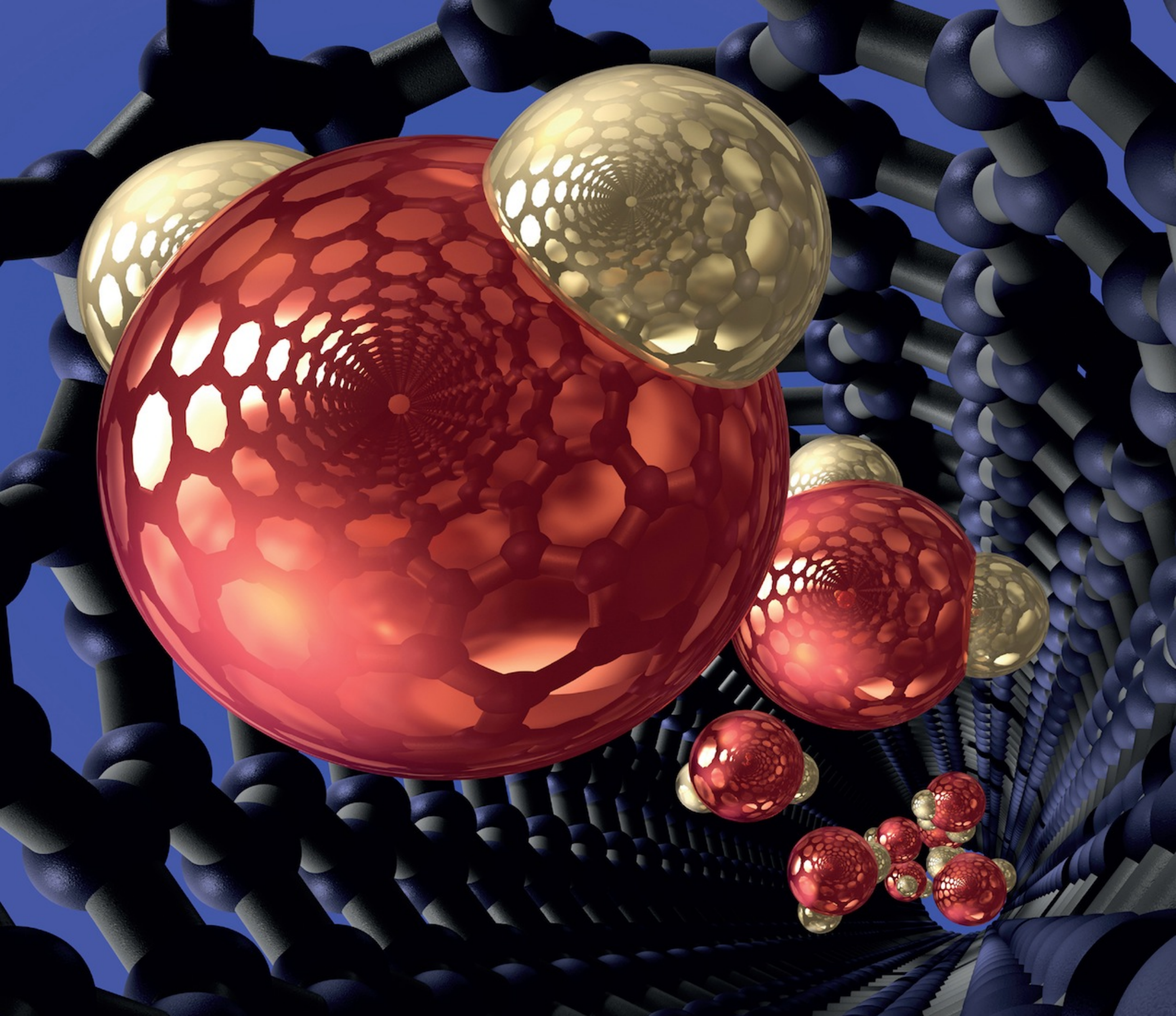

CHEMISTRY

13e

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Raymond Chang | Jason Overby

11
Na
Sodium
22.99

- 11 — Atomic number
- 22.99 — Atomic mass

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
🟦 1 **H** Hydrogen 1.008																	🟦 2 **He** Helium 4.003
🟩 3 **Li** Lithium 6.941	🟩 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
🟩 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 32.07	🟦 17 **Cl** Chlorine 35.45	🟦 18 **Ar** Argon 39.95
🟩 19 **K** Potassium 39.10	🟩 20 **Ca** Calcium 40.08	🟩 21 **Sc** Scandium 44.96	🟩 22 **Ti** Titanium 47.88	🟩 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 65.39	🟩 31 **Ga** Gallium 69.72	🟪 32 **Ge** Germanium 72.59	🟪 33 **As** Arsenic 74.92	🟦 34 **Se** Selenium 78.96	🟦 35 **Br** Bromine 79.90	🟦 36 **Kr** Krypton 83.80
🟩 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 95.94	🟩 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
🟩 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 183.9	🟩 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 (210)	🟪 85 **At** Astatine (210)	🟦 86 **Rn** Radon (222)
🟩 87 **Fr** Francium (223)	🟩 88 **Ra** Radium (226)	🟩 89 **Ac** Actinium (227)	🟩 104 **Rf** Rutherfordium (257)	🟩 105 **Db** Dubnium (260)	🟩 106 **Sg** Seaborgium (263)	🟩 107 **Bh** Bohrium (262)	🟩 108 **Hs** Hassium (265)	🟩 109 **Mt** Meitnerium (266)	🟩 110 **Ds** Darmstadtium (269)	🟩 111 **Rg** Roentgenium (272)	🟩 112 **Cn** Copernicium (285)	🟩 113 **Nh** Nihonium (286)	🟩 114 **Fl** Flerovium (289)	🟩 115 **Mc** Moscovium (290)	🟪 116 **Lv** Livermorium (293)	🟪 117 **Ts** Tennessine (294)	🟦 118 **Og** Oganesson (294)

🟩 58 **Ce** Cerium 140.1	🟩 59 **Pr** Praseodymium 140.9	🟩 60 **Nd** Neodymium 144.2	🟩 61 **Pm** Promethium (147)	🟩 62 **Sm** Samarium 150.4	🟩 63 **Eu** Europium 152.0	🟩 64 **Gd** Gadolinium 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
🟩 90 **Th** Thorium 232.0	🟩 91 **Pa** Protactinium (231)	🟩 92 **U** Uranium 238.0	🟩 93 **Np** Neptunium (237)	🟩 94 **Pu** Plutonium (242)	🟩 95 **Am** Americium (243)	🟩 96 **Cm** Curium (247)	🟩 97 **Bk** Berkelium (247)	🟩 98 **Cf** Californium (249)	🟩 99 **Es** Einsteinium (254)	🟩 100 **Fm** Fermium (253)	🟩 101 **Md** Mendelevium (256)	🟩 102 **No** Nobelium (254)	🟩 103 **Lr** Lawrencium (257)

🟩 Metals

🟪 Metalloids

🟦 Nonmetals

The 1–18 group designation has been recommended by the International Union of Pure and Applied Chemistry (IUPAC) but is not yet in wide use. In this text we use the standard U.S. notation for group numbers (1A–8A and 1B–8B). In 2011 IUPAC revised the atomic masses of some elements. The changes are minor and they are not adopted in the present edition of this text.

The Elements with Their Symbols and Atomic Masses*

Element	Symbol	Atomic Number	Atomic Mass†
Actinium	Ac	89	(227)
Aluminum	Al	13	26.98
Americium	Am	95	(243)
Antimony	Sb	51	121.8
Argon	Ar	18	39.95
Arsenic	As	33	74.92
Astatine	At	85	(210)
Barium	Ba	56	137.3
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.012
Bismuth	Bi	83	209.0
Bohrium	Bh	107	(262)
Boron	B	5	10.81
Bromine	Br	35	79.90
Cadmium	Cd	48	112.4
Calcium	Ca	20	40.08
Californium	Cf	98	(249)
Carbon	C	6	12.01
Cerium	Ce	58	140.1
Cesium	Cs	55	132.9
Chlorine	Cl	17	35.45
Chromium	Cr	24	52.00
Cobalt	Co	27	58.93
Copernicium	Cn	112	(285)
Copper	Cu	29	63.55
Curium	Cm	96	(247)
Darmstadtium	Ds	110	(269)
Dubnium	Db	105	(260)
Dysprosium	Dy	66	162.5
Einsteinium	Es	99	(254)
Erbium	Er	68	167.3
Europium	Eu	63	152.0
Fermium	Fm	100	(253)
Flerovium	Fl	114	(289)
Fluorine	F	9	19.00
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.3
Gallium	Ga	31	69.72
Germanium	Ge	32	72.59
Gold	Au	79	197.0
Hafnium	Hf	72	178.5
Hassium	Hs	108	(265)
Helium	He	2	4.003
Holmium	Ho	67	164.9
Hydrogen	H	1	1.008
Indium	In	49	114.8
Iodine	I	53	126.9
Iridium	Ir	77	192.2
Iron	Fe	26	55.85
Krypton	Kr	36	83.80
Lanthanum	La	57	138.9
Lawrencium	Lr	103	(257)
Lead	Pb	82	207.2
Lithium	Li	3	6.941
Livermorium	Lv	116	(293)
Lutetium	Lu	71	175.0
Magnesium	Mg	12	24.31
Manganese	Mn	25	54.94
Meitnerium	Mt	109	(266)
Mendelevium	Md	101	(256)
Mercury	Hg	80	200.6
Molybdenum	Mo	42	95.94
Moscovium	Mc	115	(288)
Neodymium	Nd	60	144.2
Neon	Ne	10	20.18
Neptunium	Np	93	(237)
Nickel	Ni	28	58.69
Nihonium	Nh	113	(284)
Niobium	Nb	41	92.91
Nitrogen	N	7	14.01
Nobelium	No	102	(253)
Oganesson	Og	118	(294)
Osmium	Os	76	190.2
Oxygen	O	8	16.00
Palladium	Pd	46	106.4
Phosphorus	P	15	30.97
Platinum	Pt	78	195.1
Plutonium	Pu	94	(242)
Polonium	Po	84	(210)
Potassium	K	19	39.10
Praseodymium	Pr	59	140.9
Promethium	Pm	61	(147)
Protactinium	Pa	91	(231)
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.9
Roentgenium	Rg	111	(272)
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.1
Rutherfordium	Rf	104	(257)
Samarium	Sm	62	150.4
Scandium	Sc	21	44.96
Seaborgium	Sg	106	(263)
Selenium	Se	34	78.96
Silicon	Si	14	28.09
Silver	Ag	47	107.9
Sodium	Na	11	22.99
Strontium	Sr	38	87.62
Sulfur	S	16	32.07
Tantalum	Ta	73	180.9
Technetium	Tc	43	(99)
Tellurium	Te	52	127.6
Tennessine	Ts	117	(294)
Terbium	Tb	65	158.9
Thallium	Tl	81	204.4
Thorium	Th	90	232.0
Thulium	Tm	69	168.9
Tin	Sn	50	118.7
Titanium	Ti	22	47.88
Tungsten	W	74	183.9
Uranium	U	92	238.0
Vanadium	V	23	50.94
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.0
Yttrium	Y	39	88.91
Zinc	Zn	30	65.39
Zirconium	Zr	40	91.22

*All atomic masses have four significant figures. These values are recommended by the Committee on Teaching of Chemistry, International Union of Pure and Applied Chemistry.

†Approximate values of atomic masses for radioactive elements are given in parentheses.

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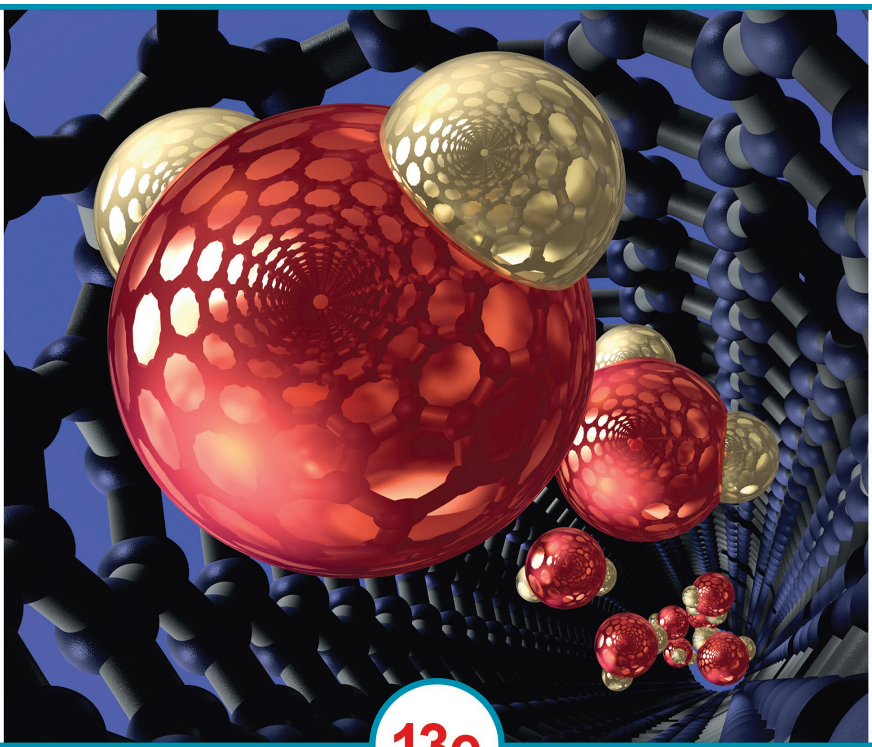

13e

Raymond Chang

Williams College

Jason Overby

College of Charleston

Mc Graw Hill Education

CHEMISTRY, THIRTEENTH EDITION

Published by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121.

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 21 20 19 18 17 18

ISBN 978-1-259-91115-6
MHID 1-259-91115-2

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Library of Congress Cataloging-in-Publication Data

Names: Chang, Raymond, author. | Overby, Jason, 1970- author.
Title: Chemistry.
Description: 13e [13th edition] / Raymond Chang, Williams College, Jason Overby, College of Charleston. | New York, NY : McGraw-Hill Education, [2019] | Includes index.
Identifiers: LCCN 2017038162| ISBN 9781259911156 (alk. paper) | ISBN 1259911152 (alk. paper)
Subjects: LCSH: Chemistry—Textbooks.
Classification: LCC QD31.3 .C38 2019 | DDC 540—dc23 LC record available at https://lccn.loc.gov/2017038162

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About the Authors

©Margaret Chang

Raymond Chang was born in Hong Kong and grew up in Shanghai and Hong Kong. He received his B.Sc. degree in chemistry from London University, and his Ph.D. in chemistry from Yale University. After doing postdoctoral research at Washington University and teaching for a year at Hunter College of the City University of New York, he joined the chemistry department at Williams College.

Professor Chang served on the American Chemical Society Examination Committee, the National Chemistry Olympiad Examination, and the Graduate Record Examination (GRE) Committee. He wrote books on physical chemistry, industrial chemistry, and physical science. He also coauthored books on the Chinese language, children's picture books, and a novel for young readers.

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Jason Overby was born in Bowling Green, Kentucky, and raised in Clarksville, Tennessee. He received his B.S. in chemistry and political science from the University of Tennessee at Martin. After obtaining his Ph.D. in inorganic chemistry from Vanderbilt University, Jason conducted postdoctoral research at Dartmouth College.

Since joining the Department of Chemistry and Biochemistry at the College of Charleston, South Carolina, Jason has taught a variety of courses ranging from general chemistry to advanced inorganic chemistry. He is also interested in the integration of technology into the classroom, with a particular focus on adaptive learning. Additionally, he conducts research with undergraduates in inorganic and organic synthetic chemistry as well as computational organometallic chemistry.

In his free time, he enjoys boating, bowling, and cooking. He is also involved with USA Swimming as a nationally certified starter and stroke-and-turn official. He lives in South Carolina with his wife Robin and two daughters, Emma and Sarah.

Contents in Brief

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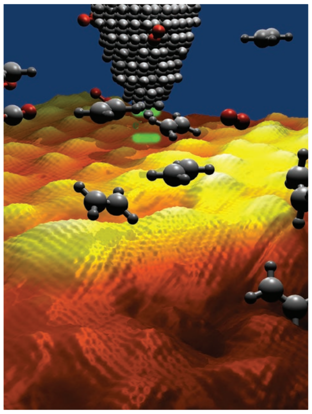

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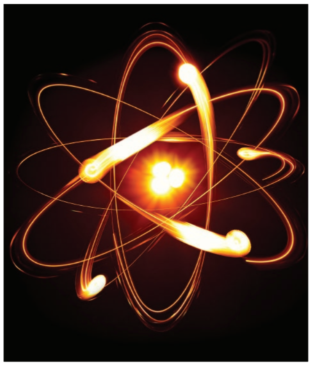

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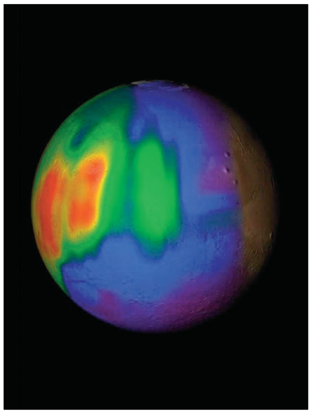

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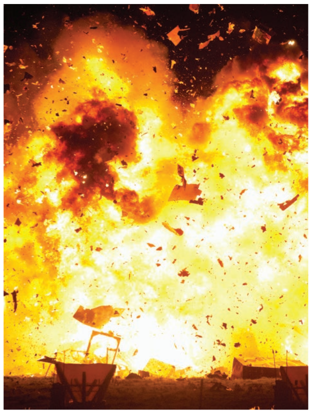

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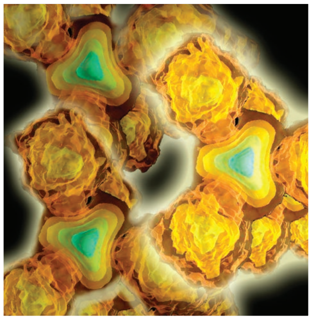

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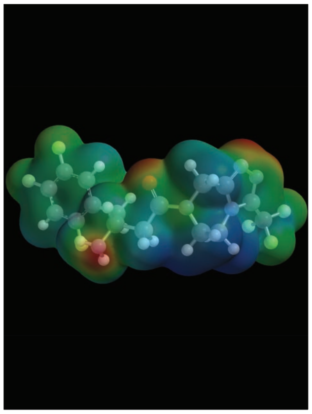

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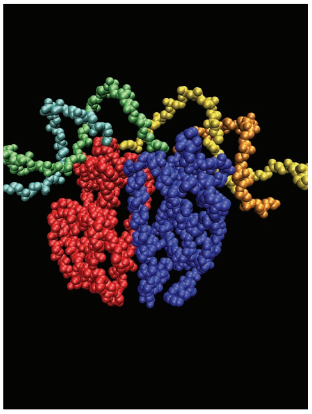

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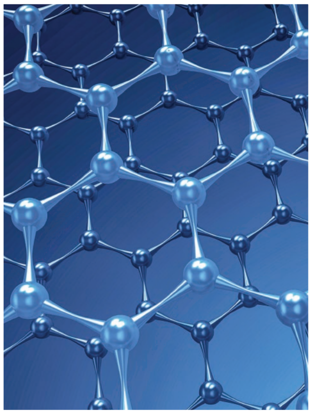

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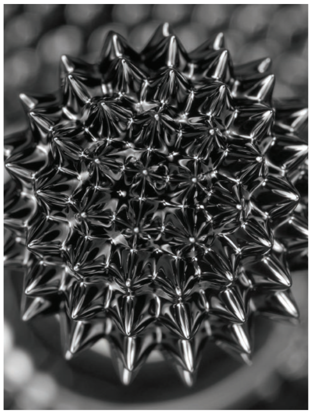

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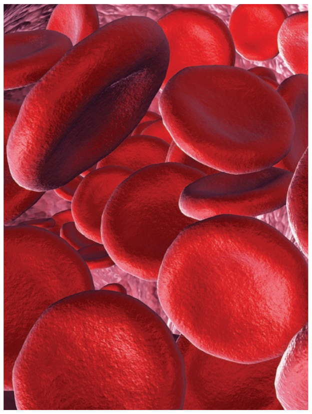

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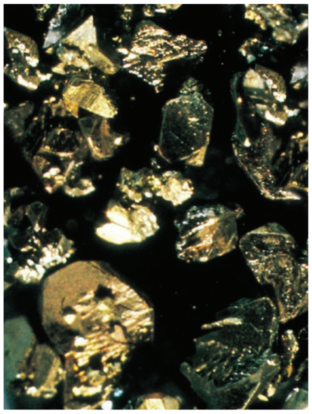

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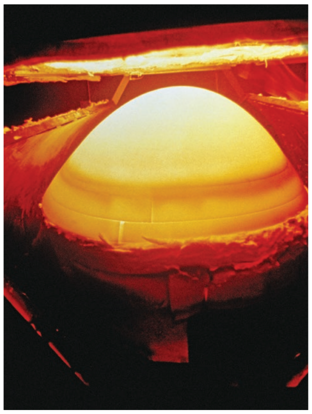

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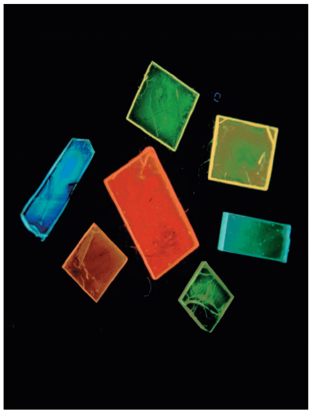

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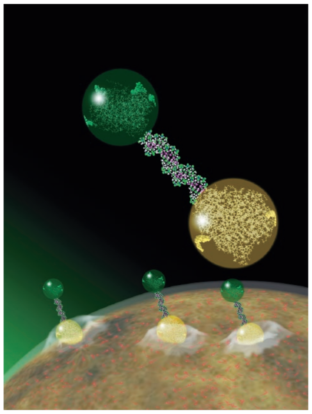

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Synthetic and Natural Organic Polymers 1054

List of Applications

The opening sentence of this text is, “Chemistry is an active, evolving science that has vital importance to our world, in both the realm of nature and the realm of society.” Throughout the text, Chemistry in Action boxes and Chemical Mysteries give specific examples of chemistry as active and evolving in all facets of our lives.

Chemistry in Action

Chemical Mystery

List of Videos

The videos below are correlated to ***Chemistry***. Within the chapter are icons letting the student and instructor know that a video is available for a specific topic. Videos can be found in the Connect ebook.

Absorption of Color (23.5)
Acid Ionization (15.5)
Acid-Base Titrations (16.4)
Activation Energy (13.4)
Alpha, Beta, and Gamma Rays (2.2)
α-Particle Scattering (2.2)
Aluminum Production (21.7)
Atomic and Ionic Radius (8.3)
Atomic Line Spectra (7.3)
Base Ionization (15.6)
Buffer Solutions (16.3)
Catalysis (13.6)
Cathode Ray Tube (2.2)
Chemical Equilibrium (14.1)
Chirality (23.4, 24.2)
Collecting a Gas over Water (5.6)
Cu/Zn Voltaic Cell (18.2)
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Diffusion of Gases (5.7)
Dissociation of Strong and Weak Acids (15.4)
Dissolution of an Ionic and a Covalent Compound (12.2)
Electron Configurations (7.8)
Emission Spectra (7.3)
Equilibrium Vapor Pressure (11.8)
Formation of a Covalent Bond (9.4)
Formation of Ag_2S by Oxidation-Reduction (4.4)
Formation of an Ionic Compound (2.7)
Galvanic Cells (18.2)
The Gas Laws (5.3)
Heat Flow (6.2)
Hybridization (10.4)
Hydration (4.1)
Influence of Shape on Polarity (10.2)
Ionic and Covalent Bonding (9.4)
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Le Châtelier's Principle (14.5)
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Millikan Oil Drop (2.2)
Molecular Shape and Orbital Hybridization (10.4)
Neutralization Reactions (4.3)
Nuclear Fission (19.5)
Operation of a Voltaic Cell (18.2)
Orientation of Collision (13.4)
Osmosis (12.6)
Oxidation-Reduction Reactions (4.4)
Packing Spheres (11.4)
Phase Diagrams and the States of Matter (11.9)
Polarity of Molecules (10.2)
Properties of Buffers (16.3)
Radioactive Decay (19.3)
Reaction of Cu with $AgNO_3$ (4.4)
Reaction of Magnesium and Oxygen (4.4, 9.2)
Resonance (9.8)
Rutherford's Experiment (2.2)
Sigma and Pi Bonds (10.5)
Strong Electrolytes, Weak Electrolytes, and Nonelectrolytes (4.1)
VSEPR Theory (10.1)
VSEPR (10.1)

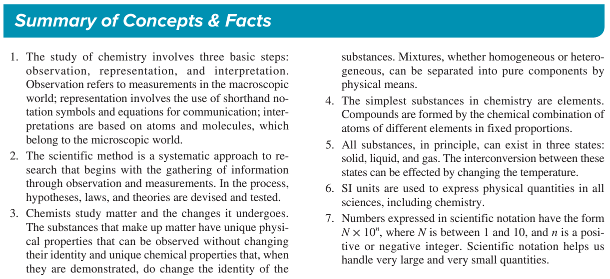
Preface

The thirteenth edition follows the long tradition of sustaining a firm foundation in the concepts of chemical principles and instilling an appreciation of the important role chemistry plays in our daily lives. We believe that it is our responsibility to help both instructors and students in their pursuit of this goal by presenting a broad range of chemical topics in a logical format. At all times, we strive to balance theory and application and to illustrate principles with applicable examples whenever possible.

As in previous editions, our goal is to create a test that clearly and concisely explains abstract concepts yet comprehensive enough that students are prepared to make the move forward in the chemistry curriculum. Encouraging feedback from instructors and students alike reaffirm that this approach is effective.

Review of Concepts and Facts

In previous editions, Review of Facts questions were provided throughout various sections of the book as a way for students to quickly gauge their understanding of a concept just presented. We have now expanded these checks to be a Review of Concepts and Facts provided at the end of most sections in a chapter. Over 170 new questions have been added to the Review of Concepts and Facts boxes ensuring students have ample opportunity to practice and review the major concepts and facts presented in that section. The answers to each of these questions are provided at the end of the chapter.

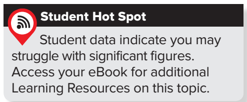


Summary of Concepts & Facts

1. The study of chemistry involves three basic steps: observation, representation, and interpretation. Observation refers to measurements in the macroscopic world; representation involves the use of shorthand notation symbols and equations for communication; interpretations are based on atoms and molecules, which belong to the microscopic world.
2. The scientific method is a systematic approach to research that begins with the gathering of information through observation and measurements. In the process, hypotheses, laws, and theories are devised and tested.
3. Chemists study matter and the changes it undergoes. The substances that make up matter have unique physical properties that can be observed without changing their identity and unique chemical properties that, when they are demonstrated, do change the identity of the substances. Mixtures, whether homogeneous or heterogeneous, can be separated into pure components by physical means.
4. The simplest substances in chemistry are elements. Compounds are formed by the chemical combination of atoms of different elements in fixed proportions.
5. All substances, in principle, can exist in three states: solid, liquid, and gas. The interconversion between these states can be effected by changing the temperature.
6. SI units are used to express physical quantities in all sciences, including chemistry.
7. Numbers expressed in scientific notation have the form $N \times 10^n$, where N is between 1 and 10, and n is a positive or negative integer. Scientific notation helps us handle very large and very small quantities.

Student Hot Spots

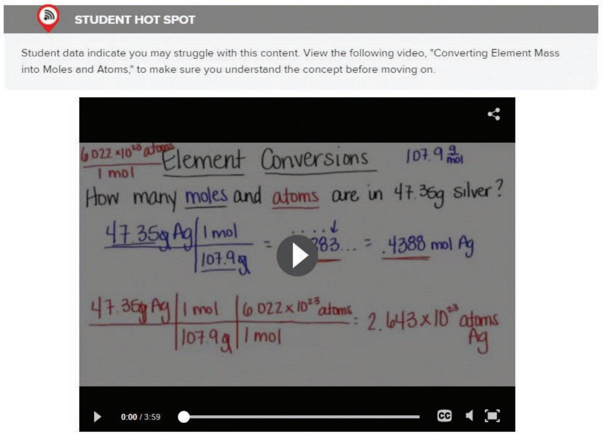
The adaptive reading tool SmartBook® now gives authors a detailed analysis of student performance on various learning objectives and concepts. With this powerful insight into the ideas and concepts students struggle with, we are now able to provide strategically-placed notifications about access to additional learning resources. Identified areas of particularly difficult content are now denoted with a margin note called "Student Hot Spots". These are intended to direct students to additional learning resources specific to that content. Students now have access to over 1,000 digital learning resources throughout the SmartBook® version of this text. Included in these learning resources are over 200 videos of chemistry faculty solving actual problems or explaining concepts.



Student Hot Spot

Student data indicate you may struggle with significant figures. Access your eBook for additional Learning Resources on this topic.

In the electronic version of this text, all the learning resources for the Student Hot Spots are readily available.



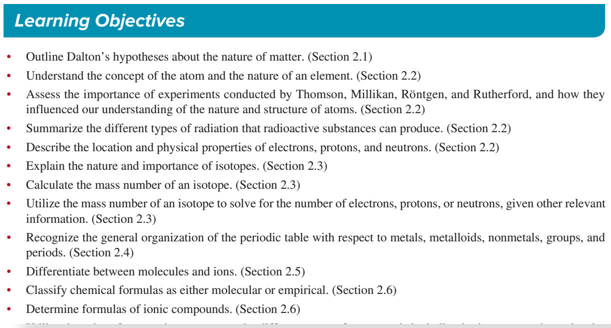
STUDENT HOT SPOT

Student data indicate you may struggle with this content. View the following video, "Converting Element Mass into Moles and Atoms," to make sure you understand the concept before moving on.

Further, access to student results has guided the editing of content in many chapters. While many of the changes are subtle, some are more comprehensive. The ability to edit based on real time assessment data from students is the new paradigm for textbook authoring. Undoubtedly this changes how we provide and enhance learning materials for our students in the future!

Learning Objectives

All chapters now have a comprehensive list of learning objectives provided to help facilitate instructors' assessment of their students. Every learning objective item is tagged by its location in the chapter. Further, each learning objective is written using only appropriate action verbs based on Bloom's taxonomy.



Learning Objectives

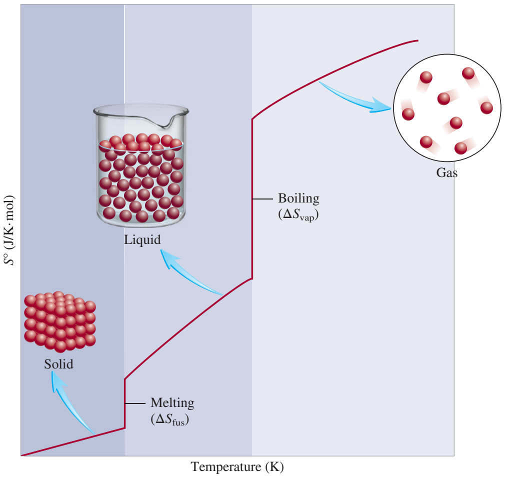
- Outline Dalton's hypotheses about the nature of matter. (Section 2.1)
- Understand the concept of the atom and the nature of an element. (Section 2.2)
- Assess the importance of experiments conducted by Thomson, Millikan, Röntgen, and Rutherford, and how they influenced our understanding of the nature and structure of atoms. (Section 2.2)
- Summarize the different types of radiation that radioactive substances can produce. (Section 2.2)
- Describe the location and physical properties of electrons, protons, and neutrons. (Section 2.2)
- Explain the nature and importance of isotopes. (Section 2.3)
- Calculate the mass number of an isotope. (Section 2.3)
- Utilize the mass number of an isotope to solve for the number of electrons, protons, or neutrons, given other relevant information. (Section 2.3)
- Recognize the general organization of the periodic table with respect to metals, metalloids, nonmetals, groups, and periods. (Section 2.4)
- Differentiate between molecules and ions. (Section 2.5)
- Classify chemical formulas as either molecular or empirical. (Section 2.6)
- Determine formulas of ionic compounds. (Section 2.6)

Questions and Problems

The Review Questions and Problems at the end of each chapter have been reorganized so that they fully correlate to a given section. In many cases, the heading for a group of questions was revised to reflect the title of a section. These changes should increase the ease with which students and instructors alike can identify appropriate questions and problems for practice or assignments.

Art Program and Design

For this edition, the art program was thoroughly revised to impart a more modern look and enhance visibility. Clear graphics are a vital component of the student learning process and as such, all graphs, periodic tables, and other figures have been updated with a new look and color scheme. In some instances, illustrations have been replaced with scientifically accurate photographs for enhanced chemical context. Many chapter opening photographs have been updated for new insights into various chemical topics and applications.



In addition to the more than 170 new Review of Concepts & Facts questions that have been added throughout the chapters, following are just a few of the highlights of the 13th edition content revision.

Chapter 1

- A revised discussion of the difference between intensive and extensive properties is provided.
- Table 1.3 has been expanded to include the common prefix peta-.
- A more detailed discussion of accuracy and precision has been included.

Chapter 3 The language concerning limiting reactants versus limiting reagents has been made consistent.

Chapter 7 A new worked example concerning quantum numbers has been included.

Chapters 2, 7, 8, 19, and 23 Figures and tables throughout have been updated to reflect the newest additions to the periodic table.

Problem Solving

The development of problem-solving skills has always been a major objective of this text. The two major categories of learning are shown next.

Worked examples follow a proven step-by-step strategy and solution.

- **Problem statement** is the reporting of the facts needed to solve the problem based on the question posed.
- **Strategy** is a carefully thought-out plan or method to serve as an important function of learning.
- **Solution** is the process of solving a problem given in a stepwise manner.
- **Check** enables the student to compare and verify with the source information to make sure the answer is reasonable.
- **Practice Exercise** provides the opportunity to solve a similar problem in order to become proficient in this problem type. The Practice Exercises are available in the Connect electronic homework system. The margin note lists additional similar problems to work in the end-of-chapter problem section.

End-of-Chapter Problems are organized in various ways. Each section under a topic heading begins with Review Questions followed by Problems. The Additional Problems section provides more problems not organized by section, followed by the problem type Interpreting, Modeling & Estimating.

Many of the examples and end-of-chapter problems present extra tidbits of knowledge and enable the student to solve a chemical problem that a chemist would solve. The examples and problems show students the real world of chemistry and applications to everyday life situations.

Visualization

Graphs and Flow Charts are important in science. In *Chemistry,* flow charts show the thought process of a concept and graphs present data to comprehend the concept. A significant number of Problems and Review of Concepts & Facts, including many new to this edition, include graphical data.

Molecular art appears in various formats to serve different needs. Molecular models help to visualize the three-dimensional arrangement of atoms in a molecule. Electrostatic potential maps illustrate the electron density distribution in molecules. Finally, there is the macroscopic to microscopic art helping students understand processes at the molecular level.

Photos are used to help students become familiar with chemicals and understand how chemical reactions appear in reality.

Figures of apparatus enable the student to visualize the practical arrangement in a chemistry laboratory.

Study Aids

Setting the Stage

Each chapter starts with the Chapter Outline and A Look Ahead.

Chapter Outline enables the student to see at a glance the big picture and focus on the main ideas of the chapter.

A Look Ahead provides the student with an overview of concepts that will be presented in the chapter.

Tools to Use for Studying

Useful aids for studying are plentiful in *Chemistry* and should be used constantly to reinforce the comprehension of chemical concepts.

Marginal Notes are used to provide hints and feedback to enhance the knowledge base for the student.

Worked Examples along with the accompanying Practice Exercises are very important tools for learning and mastering chemistry. The problem-solving steps guide the student through the critical thinking necessary for succeeding in chemistry. Using sketches helps student understand the inner workings of a problem. Similar problems in the end-of-chapter problems section are listed at the end of the examples, enabling the student to apply new skill to other problems of the same type. Answers to the Practice Exercises are listed at the end of the chapter problems.

Key Equations are highlighted within the chapter, drawing the student's eye to material that needs to be understood and retained. The key equations are also presented in the chapter summary materials for easy access in review and study.

Summary of Concepts & Facts provides a quick review of concepts presented and discussed in detail within the chapter.

Key Words are a list of all important terms to help the student understand the language of chemistry.

Testing Your Knowledge

Review of Concepts & Facts lets students pause and check to see if they understand the concept presented and discussed in the section occurred. Answers to the Review of Concepts can be found in the Student Solution Manual.

End-of-Chapter Problems enable the student to practice critical thinking and problem-solving skills. The problems are broken into various types:

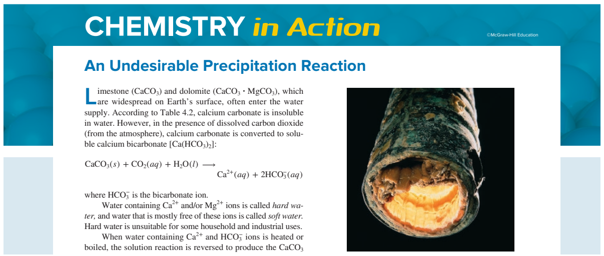
- By chapter section. Starting with Review Questions to test basic conceptual understanding, followed by Problems to test the student's skill in solving problems for that particular section of the chapter.
- Additional Problems uses knowledge gained from the various sections and/or previous chapters to solve the problem.
- Interpreting, Modeling & Estimating problems teach students the art of formulating models and estimating ballpark answers based on appropriate assumptions.

Real-Life Relevance

Interesting examples of how chemistry applies to life are used throughout the text. Analogies are used where appropriate to help foster understanding of abstract chemical concepts.

End-of-Chapter Problems pose many relevant questions for the student to solve. Examples include Why do swimming coaches sometimes place a drop of alcohol in a swimmer's ear to draw out water? How does one estimate the pressure in a carbonated soft drink bottle before removing the cap?

Chemistry in Action boxes appear in every chapter on a variety of topics, each with its own story of how chemistry can affect a part of life. The student can learn about the science of scuba diving and nuclear medicine, among many other interesting cases.



CHEMISTRY *in Action*

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An Undesirable Precipitation Reaction

Limestone ($CaCO_3$) and dolomite ($CaCO_3 \cdot MgCO_3$), which are widespread on Earth's surface, often enter the water supply. According to Table 4.2, calcium carbonate is insoluble in water. However, in the presence of dissolved carbon dioxide (from the atmosphere), calcium carbonate is converted to soluble calcium bicarbonate [$Ca(HCO_3)_2$]:

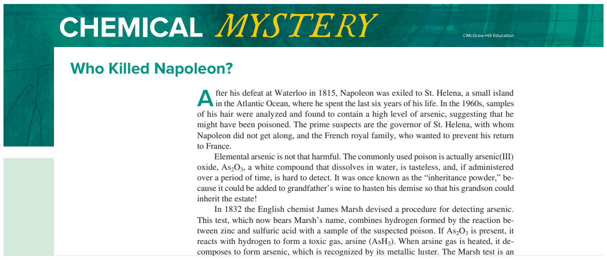
$$CaCO_3(s) + CO_2(aq) + H_2O(l) \longrightarrow Ca^{2+}(aq) + 2HCO_3^-(aq)$$

where HCO_3^- is the bicarbonate ion.

Water containing Ca^{2+} and/or Mg^{2+} ions is called *hard water,* and water that is mostly free of these ions is called *soft water.* Hard water is unsuitable for some household and industrial uses.

When water containing Ca^{2+} and HCO_3^- ions is heated or boiled, the solution reaction is reversed to produce the $CaCO_3$

Chemical Mystery poses a mystery case to the student. A series of chemical questions provide clues as to how the mystery could possibly be solved. Chemical Mystery will foster a high level of critical thinking using the basic problem-solving steps built up throughout the text.



CHEMICAL *MYSTERY*

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Who Killed Napoleon?

After his defeat at Waterloo in 1815, Napoleon was exiled to St. Helena, a small island in the Atlantic Ocean, where he spent the last six years of his life. In the 1960s, samples of his hair were analyzed and found to contain a high level of arsenic, suggesting that he might have been poisoned. The prime suspects are the governor of St. Helena, with whom Napoleon did not get along, and the French royal family, who wanted to prevent his return to France.

Elemental arsenic is not that harmful. The commonly used poison is actually arsenic(III) oxide, As_2O_3, a white compound that dissolves in water, is tasteless, and, if administered over a period of time, is hard to detect. It was once known as the "inheritance powder," because it could be added to grandfather's wine to hasten his demise so that his grandson could inherit the estate!

In 1832 the English chemist James Marsh devised a procedure for detecting arsenic. This test, which now bears Marsh's name, combines hydrogen formed by the reaction between zinc and sulfuric acid with a sample of the suspected poison. If As_2O_3 is present, it reacts with hydrogen to form a toxic gas, arsine (AsH_3). When arsine gas is heated, it decomposes to form arsenic, which is recognized by its metallic luster. The Marsh test is an

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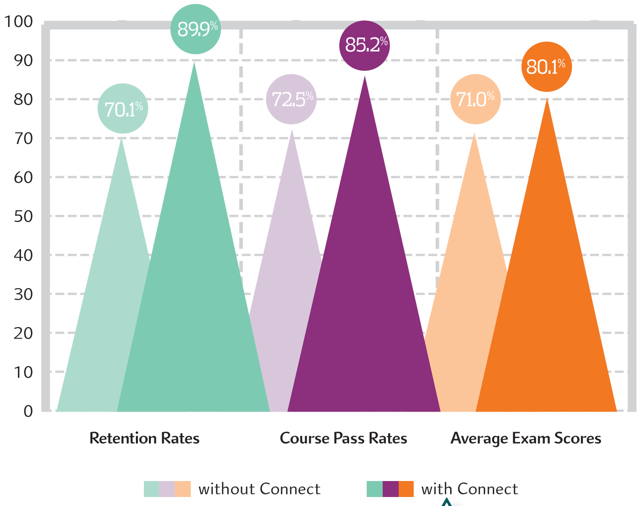

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- Connect automatically grades assignments and quizzes, providing easy-to-read reports on individual and class performance.


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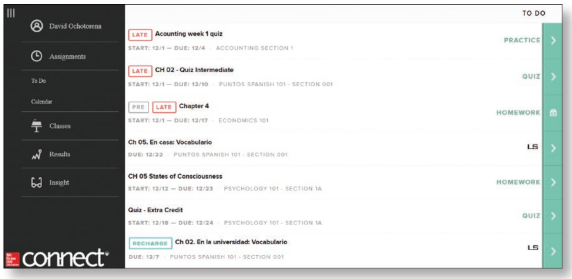


LATE Acounting week 1 quiz
START: 12/1 — DUE: 12/4 · ACCOUNTING SECTION 1
PRACTICE

LATE CH 02 - Quiz Intermediate
START: 12/1 — DUE: 12/10 · PUNTOS SPANISH 101 - SECTION 001
QUIZ

PRE LATE Chapter 4
START: 12/1 — DUE: 12/17 · ECONOMICS 101
HOMEWORK

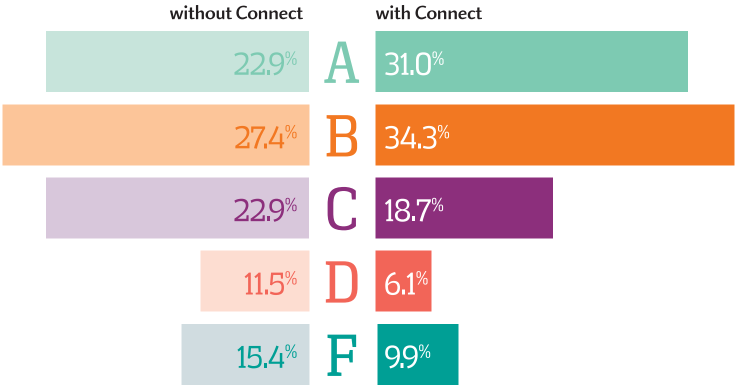
Ch 05. En casa: Vocabulario
DUE: 12/22 · PUNTOS SPANISH 101 - SECTION 001
LS

CH 05 States of Consciousness
START: 12/12 — DUE: 12/23 · PSYCHOLOGY 101 - SECTION 1A
HOMEWORK

Quiz - Extra Credit
START: 12/18 — DUE: 12/24 · PSYCHOLOGY 101 - SECTION 1A
QUIZ

RECHARGE Ch 02. En la universidad: Vocabulario
DUE: 12/7 · PUNTOS SPANISH 101 - SECTION 001
LS

Impact on Final Course Grade Distribution



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Instructor and Student Resources

McGraw Hill Education connect

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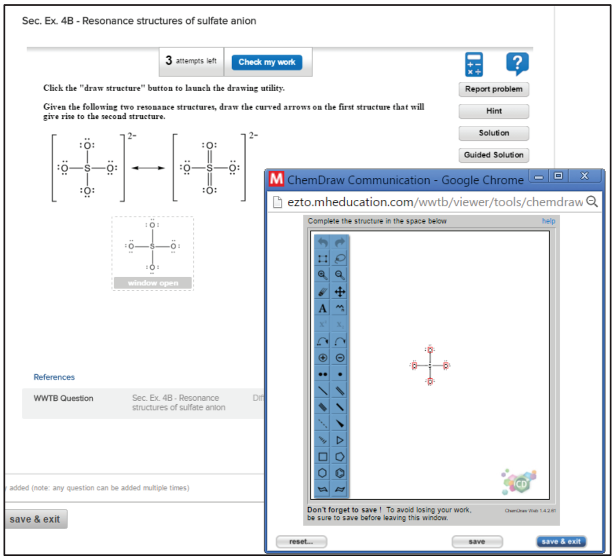
A robust set of questions, problems, and interactive figures are presented and aligned with the textbook's learning goals. The integration of **ChemDraw by PerkinElmer,** the industry standard in chemical drawing software, allows students to create accurate chemical structures in their online homework assignments. As an instructor, you can edit existing questions and write entirely new problems. Track individual student performance—by question, assignment, or in relation to the class overall—with detailed grade reports. Integrate grade reports easily with Learning Management Systems (LMS), such as WebCT and Blackboard—and much more. Also available within Connect, our adaptive SmartBook has been supplemented with additional learning resources tied to each learning objective to provide point-in-time help to students who need it. To learn more, visit www.mheducation.com.



Sec. Ex. 4B - Resonance structures of sulfate anion

Click the "draw structure" button to launch the drawing utility.

Given the following two resonance structures, draw the curved arrows on the first structure that will give rise to the second structure.

WWTB Question Sec. Ex. 4B - Resonance structures of sulfate anion

added (note: any question can be added multiple times)

ezto.mheducation.com/wwtb/viewer/tools/chemdraw

Complete the structure in the space below

Don't forget to save ! To avoid losing your work, be sure to save before leaving this window.

Instructors have access to the following instructor resources through Connect.

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- **Instructor's Solutions Manual** This supplement contains complete, worked-out solutions for *all* the end-of-chapter problems in the text.

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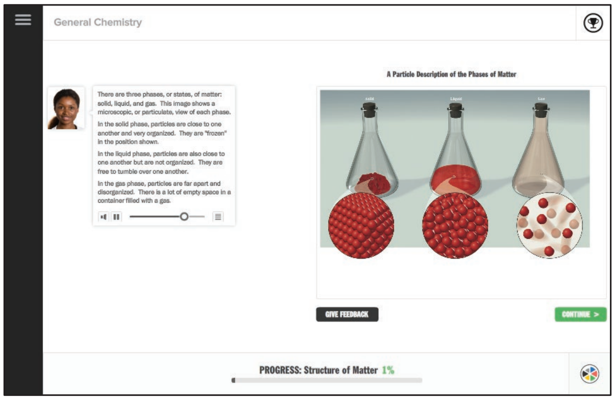

There are three phases, or states, of matter: solid, liquid, and gas. This image shows a microscopic, or particulate, view of each phase.

In the solid phase, particles are close to one another and very organized. They are "frozen" in the position shown.

In the liquid phase, particles are also close to one another but are not organized. They are free to tumble over one another.

In the gas phase, particles are far apart and disorganized. There is a lot of empty space in a container filled with a gas.

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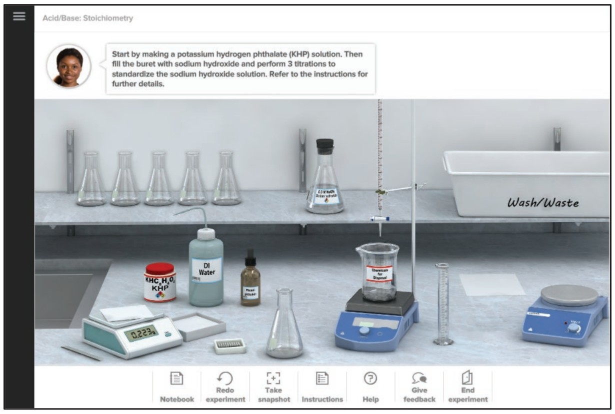
Based on the same world-class, superbly adaptive technology as LearnSmart, **McGraw-Hill LearnSmart Labs** is a must-see, outcomes-based lab simulation. It assesses a student's knowledge and adaptively corrects deficiencies, allowing the student to learn faster and retain more knowledge with greater success. First, a student's knowledge is adaptively leveled on core learning outcomes: Questioning reveals knowledge deficiencies that are corrected by the delivery of content that is conditional on a student's response. Then, a simulated lab experience requires the student to think and act like a scientist: Recording, interpreting, and analyzing data using simulated equipment found in labs and clinics. The student is allowed to make mistakes—a powerful part of the learning experience! A virtual coach provides subtle hints when needed, asks questions about the student's choices, and allows the student to reflect on and correct those mistakes. Whether your need is to overcome the logistical challenges of a traditional lab, provide better lab prep, improve student performance, or make your online experience one that rivals the real world, LearnSmart Labs accomplishes it all.



Start by making a potassium hydrogen phthalate (KHP) solution. Then fill the buret with sodium hydroxide and perform 3 titrations to standardize the sodium hydroxide solution. Refer to the instructions for further details.

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Student Solutions Manual

Students will find answers to the Practice Exercises and detailed solutions for selected problems from the text in the Student Solutions manual. In addition, there are problem-solving strategies and tutorial solutions that surround each chapter's most important topics and problem types.

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Acknowledgments

We would like to thank the following reviewers and symposium participants of this and the previous editions:

Ramesh Arasasingham, *University of California at Irvine*
Kathryn S. Asala, *University of North Carolina, Charlotte*
Mohd Asim Ansari, *Fullerton College*
Keith Baessler, *Suffolk County Community College*
Christian S. Bahn, *Montana State University*
Mary Fran Barber, *Wayne State University*
H. Laine Berghout, *Weber State University*
Feri Billiot, *Texas A&M University Corpus Christi*
Julie Biteen, *University of Michigan*
John Blaha, *Columbus State Community College*
Marco Bonizzoni, *University of Alabama–Tuscaloosa*
Christopher Bowers, *Ohio Northern University*
Bryan Breyfogle, *Missouri State University*
Steve Burns, *St. Thomas Aquinas College*
Mark L. Campbell, *United States Naval Academy*
Tara Carpenter, *University of Maryland*
David Carter, *Angelo State*
Joel Caughran, *University of Georgia*
Daesung Chong, *Ball State University*
Elzbieta Cook, *Louisiana State University*
Robert L. Cook, *Louisiana State University*
Colleen Craig, *University of Washington*
Brandon Cruickshank, *Northern Arizona University–Flagstaff*
Elizabeth A. Clizbe, *SUNY Buffalo*
Mohammed Daoudi, *University of Central Florida*
Jay Deiner, *New York City College of Technology*
Dawn Del Carlo, *University of Northern Iowa*
Milagros Delgado, *Florida International University, Biscayne Bay Campus*
Michael Denniston, *Georgia Perimeter College*
Stephanie R. Dillon, *Florida State University*
Anne Distler, *Cuyahoga Community College*
Bill Donovan, *University of Akron*
Mathilda D. Doorley, *Southwest Tennessee Community College*
Jack Eichler, *University of California–Riverside*
Bradley D. Fahlman, *Central Michigan University*
Lee Friedman, *University of Maryland–College Park*
Tiffany Gierasch, *University of Maryland–Baltimore County*
Cameon Geyer, *Olympic College*
John Gorden, *Auburn University*
Tracy Hamilton, *University of Alabama–Birmingham*
Tony Hascall, *Northern Arizona University*
Lindsay M. Hinkle, *Harvard University*
Rebecca Hoenigman, *Community College of Aurora*
T. Keith Hollis, *Mississippi State University*
Byron Howell, *Tyler Junior College*
Michael R. Ivanov, *Northeast Iowa Community College*
David W. Johnson, *University of Dayton*
Steve Johnson, *University of New England*
Mohammad Karim, *Tennessee State University–Nashville*
Jeremy Karr, *College of Saint Mary*
Vance Kennedy, *Eastern Michigan University*
Katrina Kline, *University of Missouri*
An-Phong Lee, *Florida Southern College*
Debbie Leedy, *Glendale Community College*
Willem R. Leenstra, *University of Vermont*
Barbara S. Lewis, *Clemson University*
Scott Luaders, *Quincy University*
Vicky Lykourinou, *University of South Florida*
Yinfa Ma, *Missouri University of Science and Technology*
Sara-Kaye Madsen, *South Dakota State University*
Sharyl Majorski, *Central Michigan University*
Ben Martin, *Texas State University*
Roy McClean, *United States Naval Academy*
Helene Maire-Afeli, *University of South Carolina–Union*
Tracy McGill, *Emory University*
David M. McGinnis, *University of Arkansas–Fort Smith*
Thomas McGrath, *Baylor University*
Deb Mlsna, *Mississippi State University*
Patricia Muisener, *University of South Florida*
Kim Myung, *Georgia Perimeter College*
Anne-Marie Nickel, *Milwaukee School of Engineering*
Krista Noren-Santmyer, *Hillsborough Community College–Brandon*
Greg Oswald, *North Dakota State University*
John W. Overcash, *University of Illinois–Urbana–Champaign*
Shadrick Paris, *Ohio University*
Manoj Patil, *Western Iowa Technical College*
John Pollard, *University of Arizona*
Ramin Radfar, *Wofford College*
Betsy B. Ratcliff, *West Virginia University*
Mike Rennekamp, *Columbus State Community College*
Thomas G. Richmond, *University of Utah*
Steven Rowley, *Middlesex County College*
Joel W. Russell, *Oakland University*
Raymond Sadeghi, *University of Texas–San Antonio*
Richard Schwenz, *University of Northern Colorado*

Chad Snyder, *Grace College*
Allison S. Soult, *University of Kentucky*
Richard Spinney, *The Ohio State University*
Anne M. Spuches, *East Carolina University*
John Stubbs, *University of New England*
Katherine Stumpo, *University of Tennessee–Martin*
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Charles Taylor, *Florence Darlington Technical College*
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Stan Whittingham, *Binghamton University*
Troy Wolfskill, *Stony Brook University*
Anthony Wren, *Butte College*
Fadi Zaher, *Gateway Technical College*

Connect: Chemistry has been greatly enhanced by the efforts of Yasmin Patell, *Kansas State University;* MaryKay Orgill, *University of Nevada–Las Vegas;* Mirela Krichten, *The College of New Jersey;* who did a masterful job of authoring hints and feedback to augment all of the system's homework problems.

Thanks also to David G. Jones and Margaret Ruth Leslie who helped write and review learning goal-oriented content for our **SmartBook.**

We have benefited much from discussions with our colleagues at Williams College and the College of Charleston, and correspondence with instructors here and abroad.

It is a pleasure to acknowledge the support given us by the following members of McGraw-Hill Higher Education: Executive Portfolio Manager Dr. David Spurgeon, Lead Product Developer Robin Reed, Senior Director of Digital Content Dr. Shirley Hino, Senior Marketing Manager Matt Garcia, Product Development Coordinators Megan Platt and Marisa Dobbeleare, Program Manager Lora Neyens, Content Project Manager Sherry Kane and Lead Assessment Content Project Manager Tammy Juran, Lead Designer David Hash, and Senior Content Licensing Specialist Lori Hancock.

A Note to the Student

General chemistry is commonly perceived to be more difficult than most other subjects. There is some justification for this perception. For one thing, chemistry has a very specialized vocabulary. At first, studying chemistry is like learning a new language. Furthermore, some of the concepts are abstract. Nevertheless, with diligence you can complete this course successfully, and you might even enjoy it. Here are some suggestions to help you form good study habits and master the material in this text.

- Attend classes regularly and take careful notes.
- If possible, always review the topics discussed in class the same day they are covered in class. Use this book to supplement your notes.
- Think critically. Ask yourself if you really understand the meaning of a term or the use of an equation. A good way to test your understanding is to explain a concept to a classmate or some other person.
- Do not hesitate to ask your instructor or your teaching assistant for help.

The thirteenth edition tools for *Chemistry* are designed to enable you to do well in your general chemistry course. The following guide explains how to take full advantage of the text, technology, and other tools.

- Before delving into the chapter, read the chapter *outline* and the chapter *introduction* to get a sense of the important topics. Use the outline to organize your note taking in class.
- At the end of each chapter you will find a summary of facts and concepts, the key equations, and a list of key words, all of which will help you review for exams.
- Definitions of the key words can be studied in context on the pages cited in the end-of-chapter list or in the glossary at the back of the book.
- Careful study of the worked-out examples in the body of each chapter will improve your ability to analyze problems and correctly carry out the calculations needed to solve them. Also take the time to work through the practice exercise that follows each example to be sure you understand how to solve the type of problem illustrated in the example. The answers to the practice exercises appear at the end of the chapter, following the questions and problems. For additional practice, you can turn to similar problems referred to in the margin next to the example.
- The questions and problems at the end of the chapter are organized by section.
- The back inside cover shows a list of important figures and tables with page references. This index makes it convenient to quickly look up information when you are solving problems or studying related subjects in different chapters.

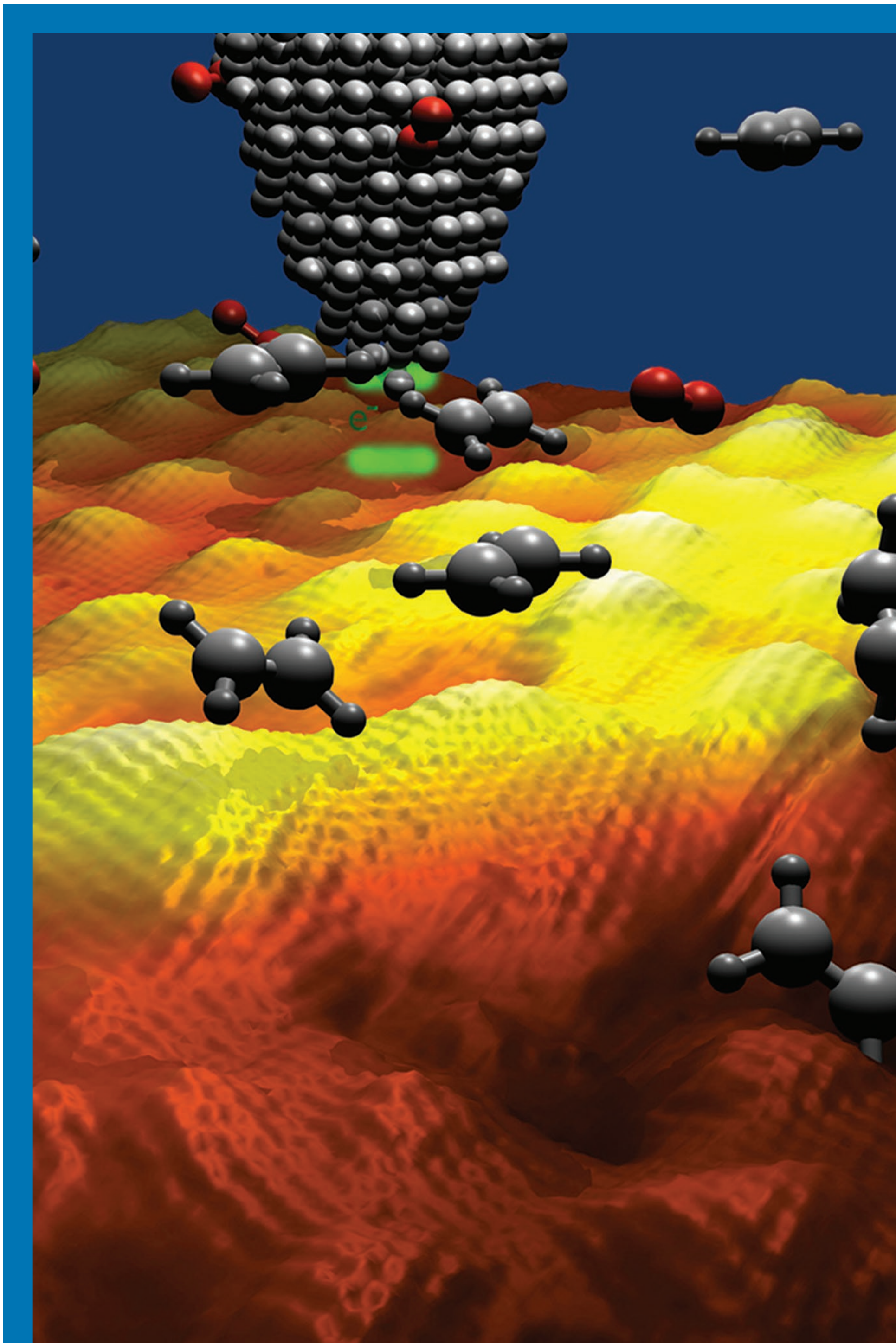
If you follow these suggestions and stay up-to-date with your assignments, you should find that chemistry is challenging, but less difficult and much more interesting than you expected.

—Raymond Chang and Jason Overby

CHAPTER

1

Chemistry
The Study of Change



A scanning tunneling microscope probes individual small molecules when they adsorb on graphene, a single-atom thin sheet of carbon atoms.
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CHAPTER OUTLINE

A LOOK AHEAD

- We begin with a brief introduction to the study of chemistry and describe its role in our modern society. (1.1 and 1.2)
- Next, we become familiar with the scientific method, which is a systematic approach to research in all scientific disciplines. (1.3)
- We define matter and note that a pure substance can either be an element or a compound. We distinguish between a homogeneous mixture and a heterogeneous mixture. We also learn that, in principle, all matter can exist in one of three states: solid, liquid, and gas. (1.4 and 1.5)
- To characterize a substance, we need to know its physical properties, which can be observed without changing its identity and chemical properties, which can be demonstrated only by chemical changes. (1.6)
- Being an experimental science, chemistry involves measurements. We learn the basic SI units and use the SI-derived units for quantities like volume and density. We also become familiar with the three temperature scales: Celsius, Fahrenheit, and Kelvin. (1.7)
- Chemical calculations often involve very large or very small numbers and a convenient way to deal with these numbers is the scientific notation. In calculations or measurements, every quantity must show the proper number of significant figures, which are the meaningful digits. (1.8)
- We learn that dimensional analysis is useful in chemical calculations. By carrying the units through the entire sequence of calculations, all the units will cancel except the desired one. (1.9)
- Solving real-world problems frequently involves making assumptions and simplifications. (1.10)

Chemistry is an active, evolving science that has vital importance to our world, in both the realm of nature and the realm of society. Its roots are ancient, but as we will see, chemistry is every bit a modern science.

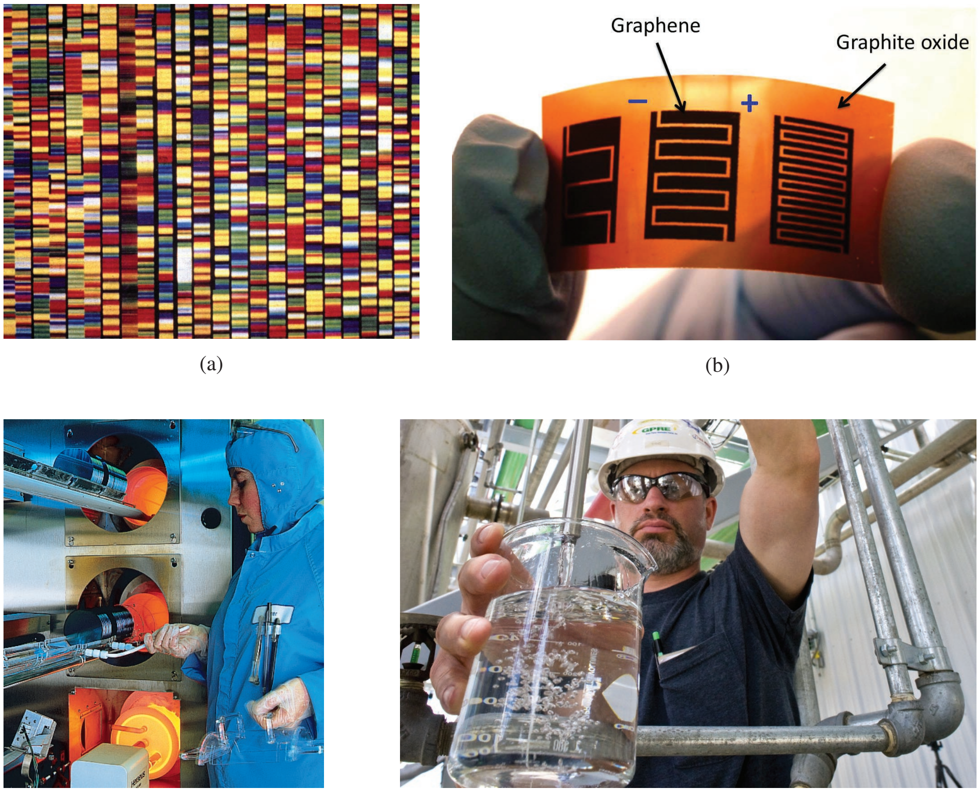
We will begin our study of chemistry at the macroscopic level, where we can see and measure the materials of which our world is made. In this chapter, we will discuss the scientific method, which provides the framework for research not only in chemistry but in all other sciences as well. Next we will discover how scientists define and characterize matter. Then we will spend some time learning how to handle numerical results of chemical measurements and solve numerical problems. In Chapter 2, we will begin to explore the microscopic world of atoms and molecules.

1.1 Chemistry: A Science for the Twenty-First Century

Chemistry is *the study of matter and the changes it undergoes.* Chemistry is often called the central science, because a basic knowledge of chemistry is essential for students of biology, physics, geology, ecology, and many other subjects. Indeed, it is central to our way of life; without it, we would be living shorter lives in what we would consider primitive conditions, without automobiles, electricity, computers, CDs, and many other everyday conveniences.

Although chemistry is an ancient science, its modern foundation was laid in the nineteenth century, when intellectual and technological advances enabled scientists to break down substances into ever smaller components and consequently to explain many of their physical and chemical characteristics. The rapid development of increasingly sophisticated technology throughout the twentieth century has given us even greater means to study things that cannot be seen with the naked eye. Using computers and special microscopes, for example, chemists can analyze the structure of atoms and molecules—the fundamental units on which the study of chemistry is based—and design new substances with specific properties, such as drugs and environmentally friendly consumer products.

The Chinese characters for chemistry mean "the study of change."



(a) (b)

(c) (d)

Figure 1.1 *(a) The output from an automated DNA sequencing machine. Each lane displays the sequence (indicated by different colors) obtained with a separate DNA sample. (b) A graphene supercapacitor. These materials provide some of the highest known energy-to-volume ratios and response times. (c) Production of photovoltaic cells, used to convert light into electrical current. (d) Ethanol for fuel use is produced by distillation from corn.*

(a): ©Science Source; (b): Courtesy of Richard B. Kaner; (c): ©David Parker/Seagate/Science Source; (d): ©David Nunuk/Science Source

It is fitting to ask what part the central science will have in the twenty-first century. Almost certainly, chemistry will continue to play a pivotal role in all areas of science and technology. Before plunging into the study of matter and its transformation, let us consider some of the frontiers that chemists are currently exploring (Figure 1.1). Whatever your reasons for taking general chemistry, a good knowledge of the subject will better enable you to appreciate its impact on society and on you as an individual.

1.2 The Study of Chemistry

Compared with other subjects, chemistry is commonly believed to be more difficult, at least at the introductory level. There is some justification for this perception; for one thing, chemistry has a very specialized vocabulary. However, even if this is your first course in chemistry, you already have more familiarity with the subject than you may realize. In everyday conversations we hear words that have a chemical connection, although they may not be used in the scientifically correct sense. Examples are “electronic,” “quantum leap,” “equilibrium,” “catalyst,” “chain reaction,” and “critical mass.” Moreover, if you cook, then you are a practicing chemist! From experience gained in the kitchen, you know that oil and water do not mix and that boiling water left on the stove will evaporate. You apply chemical and physical principles when you use baking soda to leaven bread, choose a pressure cooker to shorten the time it takes to prepare soup, add meat tenderizer to a pot roast, squeeze lemon juice over sliced pears to prevent them from turning brown or over fish to minimize its odor, and add vinegar

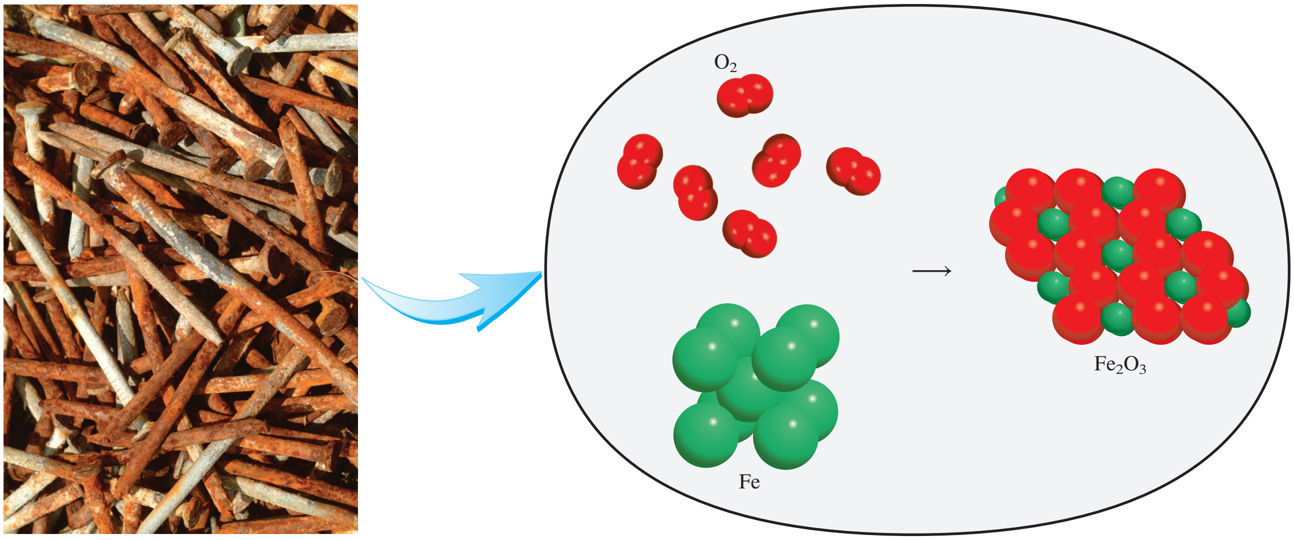


Figure 1.2 *A simplified molecular view of rust (Fe_2O_3) formation from iron (Fe) atoms and oxygen molecules (O_2). In reality, the process requires water, and rust also contains water molecules.*

©B.A.E. Inc./Alamy Stock Photo

to the water in which you are going to poach eggs. Every day we observe such changes without thinking about their chemical nature. The purpose of this course is to make you think like a chemist, to look at the *macroscopic world*—the things we can see, touch, and measure directly—and visualize the particles and events of the *microscopic world* that we cannot experience without modern technology and our imaginations.

At first some students find it confusing that their chemistry instructor and textbook seem to be continually shifting back and forth between the macroscopic and microscopic worlds. Just keep in mind that the data for chemical investigations most often come from observations of large-scale phenomena, but the explanations frequently lie in the unseen and partially imagined microscopic world of atoms and molecules. In other words, chemists often *see* one thing (in the macroscopic world) and *think* another (in the microscopic world). Looking at the rusted nails in Figure 1.2, for example, a chemist might think about the basic properties of individual atoms of iron and how these units interact with other atoms and molecules to produce the observed change.

1.3 The Scientific Method

All sciences, including the social sciences, employ variations of what is called the ***scientific method,*** *a systematic approach to research.* For example, a psychologist who wants to know how noise affects people's ability to learn chemistry and a chemist interested in measuring the heat given off when hydrogen gas burns in air would follow roughly the same procedure in carrying out their investigations. The first step is to carefully define the problem. The next step includes performing experiments, making careful observations, and recording information, or *data,* about the system—the part of the universe that is under investigation. (In the examples just discussed, the systems are the group of people the psychologist will study and a mixture of hydrogen and air.)

The data obtained in a research study may be both ***qualitative,*** *consisting of general observations about the system,* and ***quantitative,*** *comprising numbers obtained by various measurements of the system.* Chemists generally use standardized symbols and equations in recording their measurements and observations. This form of representation not only simplifies the process of keeping records, but also provides a common basis for communication with other chemists.

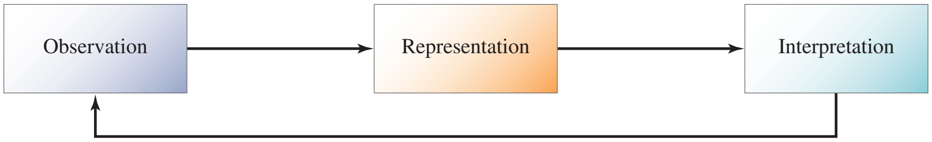


Figure 1.3 *The three levels of studying chemistry and their relationships. Observation deals with events in the macroscopic world; atoms and molecules constitute the microscopic world. Representation is a scientific shorthand for describing an experiment in symbols and chemical equations. Chemists use their knowledge of atoms and molecules to explain an observed phenomenon.*

When the experiments have been completed and the data have been recorded, the next step in the scientific method is interpretation, meaning that the scientist attempts to explain the observed phenomenon. Based on the data that were gathered, the researcher formulates a ***hypothesis,*** *a tentative explanation for a set of observations.* Further experiments are devised to test the validity of the hypothesis in as many ways as possible, and the process begins anew. Figure 1.3 summarizes the main steps of the research process.

After a large amount of data has been collected, it is often desirable to summarize the information in a concise way, as a law. In science, a ***law*** is *a concise verbal or mathematical statement of a relationship between phenomena that is always the same under the same conditions.* For example, Sir Isaac Newton's second law of motion, which you may remember from high school science, says that force equals mass times acceleration ($F = ma$). What this law means is that an increase in the mass or in the acceleration of an object will always increase its force proportionally, and a decrease in mass or acceleration will always decrease the force.

Hypotheses that survive many experimental tests of their validity may evolve into theories. A ***theory*** is *a unifying principle that explains a body of facts and/or those laws that are based on them.* Theories, too, are constantly being tested. If a theory is disproved by experiment, then it must be discarded or modified so that it becomes consistent with experimental observations. Proving or disproving a theory can take years, even centuries, in part because the necessary technology may not be available. Atomic theory, which we will study in Chapter 2, is a case in point. It took more than 2000 years to work out this fundamental principle of chemistry proposed by Democritus, an ancient Greek philosopher. A more contemporary example is the search for the Higgs boson discussed in the Chemistry in Action essay, "The Search for the Higgs Boson."

Scientific progress is seldom, if ever, made in a rigid, step-by-step fashion. Sometimes a law precedes a theory; sometimes it is the other way around. Two scientists may start working on a project with exactly the same objective, but will end up taking drastically different approaches. Scientists are, after all, human beings, and their modes of thinking and working are very much influenced by their background, training, and personalities.

The development of science has been irregular and sometimes even illogical. Great discoveries are usually the result of the cumulative contributions and experience of many workers, even though the credit for formulating a theory or a law is usually given to only one individual. There is, of course, an element of luck involved in scientific discoveries, but it has been said that "chance favors the prepared mind." It takes an alert and well-trained person to recognize the significance of an accidental discovery and to take full advantage of it. More often than not, the public learns only of spectacular scientific breakthroughs. For every success story, however, there are hundreds of cases in which scientists have spent years working on projects that ultimately led to a dead end, and in which positive achievements came only after many wrong turns and at such a slow pace that they went unheralded. Yet even the dead ends contribute something to the continually growing body of knowledge about the physical universe. It is the love of the search that keeps many scientists in the laboratory.

CHEMISTRY *in Action*

The Search for the Higgs Boson

In this chapter, we identify mass as a fundamental property of matter, but have you ever wondered: Why does matter even have mass? It might seem obvious that "everything" has mass, but is that a requirement of nature? We will see later in our studies that light is composed of particles that do not have mass when at rest, and physics tells us under different circumstances the universe might not contain *anything* with mass. Yet we know that *our* universe is made up of an uncountable number of particles with mass, and these building blocks are necessary to form the elements that make up the people to ask such questions. The search for the answer to this question illustrates nicely the process we call the scientific method.

Current theoretical models tell us that everything in the universe is based on two types of elementary particles: bosons and fermions. We can distinguish the roles of these particles by considering the building blocks of matter to be constructed from fermions, while bosons are particles responsible for the force that holds the fermions together. In 1964, three different research teams independently proposed mechanisms in which a field of energy permeates the universe, and the interaction of matter with this field is due to a specific boson associated with the field. The greater the number of these bosons, the greater the interaction will be with the field. This interaction is the property we call mass, and the field and the associated boson came to be named for Peter Higgs, one of the original physicists to propose this mechanism.

This theory ignited a frantic search for the "Higgs boson" that became one of the most heralded quests in modern science. The Large Hadron Collider at CERN in Geneva, Switzerland (described in Chapter 19), was constructed to carry out experiments designed to find evidence for the Higgs boson. In these experiments, protons are accelerated to nearly the speed of light in opposite directions in a circular 17-mile tunnel, and then allowed to collide, generating even more fundamental particles at very high energies. The data are examined for evidence of an excess of particles at an energy consistent with theoretical predictions for the Higgs boson. The ongoing process of theory suggesting experiments that give results used to evaluate and ultimately refine the theory, and so on, is the essence of the scientific method.

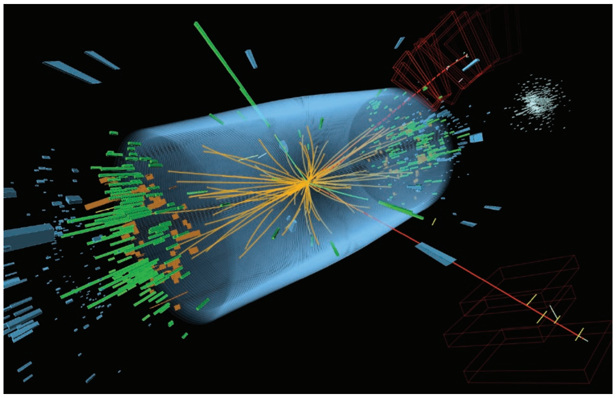


Illustration of the data obtained from decay of the Higgs boson into other particles following an 8-TeV collision in the Large Hadron Collider at CERN.
©Thomas McCauley/Lucas Taylor, CERN/Science Source

On July 4, 2012, scientists at CERN announced the discovery of the Higgs boson. It takes about 1 trillion proton–proton collisions to produce one Higgs boson event, so it requires a tremendous amount of data obtained from two independent sets of experiments to confirm the findings. In science, the quest for answers is never completely done. Our understanding can always be improved or refined, and sometimes entire tenets of accepted science are replaced by another theory that does a better job explaining the observations. For example, scientists are not sure if the Higgs boson is the only particle that confers mass to matter, or if it is only one of several such bosons predicted by other theories.

But over the long run, the scientific method has proven to be our best way of understanding the physical world. It took 50 years for experimental science to validate the existence of the Higgs boson. This discovery was greeted with great fanfare and recognized the following year with a 2013 Nobel Prize in Physics for Peter Higgs and François Englert, another one of the six original scientists who first proposed the existence of a universal field that gives particles their mass. It is impossible to imagine where science will take our understanding of the universe in the next 50 years, but we can be fairly certain that many of the theories and experiments driving this scientific discovery will be very different than the ones we use today.

Review of Concepts & Facts

1.3.1 Which of the following statements is true?
(a) A hypothesis always leads to the formulation of a law.
(b) The scientific method is a rigid sequence of steps in solving problems.
(c) A law summarizes a series of experimental observations; a theory provides an explanation for the observations.

1.3.2 A student collects the following data for a sample of an unknown liquid. Which of these data are qualitative measurements and which are quantitative measurements?
(a) The sample has a volume of 15.4 mL.
(b) The sample is a light yellow liquid.
(c) The sample feels oily.
(d) The sample has a mass of 13.2 g.

1.4 Classifications of Matter

We defined chemistry in Section 1.1 as the study of matter and the changes it undergoes. ***Matter*** is *anything that occupies space and has mass.* Matter includes things we can see and touch (such as water, earth, and trees), as well as things we cannot (such as air). Thus, everything in the universe has a "chemical" connection.

Chemists distinguish among several subcategories of matter based on composition and properties. The classifications of matter include substances, mixtures, elements, and compounds, as well as atoms and molecules, which we will consider in Chapter 2.

Substances and Mixtures

A ***substance*** is *a form of matter that has a definite (constant) composition and distinct properties.* Examples are water, ammonia, table sugar (sucrose), gold, and oxygen. Substances differ from one another in composition and can be identified by their appearance, smell, taste, and other properties.

A ***mixture*** is *a combination of two or more substances in which the substances retain their distinct identities.* Some familiar examples are air, soft drinks, milk, and cement. Mixtures do not have constant composition. Therefore, samples of air collected in different cities would probably differ in composition because of differences in altitude, pollution, and so on.

All mixtures are classified as either homogeneous or heterogeneous. When a spoonful of sugar dissolves in water we obtain a ***homogeneous mixture*** in which *the composition of the mixture is the same throughout.* If sand is mixed with iron filings, however, the sand grains and the iron filings remain separate (Figure 1.4). This type of mixture is called a ***heterogeneous mixture*** because *the composition is not uniform.*

Any mixture, whether homogeneous or heterogeneous, can be created and then separated by physical means into pure components without changing the identities of the components. Thus, sugar can be recovered from a water solution by heating the solution and evaporating it to dryness. Condensing the vapor will give us back the water component. To separate the iron-sand mixture, we can use a magnet to remove the iron filings from the sand, because sand is not attracted to the magnet [see Figure 1.4(b)]. After separation, the components of the mixture will have the same composition and properties as they did to start with.

Elements and Compounds

Substances can be either elements or compounds. An ***element*** is *a substance that cannot be separated further into simpler substances by chemical methods.* To date, 118 elements have been positively identified. Most of them occur naturally on Earth. The others have been created by scientists via nuclear processes, which are the subject of Chapter 19 of this text.

(a) (b)

Figure 1.4 *(a) The mixture contains iron filings and sand. (b) A magnet separates the iron filings from the mixture. The same technique is used on a larger scale to separate iron and steel from nonmagnetic objects such as aluminum, glass, and plastics.*

(a and b): ©McGraw-Hill Education/Ken Karp

For convenience, chemists use symbols of one or two letters to represent the elements. The first letter of a symbol is *always* capitalized, but any following letters are not. For example, Co is the symbol for the element cobalt, whereas CO is the formula for the carbon monoxide molecule. Table 1.1 shows the names and symbols of some of the more common elements. The symbols of some elements are derived from their Latin names—for example, Au from *aurum* (gold), Fe from *ferrum* (iron), and Na from *natrium* (sodium)—whereas most of them come from their English names.

Atoms of most elements can interact with one another to form compounds. Hydrogen gas, for example, burns in oxygen gas to form water, which has properties that are distinctly different from those of the starting materials. Water is made up of two parts hydrogen and one part oxygen. This composition does not change, regardless of whether the water comes from a faucet in the United States, a lake in Outer Mongolia, or the ice caps on Mars. Thus, water is a ***compound,*** *a substance composed of atoms of two or more elements chemically united in fixed proportions.* Unlike mixtures, compounds can be separated only by chemical means into their pure components.

The relationships among elements, compounds, and other categories of matter are summarized in Figure 1.5.

Table 1.1 **Some Common Elements and Their Symbols**

Name	Symbol	Name	Symbol	Name	Symbol
Aluminum	Al	Fluorine	F	Oxygen	O
Arsenic	As	Gold	Au	Phosphorus	P
Barium	Ba	Hydrogen	H	Platinum	Pt
Bismuth	Bi	Iodine	I	Potassium	K
Bromine	Br	Iron	Fe	Silicon	Si
Calcium	Ca	Lead	Pb	Silver	Ag
Carbon	C	Magnesium	Mg	Sodium	Na
Chlorine	Cl	Manganese	Mn	Sulfur	S
Chromium	Cr	Mercury	Hg	Tin	Sn
Cobalt	Co	Nickel	Ni	Tungsten	W
Copper	Cu	Nitrogen	N	Zinc	Zn

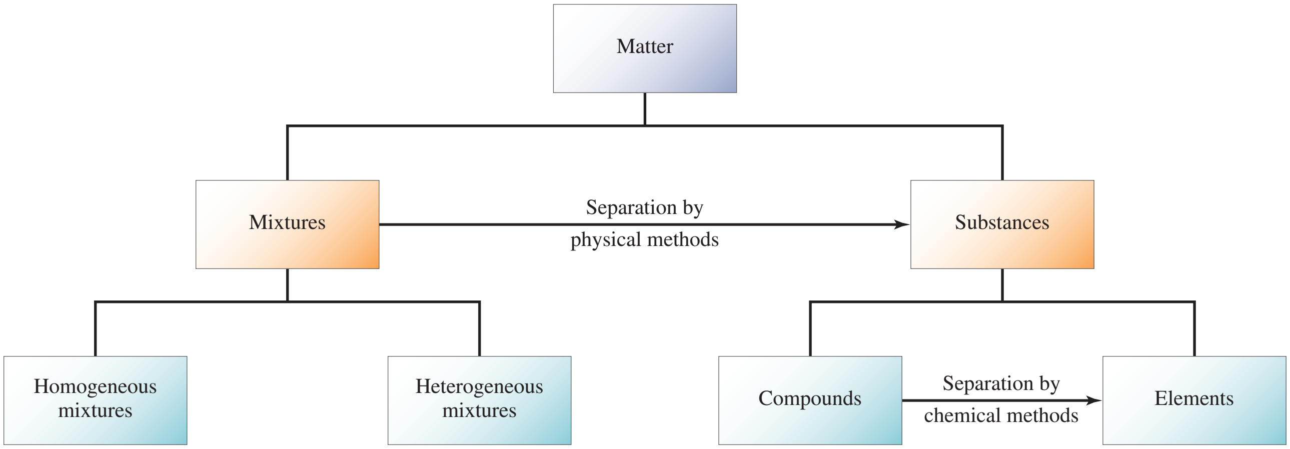
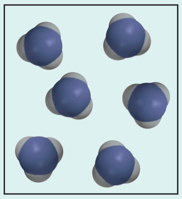
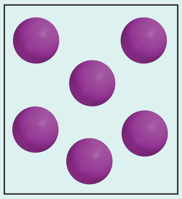


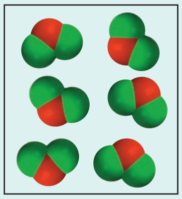
Figure 1.5 *Classification of matter.*

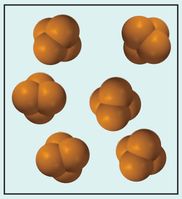
Review of Concepts & Facts

1.4.1 Which of the following diagrams represent elements and which represent compounds? Each color sphere (or truncated sphere) represents an atom. Different colored atoms indicate different elements.


(a)


(b)


(c)


(d)

1.5 The Three States of Matter

All substances, at least in principle, can exist in three states: solid, liquid, and gas. As Figure 1.6 shows, gases differ from liquids and solids in the distances between the atoms. In a solid, atoms (or molecules) are held close together in an orderly fashion with little

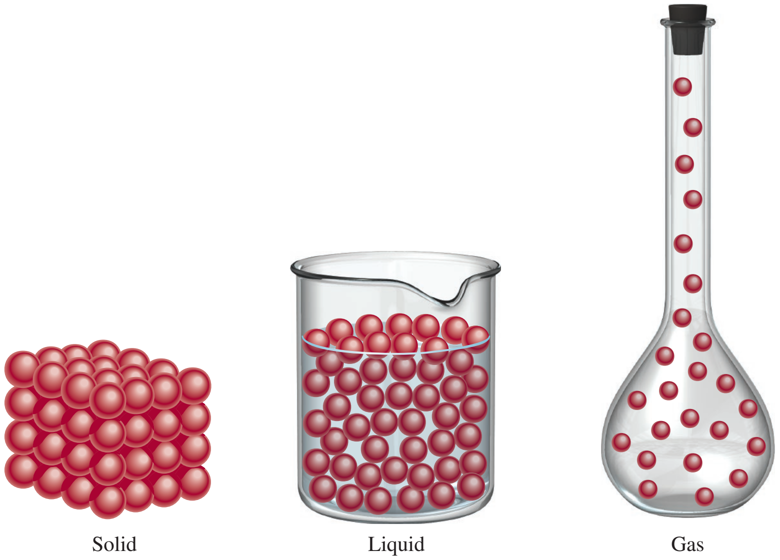


Figure 1.6 *Microscopic views of a solid, a liquid, and a gas.*