH_2CH_3 \qquad \text{and} \qquad CH_3(CH_2)_2CH_3$$

Parentheses are used here to denote a series of two —CH_2— groups.

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