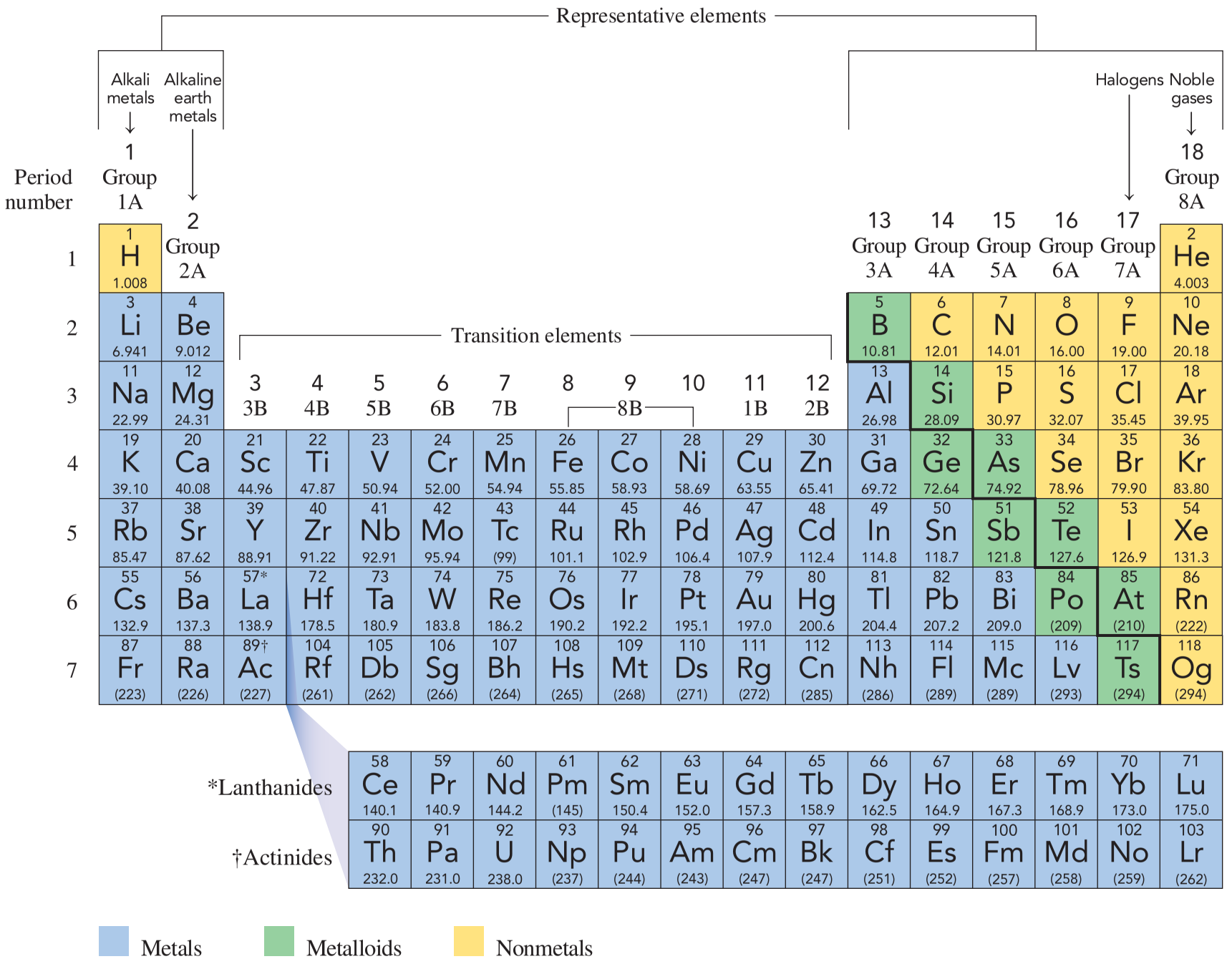
BASIC CHEMISTRY

Sixth Edition

Timberlake
&
Timberlake

Periodic Table of Elements



Atomic Masses of the Elements

Name	Symbol	Atomic Number	Atomic Mass[a]
Actinium	Ac	89	(227)[b]
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	(264)
Boron	B	5	10.81
Bromine	Br	35	79.90
Cadmium	Cd	48	112.4
Calcium	Ca	20	40.08
Californium	Cf	98	(251)
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	(271)
Dubnium	Db	105	(262)
Dysprosium	Dy	66	162.5
Einsteinium	Es	99	(252)
Erbium	Er	68	167.3
Europium	Eu	63	152.0
Fermium	Fm	100	(257)
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	72.64
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	(262)
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	(268)
Mendelevium	Md	101	(258)
Mercury	Hg	80	200.6
Molybdenum	Mo	42	95.94
Moscovium	Mc	115	(289)
Neodymium	Nd	60	144.2
Neon	Ne	10	20.18
Neptunium	Np	93	(237)
Nickel	Ni	28	58.69
Nihonium	Nh	113	(286)
Niobium	Nb	41	92.91
Nitrogen	N	7	14.01
Nobelium	No	102	(259)
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	(244)
Polonium	Po	84	(209)
Potassium	K	19	39.10
Praseodymium	Pr	59	140.9
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.0
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	(261)
Samarium	Sm	62	150.4
Scandium	Sc	21	44.96
Seaborgium	Sg	106	(266)
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	47.87
Tungsten	W	74	183.8
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	65.41
Zirconium	Zr	40	91.22

[a]Values for atomic masses are given to four significant figures.

[b]Values in parentheses are the mass number of an important radioactive isotope.

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Sixth Edition

Karen Timberlake
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About the Authors

KAREN TIMBERLAKE is Professor Emerita of Chemistry at Los Angeles Valley College, where she taught chemistry for allied health and preparatory chemistry for 36 years. She received her bachelor's degree in chemistry from the University of Washington and her master's degree in biochemistry from the University of California at Los Angeles.

Professor Timberlake has been writing chemistry textbooks for more than 40 years. During that time, her name **has become associated with the strategic use of pedagogical tools that promote student success in chemistry and the application of chemistry to real-life situations**. More than one million students have learned chemistry using texts, laboratory manuals, and study guides written by Karen Timberlake. In addition to *Basic Chemistry*, sixth edition, she is also the author of *General, Organic, and Biological Chemistry: Structures of Life*, sixth edition, with the accompanying *Study Guide and Selected Solutions Manual*, and *Chemistry: An Introduction to General, Organic, and Biological Chemistry*, thirteenth edition, with the accompanying *Study Guide and Selected Solutions Manual*, *Laboratory Manual*, and *Essential Laboratory Manual*.

Professor Timberlake belongs to numerous scientific and educational organizations including the American Chemical Society (ACS) and the National Science Teachers Association (NSTA). She has been the Western Regional Winner of Excellence in College Chemistry Teaching Award given by the Chemical Manufacturers Association. She received the McGuffey Award in Physical Sciences from the Textbook Authors Association for her textbook *Chemistry: An Introduction to General, Organic, and Biological Chemistry*, eighth edition. She received the "Texty" Textbook Excellence Award from the Textbook Authors Association for the first edition of *Basic Chemistry*. She has participated in education grants for science teaching including the Los Angeles Collaborative for Teaching Excellence (LACTE) and a Title III grant at her college. She speaks at conferences and educational meetings on the use of student-centered teaching methods in chemistry to promote the learning success of students.

Her husband, William Timberlake, who is the coauthor of this text, is Professor Emeritus of Chemistry at Los Angeles Harbor College, where he taught preparatory and organic chemistry for 36 years. He received his bachelor's degree in chemistry from Carnegie Mellon University and his master's degree in organic chemistry from the University of California at Los Angeles.

When the Professors Timberlake are not writing textbooks, they relax by playing tennis, ballroom dancing, hiking, traveling, trying new restaurants, cooking, and enjoying care of their grandchildren, Daniel and Emily.

DEDICATION

- Our son, John, daughter-in-law, Cindy, grandson, Daniel, and granddaughter, Emily, for the precious things in life
- The wonderful students over many years whose hard work and commitment always motivated us and put purpose in our writing

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Preface

Welcome to the sixth edition of *Basic Chemistry*. This chemistry text was written and designed to prepare you for science-related professions, such as engineering, nursing, medicine, environmental or agricultural science, or for careers such as laboratory technology. This text assumes no prior knowledge of chemistry. Our main objective in writing this text is to make the study of chemistry an engaging and positive experience for you by relating the structure and behavior of matter to real life. This new edition introduces more problem-solving strategies, Analyze the Problem with Connect features, Try It First and Engage features, and conceptual and challenge problems.

It is our goal to help you become a critical thinker by understanding scientific concepts that will form a basis for making important decisions about issues concerning health and the environment. Thus, we have utilized materials that

- help you to learn and enjoy chemistry
- relate chemistry to careers that interest you
- develop problem-solving skills
- promote learning and success in chemistry

Active Reading Features for Successful Learning

In this sixth edition of Basic Chemistry, we have increased our emphasis on providing features that promote student interaction with the textual content. We continue to develop features based on new research on learning theory and extend them throughout the text as a part of our study plan Strategies and Practices for Active Reading in Chemistry (SPARC).

With the success of students involved in active learning in the classroom, we see the opportunity to develop a parallel plan of reading and learning experiences using our textbook. As chemistry textbook authors we are interested in connecting cognitive science and learning research to improve student reading and learning. SPARC is the combination of utilizing reading strategies that increase learning and success in chemistry.

Strategies for Learning New Information

1. **Combine graphics with words**
   Students improve learning by receiving information in different ways. In this text, we combine text and questions with illustrations using *macro-to-micro art*, tables, graphs, diagrams, videos, photos, and concept maps.
2. **Connect abstract concepts with concrete representations**
   New concepts are illustrated and explained with *real-life examples*, *career stories and updates*, *Chemical Links to Health and the Environment*, and *Applications*. Prompts of *Key Math Skills* and *Core Chemistry Skills* alert students to the fundamental ideas in each chapter.

Strategies for Connecting New Information

3. **Ask inquiring questions**
   Engage questions throughout each chapter ask students "why," "how," and "what if," requiring them to link new information with prior knowledge.
4. **Alternate problems containing solutions with similar problems that students must solve**
   Many *Sample Problems* with *Try It First* reminders throughout each chapter contain step-by-step solutions that guide students through the process of problem-solving. An abundance of *Practice Problems*, *Understanding the Concepts*, *Additional Problems*, and *Challenge Problems* provide students with similar problem-solving experience. *Answers* are provided for immediate feedback.

Strategies for Recalling and Retrieving Information

5. **Provide opportunities to practice recall and retrieval**
   Throughout each chapter, students are encouraged to practice the recall and retrieval of material by repeating practice every few days, weeks, and even months using *Self Tests*, *Practice Problems*, *Understanding the Concepts*, *Additional Problems*, and *Challenge Problems*. *Review* prompts remind students of key ideas in previous chapters.
6. **Combine different but related topics and skills**
   Better learning can be achieved by alternating different topics and types of content. In this text, problem sets including *Understanding the Concepts*, *Additional Practice Problems*, *Challenge Problems*, and *Combining Ideas* provide students practice of different topics or skills, rather than focusing on one topic or skill.
7. **Assess to maintain and improve retention**
   Every chapter provides many types of assessment such as *Self Tests*, *Practice Problems*, *Understanding the Concepts*, *Additional Practice Problems*, *Challenge Problems*, and *Combining Ideas*. By practicing information retrieval, checking progress, and reviewing, students improve their success on exams.

New and Updated for the Sixth Edition

New and updated features have been added throughout this sixth edition, including the following:

- **NEW! Chapter Openers** provide timely examples and engaging, topical examples of the chemistry that is part of contemporary professions.
- **NEW! Chapter Openers** include references to new **Update** features at the end of the chapter that continue the story.
- **NEW! Review** heads are now listed at the beginning of each section to emphasize the Key Math Skills and Core Chemistry Skills from previous chapters required for learning new chemistry principles.
- **NEW! Pictorial Representations** using photos and graphs are added to increase the understanding of new topics.
- **NEW! Sample Problems** show **Steps** to guide the student through problem solving.
- **NEW! Self Test** icons in Sample Problems encourage students to use problem-solving strategies immediately as they review the content in a section.
- **NEW!** Expanded **Self Test** questions in **Sample Problems** provide students with additional self-testing practice.
- **NEW!** Margin icons **Practice Problems** encourage students to work related Practice Problems and self-assess as they study.
- **NEW!** Expanded **Engage Questions** and **Answers** are included in the chapter.
- **NEW!** Additional **Practice Problems** and **Challenge Problems** are added to help student practice testing and increase understanding of the concepts in the chapter.
- **NEW! Three-Dimensional Representations**, including ball-and-stick and space-filling models, are included to illustrate the shapes of molecules and polyatomic ions.
- **NEW!** Foreground colors in color palette are now ADA accessible.
- **NEW!** Multiple art pieces contain separate captions in boxes for each art.
- **NEW! Concept Maps** are tinted with color screens for emphasis of topics.
- **NEW! Interactive Videos** are added to illustrate more step-by-step problem-solving strategies.

Chapter Organization of the Sixth Edition

In each textbook we write, we consider it essential to relate every chemical concept to real-life issues. Because a chemistry course may be taught in different time frames, it may be difficult to cover all the chapters in this text. However, each chapter is a complete package, which allows some chapters to be skipped or the order of presentation to be changed.

Chapter 1, Chemistry in Our Lives, discusses the Scientific Method in everyday terms and guides students in developing a study plan for learning chemistry, with a section of Key Math Skills that reviews the basic math, including scientific notation, needed in chemistry calculations.

- The Chapter Opener tells the story of a murder and features the work and career of forensic scientists.
- The Update feature describes the forensic evidence that helps to solve the murder and includes Applications.
- An updated Section 1.3, Studying and Learning Chemistry, expands the discussion of study strategies that improve learning and understanding of content.
- A new Decimal Place Value Chart is added in Section 1.4, Key Math Skills for Chemistry, to clarify decimal place values.
- In Section 1.4, Interpreting Graphs, the format for the *x* and *y* axes is standardized.
- Key Math Skills are: Identifying Place Values, Using Positive and Negative Numbers in Calculations, Calculating Percentages, Solving Equations, Interpreting Graphs, and Writing Numbers in Scientific Notation.

Chapter 2, Chemistry and Measurements, looks at measurement and emphasizes the need to understand numerical relationships of the metric system. Significant figures are discussed in the determination of final answers. Prefixes from the metric system are used to write equalities and conversion factors for problem-solving strategies. Density is discussed and used as a conversion factor.

- The Chapter Opener tells the story of a patient with high blood pressure and features the work and career of a registered nurse.
- The Update describes the patient's status and follow-up visit with his doctor.
- In Section 2.5, conversion factors with multiple units are added in the Practice Problems.
- In Section 2.6, Steps as guides to problem solving are added to Sample Problems 2.3, 2.4, and 2.5.
- In Section 2.6, a new type of Sample Problem and new Practice Problems for the conversion of units in a fraction are added.
- Sample Problems relate problem solving to health-related topics such as the measurements of blood volume, omega-3 fatty acids, radiological imaging, body fat, cholesterol, and medication orders.
- Applications feature questions about measurements, daily values for minerals and vitamins, and equalities and conversion factors for medications.
- Key Math Skill is: Rounding Off.
- Core Chemistry Skills are: Counting Significant Figures, Using Significant Figures in Calculations, Using Prefixes, Writing Conversion Factors from Equalities, Using Conversion Factors, and Using Density as a Conversion Factor.

Chapter 3, Matter and Energy, classifies matter and states of matter, describes temperature measurement, and discusses energy, specific heat, and energy in nutrition. Physical and

chemical properties and physical and chemical changes are discussed.

- The Chapter Opener describes diet and exercise for an overweight adolescent at risk for type 2 diabetes and features the work and career of a dietitian.
- The Update describes the diet prepared with a dietitian for weight loss.
- Figures of Decomposition of Salt, and Separation of Mixtures by Filtration are moved to Section 3.2 for clarity of content.
- In Section 3.5, Specific Heat, a new Sample Problem using heat exchange data is added along with new Practice Problems.
- Practice Problems and Sample Problems include high temperatures used in cancer treatment, the energy produced by a high-energy shock output of a defibrillator, body temperature lowering using a cooling cap, ice bag therapy for muscle injury, dental implants, and energy values for food.
- Core Chemistry Skills are: Identifying Physical and Chemical Changes, Converting Between Temperature Scales, Using Energy Units, Calculating Specific Heat, and Using the Heat Equation.
- The interchapter problem set, Combining Ideas from Chapters 1 to 3, completes the chapter.

Chapter 4, Atoms and Elements, introduces elements and atoms and the periodic table. The names and symbols for the newest elements 113, Nihonium, Nh, 115, Moscovium, Mc, 117, Tennessine, Ts, and 118, Oganesson, Og, are included on the periodic table. Atomic numbers and mass numbers are determined for isotopes. Atomic mass is calculated using the masses of the naturally occurring isotopes and their abundances.

- The Chapter Opener and Update discuss the improvement in crop production and feature the work and career of a farmer.
- Atomic number and mass number are used to calculate the number of protons and neutrons in an atom.
- The number of protons and neutrons are used to calculate the mass number and to write the atomic symbol for an isotope.
- Figure 4.3 now includes Francium (Fr) in Group 1A (1), and Figure 4.4 now includes Tennessine (Ts).
- Core Chemistry Skills are: Counting Protons and Neutrons, Writing Atomic Symbols for Isotopes, and Calculating Atomic Mass.

Chapter 5, Electronic Structure of Atoms and Periodic Trends, uses the electromagnetic spectrum to explain atomic spectra and develop the concept of energy levels and sublevels. Electrons in sublevels and orbitals are represented using orbital diagrams and electron configurations. Periodic properties of elements, including atomic size, ionization energy and metallic character, are related to their valence electrons. Small periodic tables illustrate the trends of periodic properties.

- The Chapter Opener and Update discuss the development of new products of metals, plastics, and semiconductors, and career of a materials engineer.
- The electromagnetic spectrum is described with everyday examples and a diagram.
- The three-dimensional representations of the *s*, *p*, and *d* orbitals are drawn.
- The trends in periodic properties are described for valence electrons, atomic size, ionization energy, and metallic character.
- A photo of infrared radiation used to keep food warm, and a photo of gamma knife radiation used to kill cancer cells are added.
- Table 5.2 for electron capacity in sublevels is reordered with Energy Level $n = 1$ at the top and Energy Level $n = 4$ at the bottom.
- Core Chemistry Skills are: Writing Electron Configurations, Using the Periodic Table to Write Electron Configurations, and Identifying Trends in Periodic Properties.

Chapter 6, Ionic and Molecular Compounds, describes the formation of ionic and covalent bonds. Chemical formulas are written, and ionic compounds—including those with polyatomic ions—and molecular compounds are named.

- The Chapter Opener describes the chemistry of aspirin and features the work and career of a pharmacist.
- The Update describes several types of compounds at a pharmacy and includes Applications.
- New art is added or updated to provide everyday examples of the content.
- New material on polyatomic ions compares the names of *ate* ions and *ite* ions, the charge of sulfate and sulfite, phosphate and phosphite, carbonate and hydrogen carbonate, and the formulas and charges of halogen polyatomic ions with oxygen.
- Core Chemistry Skills are: Writing Positive and Negative Ions, Writing Ionic Formulas, Naming Ionic Compounds, and Writing the Names and Formulas for Molecular Compounds.

Chapter 7, Chemical Quantities, discusses Avogadro's number, the mole, and molar masses of compounds, which are used in calculations to determine the mass or number of particles in a quantity of a substance. The mass percent composition of a compound is calculated and used to determine its empirical and molecular formula.

- The Chapter Opener and Update describe the diagnosis and treatment of a pet and the work and career of a veterinarian.
- Core Chemistry Skills are: Converting Particles to Moles, Calculating Molar Mass, Using Molar Mass as a Conversion Factor, Calculating Mass Percent Composition, Calculating an Empirical Formula, and Calculating a Molecular Formula.
- The interchapter problem set, Combining Ideas from Chapters 4 to 7, completes the chapter.

Chapter 8, Chemical Reactions, shows students how to balance chemical equations, and discusses how to classify chemical reactions into types: combination, decomposition, single replacement, double replacement, combustion, and oxidation–reduction.

- The Chapter Opener and Update discuss tests and treatment for emphysema and the work and career of an exercise physiologist.
- Core Chemistry Skills are: Balancing a Chemical Equation, Classifying Types of Chemical Reactions, and Identifying Oxidized and Reduced Substances.

Chapter 9, Chemical Quantities in Reactions, describes the mole and mass relationships among the reactants and products and provides calculations of limiting reactants and percent yields. The chapter concludes with a discussion of energy in reactions.

- The Chapter Opener describes insecticides and pharmaceuticals used on a ranch and discusses the career of an environmental scientist.
- The Update describes the collection of soil and water samples for testing for insecticides.
- Mole and mass relationships among the reactants and products are examined along with calculations of percent yield and limiting reactants.
- Material including new problems with three equations and calculations using Hess's Law is rewritten for clarity.
- Core Chemistry Skills are: Using Mole–Mole Factors, Converting Grams to Grams, Calculating Quantity of Product from a Limiting Reactant, Calculating Percent Yield, and Using the Heat of Reaction.

Chapter 10, Bonding and Properties of Solids and Liquids, introduces Lewis structures for molecules and ions with single and multiple bonds as well as resonance structures. Electronegativity leads to a discussion of the polarity of bonds and molecules. Lewis structures and VSEPR theory illustrate covalent bonding and the three-dimensional shapes of molecules and ions. The intermolecular forces between particles and their impact on states of matter and changes of state are described. The energy involved with changes of state is calculated.

- The Chapter Opener and Update describe the processing of a tissue sample and the work and career of a histologist.
- New three-dimensional representations of ball-and-stick models and space-filling models are added to illustrate shapes of molecules and polyatomic ions.
- Lewis structures are drawn for molecules and ions with single, double, and triple bonds. Resonance structures are drawn if two or more Lewis structures are possible.
- Shapes and polarity of bonds and molecules are predicted using VSEPR theory.
- Intermolecular forces in compounds are discussed including ionic bonds, hydrogen bonds, dipole–dipole attractions, and dispersion forces.
- Core Chemistry Skills are: Drawing Lewis Symbols, Drawing Lewis Structures, Drawing Resonance Structures, Predicting Shape, Using Electronegativity, Identifying Polarity of Molecules, Identifying Intermolecular Forces, and Calculating Heat for Change of State.
- The interchapter problem set, Combining Ideas from Chapters 8 to 10, completes the chapter.

Chapter 11, Gases, discusses the properties of gases and calculates changes in gases using the gas laws: Boyle's, Charles's, Gay-Lussac's, Avogadro's, Dalton's, and the Ideal Gas Law. Problem-solving strategies enhance the discussion and calculations with gas laws including chemical reactions using the ideal gas law.

- The Chapter Opener and Update feature the work and career of a respiratory therapist, who uses oxygen to treat a child with asthma.
- Applications include calculations of mass or pressure of oxygen in uses of hyperbaric chambers.
- Core Chemistry Skills are: Using the Gas Laws, Using the Ideal Gas Law, Calculating Mass or Volume of a Gas in a Chemical Reaction, and Calculating Partial Pressure.

Chapter 12, Solutions, describes solutions, electrolytes, saturation and solubility, insoluble salts, concentrations, and osmosis. The concentrations of solutions are used to determine volume or mass of solute. The volumes and molarities of solutions are used in calculations for dilutions and titration. Properties of solutions, freezing and boiling points, osmosis, and dialysis are discussed.

- The Chapter Opener describes a patient with kidney failure and dialysis treatment and features the work and career of a dialysis nurse.
- The Update discusses dialysis treatment and electrolyte levels in the dialysate fluid.
- A new example of suspensions used to purify water in treatment plants is added.
- New art illustrates the freezing point decrease and boiling point increase for aqueous solutions with increasing number of moles of solute in one kilogram of water.
- Core Chemistry Skills are: Using Solubility Rules, Calculating Concentration, Using Concentration as a Conversion Factor, Calculating the Quantity of a Reactant or Product for a Chemical Reaction in Solution, and Calculating the Freezing Point/Boiling Point of a Solution.

Chapter 13, Reaction Rates and Chemical Equilibrium, looks at the rates of reactions and the equilibrium condition when forward and reverse rates for a reaction become equal. Equilibrium expressions for reactions are written and equilibrium constants are calculated. The equilibrium constant is used to calculate the concentration of a reactant or product at equilibrium. Le Châtelier's principle is used to evaluate the impact on concentrations when stress is placed on a system at equilibrium. The concentrations of solutes in a solution is used to calculate the solubility product constant (K_{sp}).

- The Chapter Opener and Update discuss the equilibrium of CO_2 in the ocean and feature the work and career of a chemical oceanographer.
- Core Chemistry Skills are: Writing the Equilibrium Expression, Calculating an Equilibrium Constant, Calculating Equilibrium Concentrations, Using Le Châtelier's Principle, Writing the Solubility Product Expression, Calculating a Solubility Product Constant, and Calculating the Molar Solubility.

Chapter 14, Acids and Bases, discusses acids and bases and their strengths, and conjugate acid–base pairs. The dissociation of strong and weak acids and bases is related to their strengths as acids or bases. The dissociation of water leads to the water dissociation expression, K_w, the pH scale, and the calculation of pH. Chemical equations for acids in reactions are balanced and titration of an acid is illustrated. Buffers are discussed along with their role in the blood. The pH of a buffer is calculated.

- The Chapter Opener describes a blood sample for an emergency room patient sent to the clinical laboratory for analysis of blood pH and CO_2 gas and describes the work and career of a medical laboratory technologist.
- The Update describes the symptoms and treatment for acid reflux disease (GERD).
- Key Math Skills are: Calculating pH from $[H_3O^+]$, and Calculating $[H_3O^+]$ from pH.
- Core Chemistry Skills are: Identifying Conjugate Acid–Base Pairs, Calculating $[H_3O^+]$ and $[OH^-]$ in Solutions, Writing Equations for Reactions of Acids and Bases, Calculating Molarity or Volume of an Acid or Base in a Titration, and Calculating the pH of a Buffer.
- The interchapter problem set, Combining Ideas from Chapters 11 to 14, completes the chapter.

Chapter 15, Oxidation and Reduction, looks at the characteristics of oxidation and reduction reactions. Oxidation numbers are assigned to the atoms in elements, molecules, and ions to determine the components that lose electrons during oxidation and gain electrons during reduction. The half-reaction method is utilized to balance oxidation–reduction reactions. The production of electrical energy in voltaic cells and the requirement of electrical energy in electrolytic cells are diagrammed using half-cells. The activity series is used to determine the spotaneous direction of an oxidation–reduction reaction.

- The Chapter Opener and Update discuss the reactions involved in teeth whitening and the work and career of a dentist.
- New material and art on lithium-ion batteries is added.
- Core Chemistry Skills are: Assigning Oxidation Numbers, Using Oxidation Numbers, Identifying Oxidizing and Reducing Agents, Using Half-Reactions to Balance Redox Equations, and Identifying Spontaneous Reactions.

Chapter 16, Nuclear Chemistry, looks at the types of radiation emitted from the nuclei of radioactive atoms. Nuclear equations are written and balanced for both naturally occurring radioactivity and artificially produced radioactivity. The half-lives of radioisotopes are discussed, and the amount of time for a sample to decay is calculated. Radioisotopes important in the field of nuclear medicine are described. Fission and fusion and their role in energy production are discussed.

- The Chapter Opener and Update describe a stress test using a radioactive isotope and feature the work and career of a radiation technologist.
- Core Chemistry Skills are: Writing Nuclear Equations, and Using Half-Lives.
- The interchapter problem set, Combining Ideas from Chapters 15 and 16, completes the chapter.

Chapter 17, Organic Chemistry, compares inorganic and organic compounds, and describes the condensed structural and line-angle formulas of alkanes, alkenes, alcohols, ethers, aldehydes, ketones, carboxylic acids, esters, amines, and amides.

- The Chapter Opener and Update describe emergency treatment for burns and feature the work and career of a firefighter/emergency medical technician.
- The properties of organic and inorganic compounds are compared in Table 17.1.
- Line-angle formulas are added to Table 17.2 IUPAC Names and Formulas of the First 10 Alkanes.
- More line-angle structures are included in text examples, sample problems, questions, and problems.
- The two-dimensional and three-dimensional representations of methane and ethane are illustrated using condensed structural formulas, expanded structural formulas, ball-and-stick models, space-filling models, and wedge–dash models.
- Core Chemistry Skills are: Naming and Drawing Alkanes, Writing Equations for Hydrogenation and Polymerization, Naming Aldehydes and Ketones, Naming Carboxylic Acids, Forming Esters, and Forming Amides.

Chapter 18, Biochemistry, looks at the chemical structures and reactions of chemicals that occur in living systems. We focus on four types of biomolecules—carbohydrates, lipids, proteins, and nucleic acids—as well as their biochemical reactions.

- The Chapter Opener and Update describe diagnosis and treatment of diabetes and feature the work and career of a diabetes nurse.
- Monosaccharides are classified as aldo or keto pentoses or hexoses.
- Haworth structures are drawn for monosaccharides, disaccharides, and polysaccharides.
- The shapes of proteins are related to the activity and regulation of enzyme activity.
- The genetic code is described and utilized in the process of protein synthesis.
- Core Chemistry Skills are: Drawing Haworth Structures, Identifying Fatty Acids, Drawing Structures for Triacylglycerols, Drawing the Structure for an Amino Acid at Physiological pH, Identifying the Primary, Secondary, Tertiary, and Quaternary Structures of Proteins, Writing the Complementary DNA Strand, Writing the mRNA Segment for a DNA Template, and Writing the Amino Acid for an mRNA Codon.
- The interchapter problem set, Combining Ideas from Chapters 17 and 18, completes the chapter.

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Thanks to Kristen Flathman, Managing Producer, Coleen Morrison, Courseware Analyst, and Barbara Yien, Courseware Director, for their excellent review of pages and helpful suggestions.

We am especially proud of the art program in this text, which lends beauty and understanding to chemistry. We would like to thank Jay McElroy, Art Courseware Analyst, and Stephanie Marquez and Alicia Elliott, Photo and Illustration Project Managers, Mark Ong, Design Manager, and Tamara Newnam, Cover and Interior Designer, whose creative ideas provided the outstanding design for the cover and pages of the book. We appreciate the tireless efforts of Namrata Aggarwal, Photo Researcher, and Matt Perry, Rights and Permissions Project Manager, in researching and selecting vivid photos for the text so that students can see the beauty of chemistry. Thanks also to *Bio-Rad Laboratories* for their courtesy and use of *KnowItAll ChemWindows*, drawing software that helped us produce chemical structures for the manuscript. The macro-to-micro illustrations designed by Jay McElroy and Imagineering Art give students visual impressions of the atomic and molecular organization of everyday things and are a fantastic learning tool. We also appreciate all the hard work in the field put in by the marketing team and Allison Rona, Marketing Manager.

We am extremely grateful to an incredible group of peers for their careful assessment of all the new ideas for the text; for their suggested additions, corrections, changes, and deletions; and for providing an incredible amount of feedback about improvements for the book. We admire and appreciate every one of you.

If you would like to share your experience with chemistry, or have questions and comments about this text, We would appreciate hearing from you.

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BASIC CHEMISTRY

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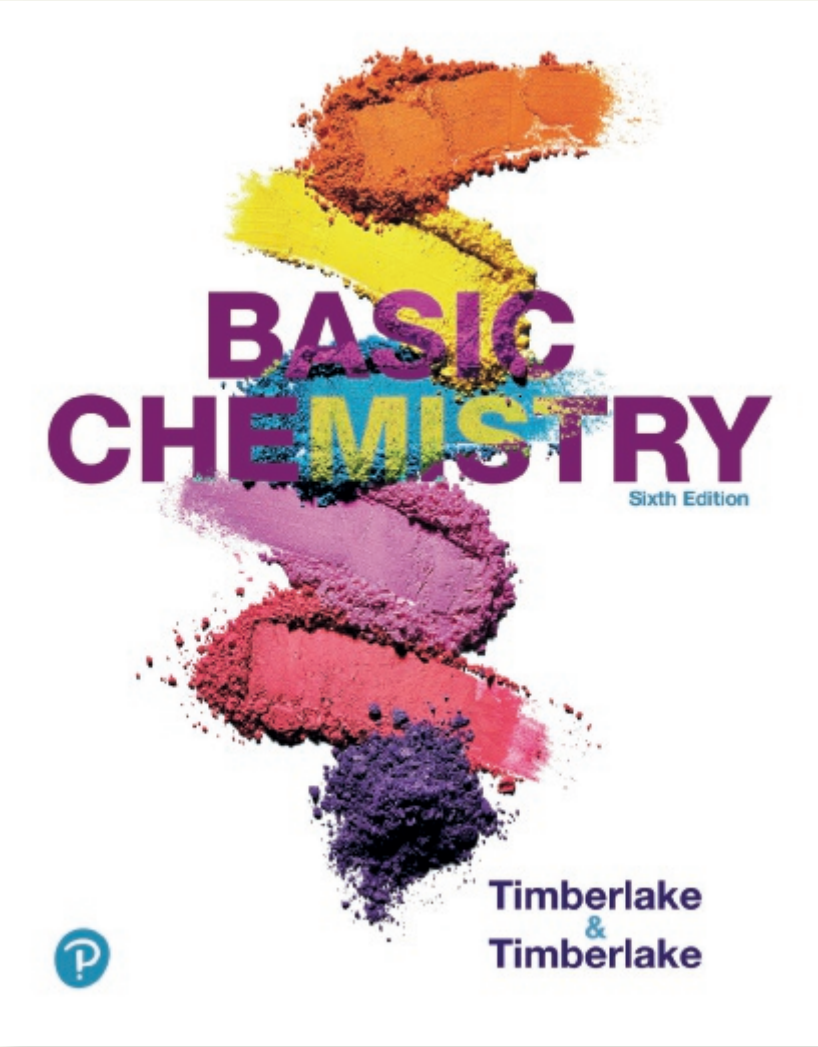
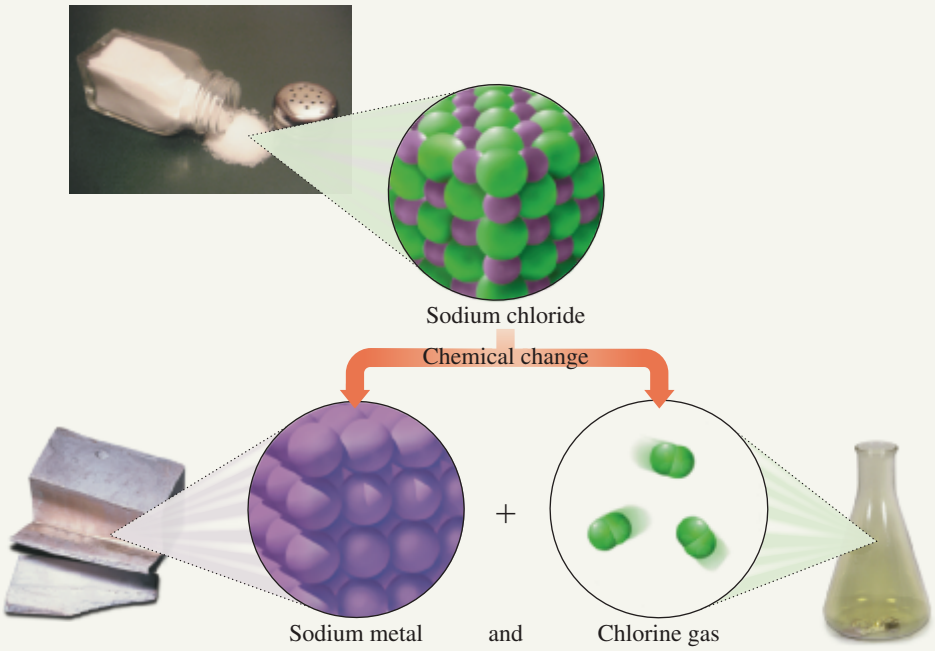
Help students master the math and problem solving they will use in their future careers

Basic Chemistry **introduces students to the essential scientific and mathematical concepts of chemistry while providing the scaffolded support they need. With accessible language and a moderate pace, the text is easy-to-follow for first-time chemistry students. The 6th Edition incorporates sound pedagogy and the best principles from learning design theory to create an updated learning program designed for today's students. The applied focus helps students connect chemistry with their interests and potential careers. Enhanced digital tools and additional practice problems in Mastering Chemistry ensure students master the basic quantitative and science skills needed to succeed in this course and beyond.**



Pearson

Art and Videos that are more understandable than ever before



Updated! Art program incorporates sound pedagogy and the best learning design principles based on the way today's students learn.

FIGURE 3.3 The decomposition of salt, NaCl, produces the elements sodium and chlorine.

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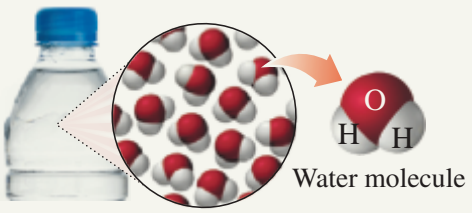
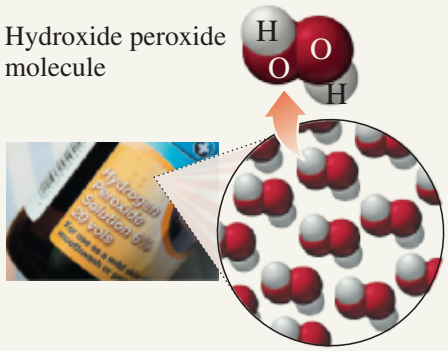
In-art captions replace long legends, and the flow and size of the art is updated to help increase student understanding.



A water molecule, H_2O, consists of two atoms of hydrogen (white) for one atom of oxygen (red).



A hydroxide peroxide molecule, H_2O_2, consists of two atoms of hydrogen (white) for every two atoms of oxygen (red).

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Engage students in learning chemistry

Chemistry Link to Health

Toxicology and Risk–Benefit Assessment

Each day, we make choices about what we do or what we eat, often without thinking about the risks associated with these choices. We are aware of the risks of cancer from smoking or the risks of lead poisoning, and we know there is a greater risk of having an accident if we cross a street where there is no light or crosswalk.

The LD_{50} of caffeine is 192 mg/kg.

A basic concept of toxicology is the statement of Paracelsus that the dose is the difference between a poison and a cure. To evaluate the level of danger from various substances, natural or synthetic, a risk assessment is made by exposing laboratory animals to the substances and monitoring the health effects. Often, doses very much greater than humans might ordinarily encounter are given to the test animals.

Many hazardous chemicals or substances have been identified by these tests. One measure of toxicity is the LD_{50}, or lethal dose, which is the concentration of the substance that causes death in 50% of the test animals. A dosage is typically measured in milligrams per kilogram (mg/kg) of body mass or micrograms per kilogram (mcg/kg) of body mass.

Other evaluations need to be made, but it is easy to compare LD_{50} values. Parathion, a pesticide, with an LD_{50} of 3 mg/kg, would be highly toxic. This means that 3 mg of parathion per kg of body mass would be fatal to half the test animals. Table salt (sodium chloride) with an LD_{50} of 3300 mg/kg would have a much lower toxicity. You would need to ingest a huge amount of salt before any toxic effect would be observed. Although the risk to animals can be evaluated in the laboratory, it is more difficult to determine the impact in the environment since there is also a difference between continued exposure and a single, large dose of the substance.

TABLE 2.9 lists some LD_{50} values and compares substances in order of increasing toxicity.

TABLE 2.9 Some LD_{50} Values for Substances Tested in Rats

Substance	LD_{50} (mg/kg)
Table sugar	29 700
Boric acid	5140
Baking soda	4220
Table salt	3300
Ethanol	2080
Aspirin	1100
Codeine	800
Oxycodone	480
Caffeine	192
DDT	113
Cocaine (injected)	95
Dichlorvos (pesticide strips)	56
Ricin	30
Sodium cyanide	6
Parathion	3

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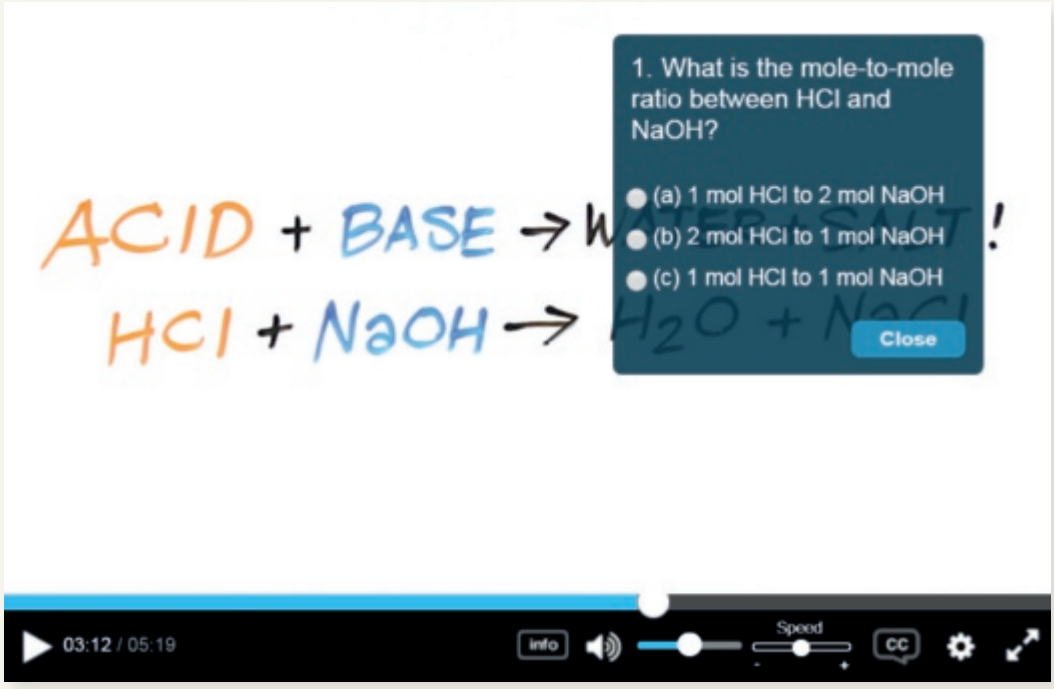
Updated! Chemistry Links to Health and Chemistry Links to the Environment appear throughout the text and relate chemistry concepts to real-life topics in health, the environment, and medicine. High-interest topics include weight loss and weight gain, hyperglycemia and hypoglycemia, antacids, gout and kidney stones, sweeteners, and essential amino acids. Follow-up questions also appear throughout the text.

Updated! Interactive Videos give students an opportunity to reinforce what they just learned by showing how chemistry works in real life and introducing a bit of humor into chemical problem solving and demonstrations. Topics include Using Conversion Factors, Mass Calculations for Reactions, Concentration of Solutions, Balancing Nuclear Equations, and Chemical v. Physical Change.



Tools to help students succeed

Features in This Text That Help You Study and Learn Chemistry

This text has been designed with study features to support your learning. On the inside of the front cover is a periodic table of the elements. On the inside of the back cover are tables that summarize useful information needed throughout your study of chemistry. Each chapter begins with *Looking Ahead*, which outlines the topics in the chapter. At the beginning of each section, a *Learning Goal* describes the topics to learn. *Review* icons in the margins refer to Key Math Skills or Core Chemistry Skills from previous chapters that relate to new material in the chapter. *Key Terms* are bolded when they first appear in the text and are summarized at the end of each chapter. They are also listed and defined in the comprehensive *Glossary and Index*, which appears at the end of the text. *Key Math Skills* and *Core Chemistry Skills* that are critical to learning chemistry are indicated by icons in the margin and summarized at the end of each chapter.

REVIEW

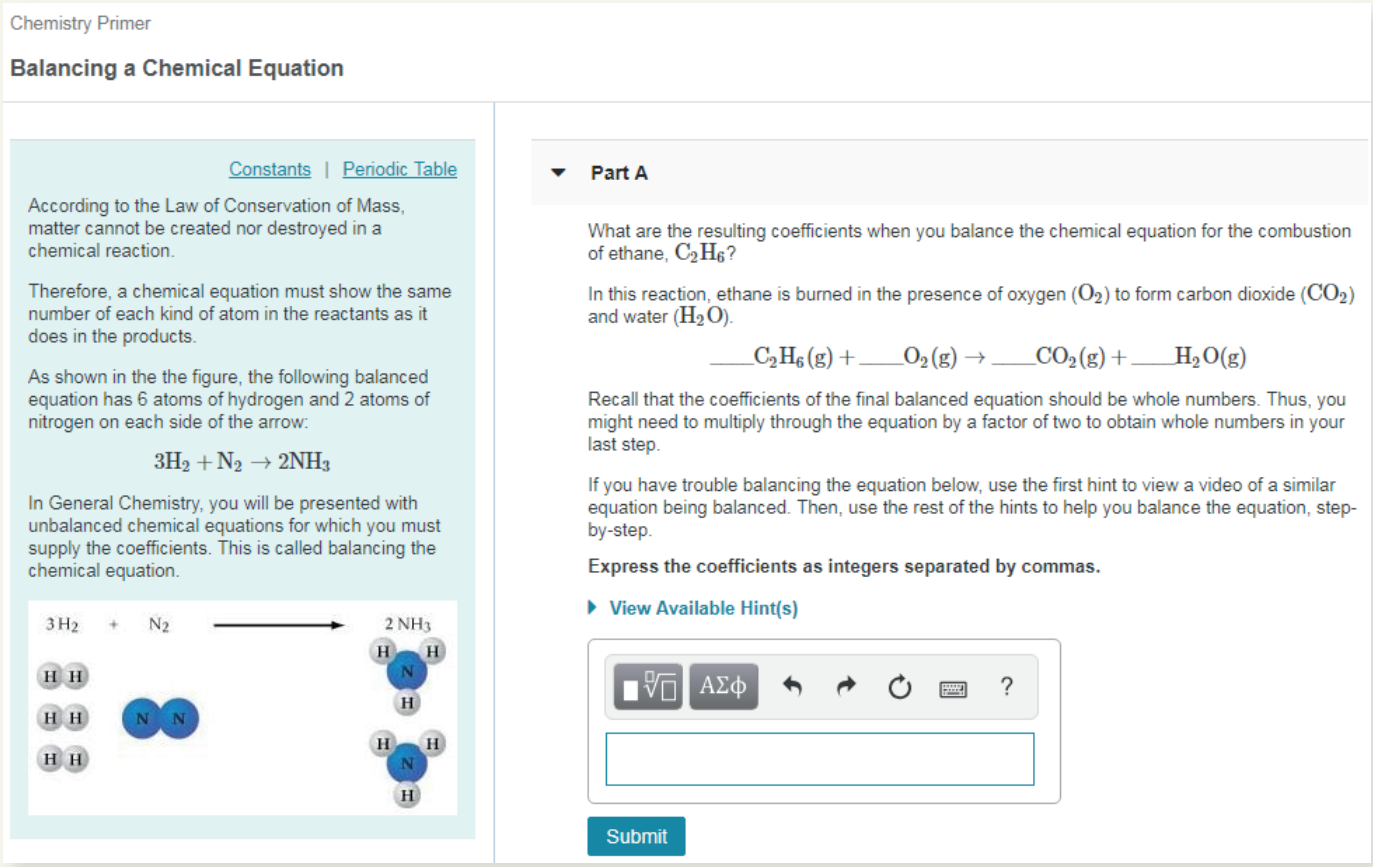
KEY MATH SKILL

CORE CHEMISTRY SKILL

ENGAGE

P. 7

Marginal notes and end-of-chapter problems deepen the connection between key math skills, core chemistry skills, textual content, practice problems, and why they are so important to success in the course.



The Chemistry Primer in Mastering Chemistry helps students remediate their chemistry math skills and prepare for their first college chemistry course. Scaled to students' needs, remediation is only suggested to students that perform poorly on an initial assessment. Remediation includes tutorials, wrong-answer specific feedback, video instruction, and stepwise scaffolding to build students' abilities.

Build students' problem-solving skills

ENGAGE 14.8
If you know the $[H_3O^+]$ of a solution, how do you use the K_w to calculate the $[OH^-]$?

SAMPLE PROBLEM 14.6 Calculating the $[H_3O^+]$ of a Solution

TRY IT FIRST

A vinegar solution has a $[OH^-] = 5.0 \times 10^{-12}$ M at 25 °C. What is the $[H_3O^+]$ of the vinegar solution? Is the solution acidic, basic, or neutral?

SOLUTION

STEP 1 State the given and needed quantities.

ANALYZE THE PROBLEM	Given	Need	Connect
	$[OH^-] = 5.0 \times 10^{-12}$ M	$[H_3O^+]$	$K_w = [H_3O^+][OH^-]$

STEP 2 Write the K_w for water and solve for the unknown $[H_3O^+]$.

$$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$$

Solve for $[H_3O^+]$ by dividing both sides by $[OH^-]$.

$$\frac{K_w}{[OH^-]} = \frac{[H_3O^+]\cancel{[OH^-]}}{\cancel{[OH^-]}}$$

$$[H_3O^+] = \frac{1.0 \times 10^{-14}}{[OH^-]}$$

STEP 3 Substitute the known $[OH^-]$ into the equation and calculate.

$$[H_3O^+] = \frac{1.0 \times 10^{-14}}{[5.0 \times 10^{-12}]} = 2.0 \times 10^{-3}\ \text{M}$$

Because the $[H_3O^+]$ of 2.0×10^{-3} M is larger than the $[OH^-]$ of 5.0×10^{-12} M, the solution is acidic.

ENGAGE 14.9
Why does the $[H_3O^+]$ of an aqueous solution increase if the $[OH^-]$ decreases?

SELF TEST 14.6

a. What is the $[H_3O^+]$ of an ammonia cleaning solution with $[OH^-] = 4.0 \times 10^{-4}$ M? Is the solution acidic, basic, or neutral?
b. The $[H_3O^+]$ of tomato juice is 6.3×10^{-5} M. What is the $[OH^-]$ of the juice? Is the tomato juice acidic, basic, or neutral?

ANSWER

a. $[H_3O^+] = 2.5 \times 10^{-11}$ M, basic **b.** $[OH^-] = 1.6 \times 10^{-10}$ M, acidic

PRACTICE PROBLEMS
Try Practice Problems 14.37 to 14.42

NEW! Pedagogical features in worked **Sample Problems** throughout the text help students build stronger problem-solving skills, setting them up for success in this and future courses.

TRY IT FIRST! Feature encourages students to solve the problem before looking at the solution.

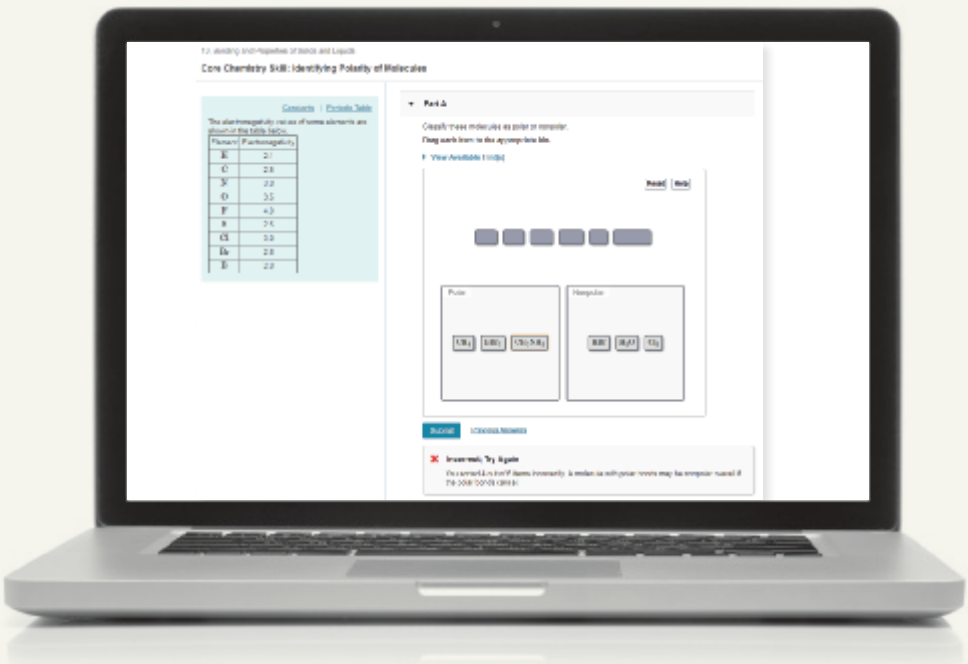
UPDATED! Connect feature added to **Analyze the Problem boxes** specify information that relates the **Given and Need** boxes to help students identify and connect the components within a word problem and show **STEPs** as guides that set up a solution strategy.

NEW! Engage questions remind students to pause and answer a question related to the material.

UPDATED! Self Tests provide students with immediate problem solving and feedback with answers.

NEW! Practice Problems suggest problems to work as students study the section.

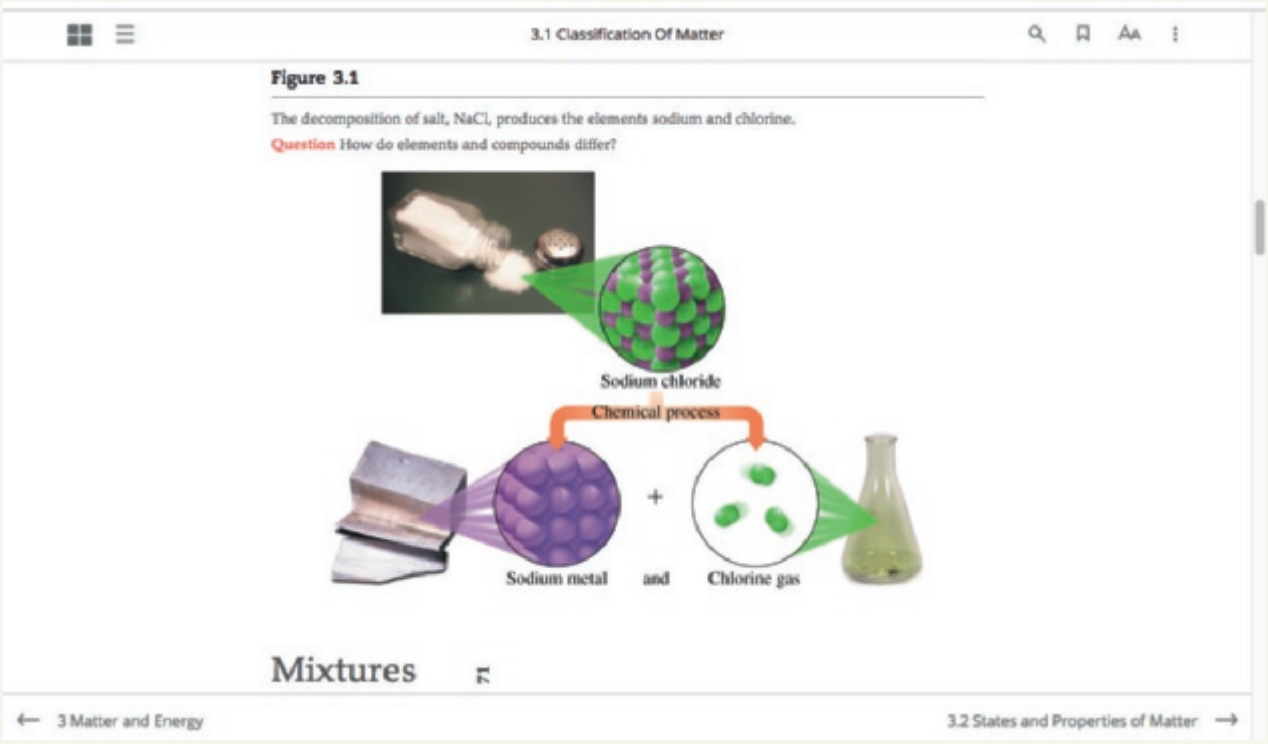
Core Chemistry Skills and Key Math Skills Tutorials in Mastering Chemistry provide assignable practice problems related to the in-text feature boxes, ensuring that students master the basic quantitative and science skills they need to succeed in the course.



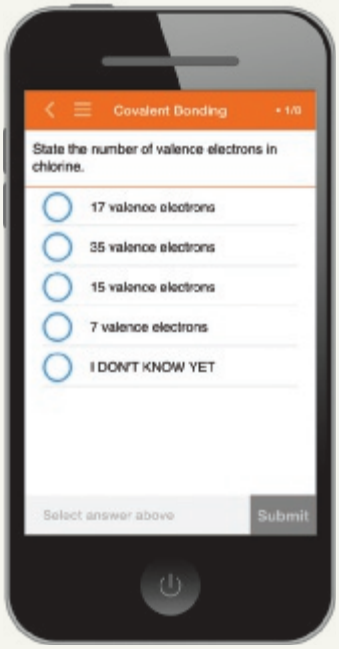
Give students anytime, anywhere access with Pearson eText

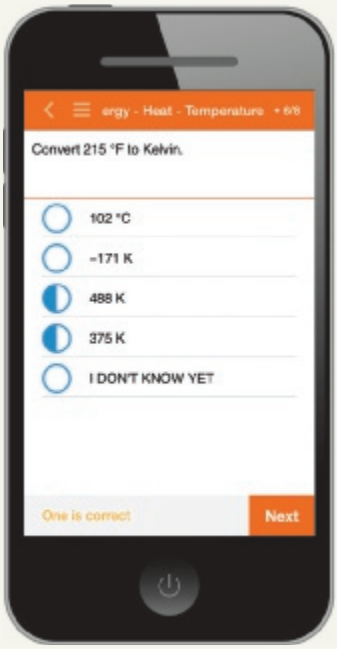
Pearson eText is a simple-to-use, mobile-optimized, personalized reading experience available within Mastering. It allows students to easily highlight, take notes, and review key vocabulary all in one place—even when offline. Seamlessly integrated videos, rich media, and interactive self-assessment questions engage students and give them access to the help they need, when they need it. Pearson eText is available within Mastering when packaged with a new book; students can also purchase Mastering with Pearson eText online.

For instructors not using Mastering, Pearson eText can also be adopted on its own as the main course material.

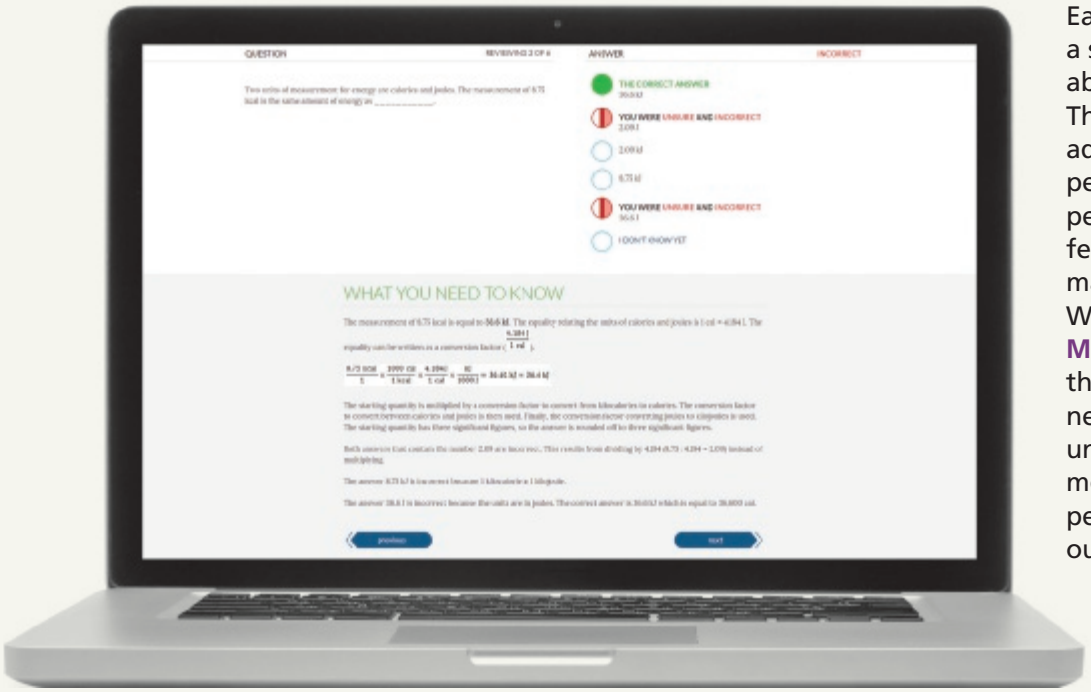


Improve learning with Dynamic Study Modules



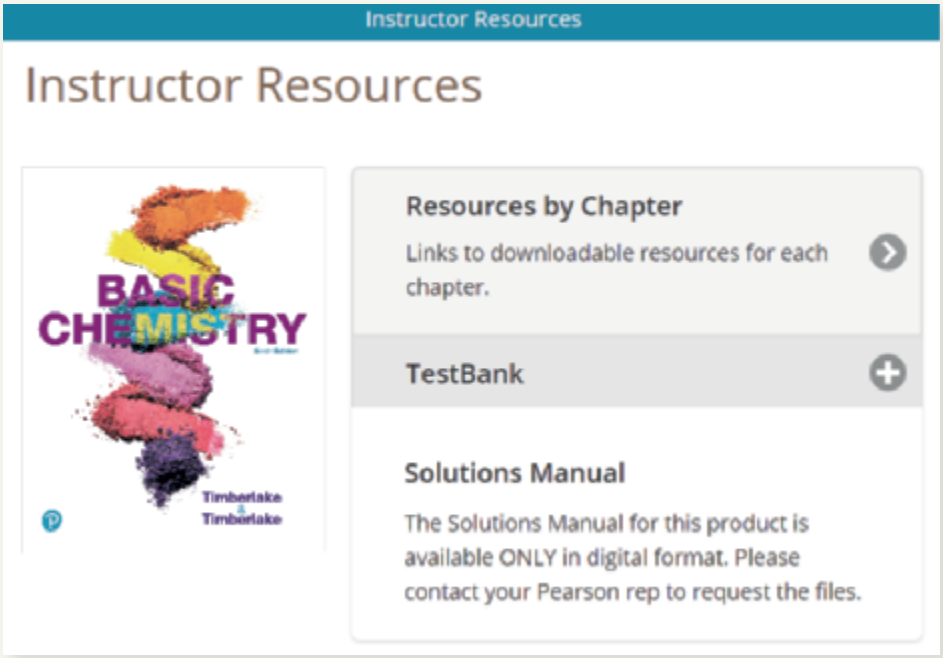


Dynamic Study Modules in Mastering Chemistry help students study effectively—and at their own pace—by keeping them motivated and engaged. The assignable modules rely on the latest research in cognitive science, using methods—such as adaptivity, gamification, and intermittent rewards—to stimulate learning and improve retention.

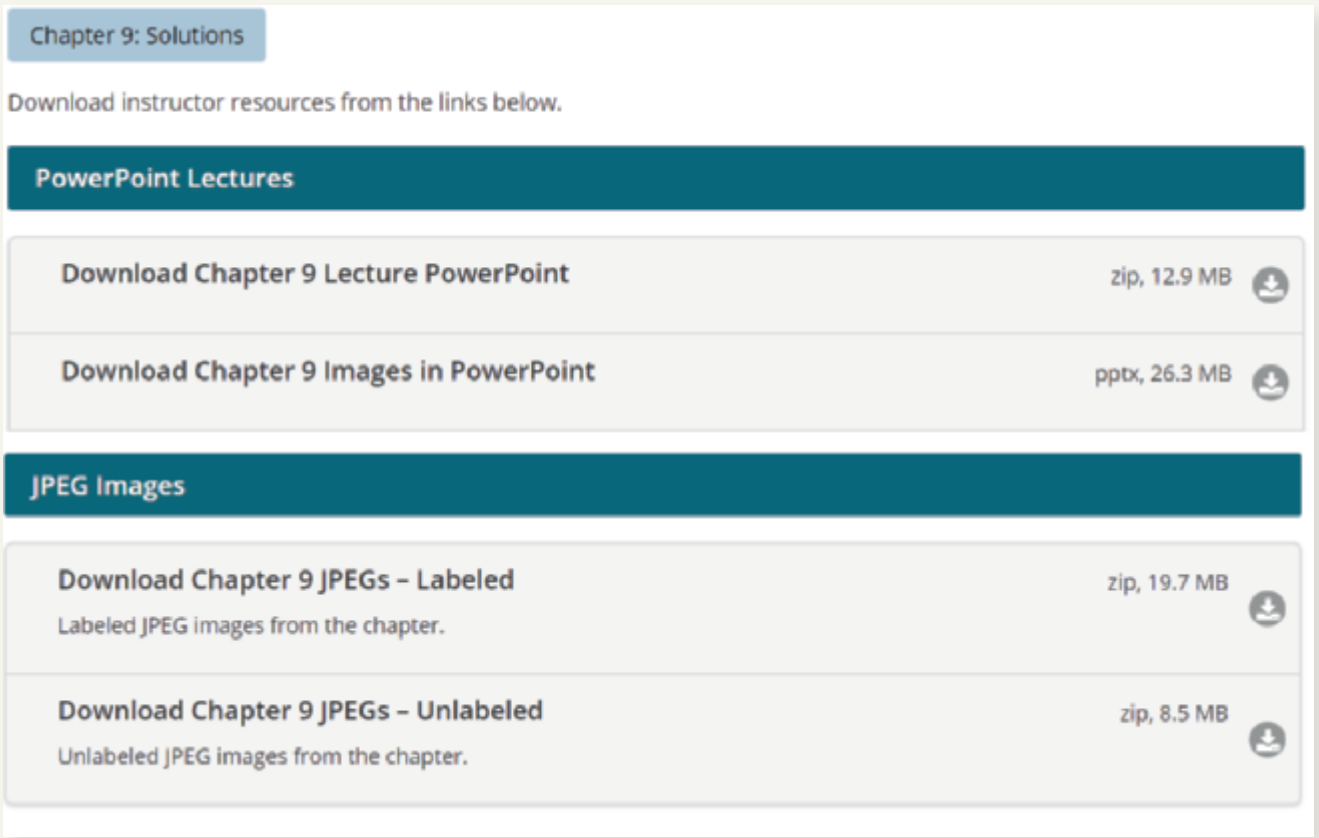


Each module poses a series of questions about a course topic. These question sets adapt to each student's performance and offer personalized, targeted feedback to help them master key concepts. With **Dynamic Study Modules,** students build the confidence they need to deepen their understanding, participate meaningfully, and perform better—in and out of class.

Instructor support you can rely on



Basic Chemistry includes a full suite of instructor support materials in the Instructor Resources area in Mastering Chemistry.



Resources include customizable PowerPoint lecture and image presentations; all images and worked examples from the text; and a test bank.

1 Chemistry in Our Lives

A call came in to 911 from a man who arrived home from work to find his wife, Gloria, lying on their living room floor. When the police arrive, they pronounce the woman dead. There is no blood at the scene, but the police do find a glass on the side table that contains a small amount of liquid. In an adjacent laundry room, the police find a half-empty bottle of antifreeze, which contains the toxic compound ethylene glycol. The bottle, glass, and liquid are bagged and sent to the forensic laboratory. At the morgue, Gloria's height is measured as 1.673 m, and her mass is 60.5 kg.

Sarah, a forensic scientist, uses scientific procedures and chemical tests to examine the evidence from law enforcement agencies. She analyzes blood, stomach contents, and the unknown liquid from Gloria's home, as well as the fingerprints on the glass. She also looks for the presence of drugs, poisons, and alcohol.

CAREER

Forensic Scientist

Most forensic scientists work in crime laboratories that are part of city or county legal systems. They analyze bodily fluids and tissue samples collected by crime scene investigators. In analyzing these samples, forensic scientists identify the presence or absence of specific chemicals within the body to help solve criminal cases. Some of the chemicals they look for include alcohol, illegal or prescription drugs, poisons, arson debris, metals, and various gases such as carbon monoxide. To identify these substances, they use a variety of instruments and highly specific methodologies. Forensic scientists analyze samples from criminal suspects, athletes, and potential employees. They also work on cases involving environmental contamination and animal samples for wildlife crimes. Forensic scientists usually have a bachelor's degree that includes courses in math, chemistry, and biology.

UPDATE Forensic Evidence Helps Solve the Crime

In the forensic laboratory, Sarah analyzes Gloria's stomach contents and blood for toxic compounds. You can view the results of the tests on the forensic evidence in the **UPDATE Forensic Evidence Helps Solve the Crime**, page 21, and determine if Gloria ingested a toxic level of ethylene glycol (antifreeze).

LOOKING AHEAD

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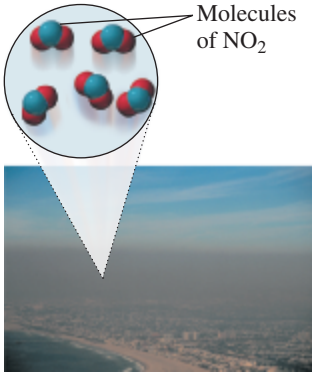


The chemical reaction of NO with oxygen in the air forms NO_2, which produces the reddish brown color of smog.

Antacid tablets undergo a chemical reaction when dropped into water.

ENGAGE 1.1

Why is water a chemical?

Toothpaste is a combination of many chemicals.

PRACTICE PROBLEMS

Try Practice Problems 1.1 to 1.6

1.1 Chemistry and Chemicals

LEARNING GOAL Define the term chemistry, and identify chemicals.

Now that you are in a chemistry class, you may be wondering what you will be learning. What questions in science have you been curious about? Perhaps you are interested in what smog is or how aspirin relieves a headache. Just like you, chemists are curious about the world we live in.

How does car exhaust produce the smog that hangs over our cities? One component of car exhaust is nitrogen oxide (NO), which forms in car engines where high temperatures convert nitrogen gas (N_2) and oxygen gas (O_2) to NO. In the atmosphere, the NO(g) reacts with $O_2(g)$ to form $NO_2(g)$, which has a reddish brown color of smog. In chemistry, reactions are written in the form of equations:

$$N_2(g) + O_2(g) \longrightarrow 2NO(g)$$
$$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$$

Smog

Why does aspirin relieve a headache? When a part of the body is injured, substances called prostaglandins are produced, which cause inflammation and pain. Aspirin acts to block the production of prostaglandins, reducing inflammation and pain. Chemists in the medical field develop new treatments for diabetes, genetic defects, cancer, AIDS, and other diseases. For the forensic scientist, the nurse, the dietitian, the chemical engineer, or the agricultural scientist, chemistry plays a central role in understanding problems and assessing possible solutions.

Chemistry

Chemistry is the study of the composition, structure, properties, and reactions of matter. *Matter* is another word for all the substances that make up our world. Perhaps you imagine that chemistry takes place only in a laboratory where a chemist is working in a white coat and goggles. Actually, chemistry happens all around you every day and has an impact on everything you use and do. You are doing chemistry when you cook food, add bleach to your laundry, or start your car. A chemical reaction has taken place when silver tarnishes or an antacid tablet fizzes when dropped into water. Plants grow because chemical reactions convert carbon dioxide, water, and energy to carbohydrates. Chemical reactions take place when you digest food and break it down into substances that you need for energy and health.

Chemicals

A **chemical** is a substance that always has the same composition and properties wherever it is found. All the things you see around you are composed of one or more chemicals. Often the terms *chemical* and *substance* are used interchangeably to describe a specific type of matter.

Every day, you use products containing substances that were developed and prepared by chemists. Soaps and shampoos contain chemicals that remove oils on your skin and scalp. In cosmetics and lotions, chemicals are used to moisturize, prevent deterioration of the product, fight bacteria, and thicken the product. Perhaps you wear a ring or watch made of gold, silver, or platinum. Your breakfast cereal is probably fortified with iron, calcium, and phosphorus, whereas the milk you drink is enriched with vitamins A and D. When you brush your teeth, the substances in toothpaste clean your teeth, prevent plaque formation, and stop tooth decay. Some of the chemicals used to make toothpaste are listed in **TABLE 1.1**.

TABLE 1.1 Chemicals Commonly Used in Toothpaste

Chemical	Function
Calcium carbonate	Used as an abrasive to remove plaque
Sorbitol	Prevents loss of water and hardening of toothpaste
Sodium lauryl sulfate	Used to loosen plaque
Titanium dioxide	Makes toothpaste white and opaque
Sodium fluorophosphate	Prevents formation of cavities by strengthening tooth enamel
Methyl salicylate	Gives toothpaste a pleasant wintergreen flavor

Branches of Chemistry

The field of chemistry is divided into several branches. *General chemistry* is the study of the composition, properties, and reactions of matter. *Organic chemistry* is the study of substances that contain the element carbon. *Biological chemistry* is the study of the chemical reactions that take place in biological systems. Today chemistry is often combined with other sciences, such as geology and physics, to form cross-disciplines such as geochemistry and physical chemistry. *Geochemistry* is the study of the chemical composition of ores, soils, and minerals of the surface of the Earth and other planets. *Physical chemistry* is the study of the physical nature of chemical systems, including energy changes.

A geochemist collects newly erupted lava samples from Kilauea Volcano, Hawaii.

PRACTICE PROBLEMS

1.1 Chemistry and Chemicals

In every chapter, odd-numbered exercises in the *Practice Problems* are paired with even-numbered exercises. The answers for the orange-shaded, odd-numbered *Practice Problems* are given at the end of each chapter. The complete solutions to the odd-numbered *Practice Problems* are in the *Study Guide and Student Solutions Manual*.

1.1 Write a one-sentence definition for each of the following:
a. chemistry **b.** chemical

1.2 Ask two of your friends (not in this class) to define the terms in problem 1.1. Do their answers agree with the definitions you provided?

Applications

1.3 Obtain a bottle of multivitamins, and read the list of ingredients. What are four chemicals from the list?

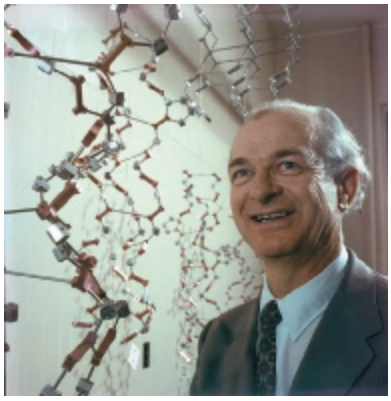
1.4 Obtain a box of breakfast cereal, and read the list of ingredients. What are four chemicals from the list?

1.5 Read the labels on some items found in a drugstore. What are the names of some chemicals contained in those items?

1.6 Read the labels on products used to wash your dishes. What are the names of some chemicals contained in those products?

1.2 Scientific Method: Thinking Like a Scientist

LEARNING GOAL Describe the scientific method.



Linus Pauling won the Nobel Prize in Chemistry in 1954.

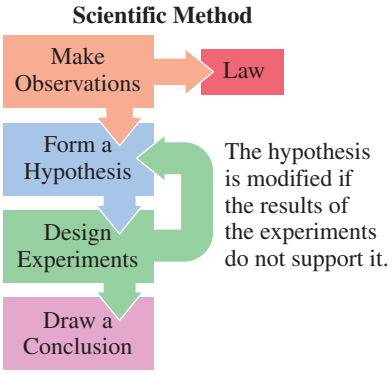
When you were very young, you explored the things around you by touching and tasting. As you grew, you asked questions about the world in which you live. What is lightning? Where does a rainbow come from? Why is the sky blue? As an adult, you may have wondered how antibiotics work or why vitamins are important to your health. Every day, you ask questions and seek answers to organize and make sense of the world around you.

When the late Nobel Laureate Linus Pauling (1901–1994) described his student life in Oregon, he recalled that he read many books on chemistry, mineralogy, and physics. "I mulled over the properties of materials: why are some substances colored and others not, why are some minerals or inorganic compounds hard and others soft?" He said, "I was building up this tremendous background of empirical knowledge and at the same time asking a great number of questions." Linus Pauling won two Nobel Prizes: the first, in 1954, was in chemistry for his work on the nature of chemical bonds and the determination of the structures of complex substances; the second, in 1962, was the Peace Prize, for his opposition to the spread of nuclear weapons.

The Scientific Method

The process of trying to understand nature is unique to each scientist. However, the **scientific method** is a process that scientists use to make observations in nature, gather data, and explain natural phenomena (see the figure on the next page).

1. **Make Observations** The first step in the scientific method is to make **observations** about nature and ask questions about what you observe. When an observation always seems to be true, it may be stated as a *law* that predicts that behavior and is often



The scientific method develops a conclusion about nature using observations, hypotheses, and experiments.

measurable. However, a law does not explain that observation. For example, we can use the *Law of Gravity* to predict that if we drop our chemistry book, it would fall on the floor, but this law does not explain why our book falls.

2. **Form a Hypothesis** A scientist forms a **hypothesis**, which gives a possible explanation of an observation or a law. The hypothesis must be stated in such a way that it can be tested by experiments.
3. **Design Experiments** To determine if a hypothesis is valid, **experiments** are done to find a relationship between the hypothesis and the observations. The results of the experiments may confirm the validity of the hypothesis. However, experiments may also show that the hypothesis is invalid, which means that it is modified or discarded. Then new experiments will be designed to test the new hypothesis.
4. **Draw a Conclusion** When many experiments give consistent results, we may draw the **conclusion** that the hypothesis is valid. Even then, more experiments are done to test the hypothesis. If new experimental results indicate the hypothesis is not valid, it is modified or replaced.

Chemistry Link to Health

Early Chemist: Paracelsus

For many centuries, chemistry has been the study of changes in matter. From the time of the ancient Greeks to the sixteenth century, alchemists described matter in terms of four components of nature: earth, air, fire, and water. By the eighth century, alchemists believed that they could change metals such as copper and lead into gold and silver. Although these efforts failed, the alchemists provided information on the chemical reactions involved in the extraction of metals from ores. The alchemists also designed some of the first laboratory equipments and developed early laboratory procedures. These early efforts were some of the first observations and experiments using the scientific method.

Paracelsus (1493–1541) was a physician and an alchemist who thought that alchemy should be about preparing new medicines. Using observation and experimentation, he proposed that a healthy body was regulated by a series of chemical processes that could be unbalanced by certain chemical compounds and rebalanced by using minerals and medicines. For example, he determined that inhaled dust caused lung disease in miners. He also thought that goiter was a problem caused by contaminated water, and he treated syphilis with compounds of mercury. His opinion of medicines was that the right dose makes the difference between a poison and a cure. Paracelsus changed alchemy in ways that helped establish modern medicine and chemistry.

Swiss physician and alchemist Paracelsus (1493–1541) believed that chemicals and minerals could be used as medicines.

Through observation you may think that you are allergic to cats.

Using the Scientific Method in Everyday Life

You may be surprised to realize that you use the scientific method in your everyday life. Suppose you visit a friend in her home. Soon after you arrive, your eyes start to itch and you begin to sneeze. Then you observe that your friend has a new cat. Perhaps you form the hypothesis that you are allergic to cats. To test your hypothesis, you leave your friend's home. If the sneezing stops, perhaps your hypothesis is correct. You test your hypothesis further by visiting another friend who also has a cat. If you start to sneeze again, your experimental results support your hypothesis, and you come to the conclusion that you are allergic to cats. However, if you continue sneezing after you leave your friend's home, your hypothesis is not supported. Now you need to form a new hypothesis, which could be that you have a cold.

ENGAGE 1.2

Why would the following statement, "Today I placed two tomato seedlings in the garden, and two more in a closet. I will give all the plants the same amount of water and fertilizer," be considered an experiment?

SAMPLE PROBLEM 1.1 Scientific Method

TRY IT FIRST

Identify each of the following as an observation, a hypothesis, an experiment, or a conclusion:

a. During an assessment in the emergency room, a nurse writes that the patient has a resting pulse of 30 beats/min.

b. Repeated studies show that lowering sodium in the diet leads to a decrease in blood pressure.
c. A nurse thinks that an incision from a recent surgery that is red and swollen is infected.

SOLUTION

a. observation **b.** conclusion **c.** hypothesis

Nurses make observations in the hospital.

SELF TEST 1.1

Identify each of the following as an observation, a hypothesis, an experiment, or a conclusion:

a. Drinking coffee at night keeps me awake.
b. I will try drinking coffee only in the morning.
c. If I stop drinking coffee in the afternoon, I will be able to sleep at night.
d. When I drink decaffeinated coffee, I sleep better at night.
e. I am going to drink only decaffeinated coffee.
f. I sleep better at night because I stopped drinking caffeinated drinks.

ANSWER

a. observation **b.** experiment **c.** hypothesis
d. observation **e.** experiment **f.** conclusion

PRACTICE PROBLEMS

Try Practice Problems 1.7 to 1.10

PRACTICE PROBLEMS

1.2 Scientific Method: Thinking Like a Scientist

1.7 Identify each activity, **a** to **f**, as an observation, a hypothesis, an experiment, or a conclusion.
At a popular restaurant, where Chang is the head chef, the following occurred:
a. Chang determined that sales of the house salad had dropped.
b. Chang decided that the house salad needed a new dressing.
c. In a taste test, Chang prepared four bowls of sliced cucumber, each with a new dressing: sesame seed, olive oil and balsamic vinegar, creamy Italian, and blue cheese.
d. Tasters rated the sesame seed salad dressing as the favorite.
e. After two weeks, Chang noted that the orders for the house salad with the new sesame seed dressing had doubled.
f. Chang decided that the sesame seed dressing improved the sales of the house salad because the sesame seed dressing enhanced the taste.

Customers rated the sesame seed dressing as the best.

1.8 Identify each activity, **a** to **f**, as an observation, a hypothesis, an experiment, or a conclusion.
Lucia wants to develop a process for dyeing shirts so that the color will not fade when the shirt is washed. She proceeds with the following activities:
a. Lucia notices that the dye in a design fades when the shirt is washed.
b. Lucia decides that the dye needs something to help it combine with the fabric.
c. She places a spot of dye on each of four shirts and then places each one separately in water, salt water, vinegar, and baking soda and water.
d. After one hour, all the shirts are removed and washed with a detergent.
e. Lucia notices that the dye has faded on the shirts in water, salt water, and baking soda, whereas the dye did not fade on the shirt soaked in vinegar.
f. Lucia thinks that the vinegar binds with the dye so it does not fade when the shirt is washed.

Applications

1.9 Identify each of the following as an observation, a hypothesis, an experiment, or a conclusion:
a. One hour after drinking a glass of regular milk, Jim experienced stomach cramps.
b. Jim thinks he may be lactose intolerant.
c. Jim drinks a glass of lactose-free milk and does not have any stomach cramps.
d. Jim drinks a glass of regular milk to which he has added lactase, an enzyme that breaks down lactose, and has no stomach cramps.

1.10 Identify each of the following as an observation, a hypothesis, an experiment, or a conclusion:
a. Sally thinks she may be allergic to shrimp.
b. Yesterday, one hour after Sally ate a shrimp salad, she broke out in hives.
c. Today, Sally had some soup that contained shrimp, but she did not break out in hives.
d. Sally realizes that she does not have an allergy to shrimp.

1.3 Studying and Learning Chemistry

LEARNING GOAL Identify strategies that are effective for learning. Develop a study plan for learning chemistry.

Here you are taking chemistry, perhaps for the first time. Whatever your reasons for choosing to study chemistry, you can look forward to learning many new and exciting ideas.

Strategies to Improve Learning and Understanding

Success in chemistry utilizes good study habits, connecting new information with your knowledge base, rechecking what you have learned and what you have forgotten, and retrieving what you have learned for an exam. Let's take a look at ways that can help you study and learn chemistry. Suppose you were asked to indicate if you think each of the following common study habits is helpful or not helpful:

	Helpful	Not helpful
Highlighting		
Underlining		
Reading the chapter many times		
Memorizing the key words		
Testing practice		
Cramming		
Studying different ideas at the same time		
Retesting a few days later		

Learning chemistry requires us to place new information in our long-term memory, which allows us to remember those ideas for an exam, a process called *retrieval*. Thus, our study habits need to help us to recall knowledge. The study habits that are not very helpful in retrieval include highlighting, underlining, reading the chapter many times, memorizing key words, and cramming. If we want to recall new information, we need to connect it with prior knowledge. By doing practice tests, you develop the skills needed to retrieve new information. We can determine how much we have learned by going back a few days later and retesting. Another useful learning strategy is to study different ideas at the same time, which allows us to connect those ideas and to differentiate between them. Although these study habits may take more time and seem more difficult, they help us find the gaps in our knowledge and connect new information with what we already know.

Tips for Using New Study Habits for Successful Learning

1. **Do not keep rereading text or notes.** Reading the same material over and over will make that material seem familiar but does not mean that you have learned it. You need to test yourself to find out what you do and do not know.
2. **Ask yourself questions as you read.** Asking yourself questions as you read requires you to interact continually with new material. The *Engage* features in the margin of this text are helpful in asking you to think about new material. By linking new material with long-term knowledge, you make pathways for retrieving new material.
3. **Self-test by giving yourself quizzes.** Using problems in the text or sample exams, practice taking tests frequently.
4. **Study at a regular pace rather than cramming.** Once you have tested yourself, go back in a few days and practice testing and retrieving information again. We do not recall all the information when we first read it. By frequent quizzing and retesting, we identify what we still need to learn. Sleep is also important for strengthening the associations between newly learned information. Lack of sleep may interfere with retrieval of information as well. So staying up all night to cram for your chemistry exam is not a good idea. Success in chemistry is a combined effort to learn new information and then to retrieve that information when you need it for an exam.

Students learn by continuously asking and answering questions as they study new material.

5. **Study different topics in a chapter, and relate the new concepts to concepts you know.** We learn material more efficiently by relating it to information we already know. By increasing connections between concepts, we can retrieve information when we need it.

Helpful	Not helpful
Testing practice	Highlighting
Studying different ideas at the same time	Underlining
Retesting a few days later	Reading the chapter many times
	Memorizing the key words
	Cramming

ENGAGE 1.3

Why is self-testing helpful for learning new concepts?

SAMPLE PROBLEM 1.2 Strategies for Learning Chemistry

TRY IT FIRST

Predict which student, **a**, **b**, or **c**, will be most successful on the exam.

a. Bill, who reads the chapter four times
b. Jennifer, who reads the chapter two times and works all the problems at the end of each section
c. Mark, who reads the chapter the night before the exam

SOLUTION

b. Jennifer, who reads the chapter two times and works all the problems at the end of each section, interacts with the content in the chapter using self-testing to make connections between concepts and practicing retrieving information learned previously.

SELF TEST 1.2

What are two more ways that Jennifer could improve her retrieval of information?

ANSWER

1. Jennifer could wait two or three days and practice working the problems in each section again to determine how much she has learned. Retesting strengthens connections between new and previously learned information for longer lasting memory and more efficient retrieval.
2. Jennifer could also ask questions as she reads and try to study at a regular pace to avoid cramming.

Features in This Text That Help You Study and Learn Chemistry

This text has been designed with study features to support your learning. On the inside of the front cover is a periodic table of the elements. On the inside of the back cover are tables that summarize useful information needed throughout your study of chemistry. Each chapter begins with *Looking Ahead*, which outlines the topics in the chapter. At the beginning of each section, a *Learning Goal* describes the topics to learn. *Review* icons in the margins refer to Key Math Skills or Core Chemistry Skills from previous chapters that relate to new material in the chapter. *Key Terms* are bolded when they first appear in the text and are summarized at the end of each chapter. They are also listed and defined in the comprehensive *Glossary and Index*, which appears at the end of the text. *Key Math Skills* and *Core Chemistry Skills* that are critical to learning chemistry are indicated by icons in the margin and summarized at the end of each chapter.

Before you begin reading, obtain an overview of a chapter by reviewing the topics in Looking Ahead. As you prepare to read a section of the chapter, look at the section title, and turn it into a question. Asking yourself questions about new topics builds new connections to material you have already learned. For example, for Section 1.1, "Chemistry and Chemicals," you could ask, "What is chemistry?" or "What are chemicals?" At the beginning of

REVIEW

KEY MATH SKILL

CORE CHEMISTRY SKILL

ENGAGE

each section, a *Learning Goal* states what you need to understand. As you read the text, you will see *Engage* questions in the margin, which remind you to pause your reading and test yourself with a question related to the material. The *Answers to Engage Questions* are at the end of each chapter.

Several *Sample Problems* are included in each chapter. The *Try It First* feature reminds you to work the problem before you look at the *Solution*. It is helpful to try to work a problem first because it helps you link what you know to what you need to learn. The *Analyze the Problem* feature includes *Given*, the information you have; *Need*, what you have to accomplish; and *Connect*, how you proceed. Sample Problems include a Solution that shows the steps you can use for problem solving. Work the associated *Self Test* problems, and compare your answer to the one provided.

At the end of each chapter section, you will find a set of *Practice Problems* that allows you to apply problem solving immediately to the new concepts. Throughout each section, *Practice Problem* icons remind you to try the indicated Practice Problems as you study. The *Applications* in the Practice Problems relate the content to health, careers, and real-life examples. The problems are paired, which means that each of the odd-numbered problems is matched to the following even-numbered problem. At the end of each chapter, the *Answers* to all the odd-numbered problems are provided. If the answers match yours, you most likely understand the topic; if not, you need to study the section again.

Throughout each chapter, boxes titled *Chemistry Link to Health* and *Chemistry Link to the Environment* help you relate the chemical concepts you are learning to real-life situations. Many of the figures and diagrams use macro-to-micro illustrations to depict the atomic level of organization of ordinary objects, such as the atoms in aluminum foil. These visual models illustrate the concepts described in the text and allow you to "see" the world in a microscopic way. *Interactive Video* suggestions illustrate content as well as problem solving.

At the end of each chapter, you will find several study aids that complete the chapter. *Chapter Reviews* provide a summary in easy-to-read bullet points, and *Concept Maps* visually show the connections between important topics. *Understanding the Concepts* are problems that use art and models to help you visualize concepts and connect them to your background knowledge. *Additional Practice Problems* and *Challenge Problems* provide additional exercises to test your understanding of the topics in the chapter.

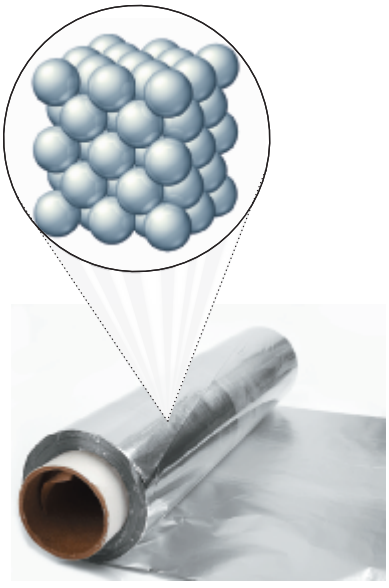
After some chapters, problem sets called *Combining Ideas* test your ability to solve problems containing material from more than one chapter.

Many students find that studying with a group can be beneficial to learning. In a group, students motivate each other to study, fill in gaps, and correct misunderstandings by teaching and learning together. Studying alone does not allow the process of peer correction. In a group, you can cover the ideas more thoroughly as you discuss the reading and problem solve with other students.

TRY IT FIRST

ANALYZE THE PROBLEM	Given	Need	Connect

PRACTICE PROBLEMS



Illustrating the atoms of aluminum in aluminum foil is an example of macro-to-micro art.

INTERACTIVE VIDEO

Pearson eText

Making a Study Plan

As you embark on your journey into the world of chemistry, think about your approach to studying and learning chemistry. You might consider some of the ideas in the following list. Check those ideas that will help you successfully learn chemistry. Commit to them now. *Your* success depends on *you*.

My study plan for learning chemistry will include the following:

_____ reading the chapter before class
_____ going to class
_____ reviewing the Learning Goals
_____ keeping a problem notebook
_____ reading the text
_____ working the Practice Problems as I read each section
_____ answering the Engage questions
_____ trying to work the Sample Problem before looking at the Solution
_____ studying different topics at the same time
_____ organizing a study group

_____ seeing the professor during office hours
_____ reviewing Key Math Skills and Core Chemistry Skills
_____ attending review sessions
_____ studying as often as I can

SAMPLE PROBLEM 1.3 A Study Plan for Learning Chemistry

TRY IT FIRST

Which of the following activities should you include in your study plan for learning chemistry successfully?

a. reading the chapter over and over until you think you understand it
b. going to the professor's office hours
c. doing the Self Test associated with each Sample Problem
d. waiting to study until the night before the exam
e. trying to work the Sample Problem before looking at the Solution
f. retesting on new information a few days later

SOLUTION

b, **c**, **e**, and **f**

SELF TEST 1.3

Which of the following will help you learn chemistry?

a. skipping review sessions
b. working Practice Problems as you read each section
c. staying up all night before an exam
d. reading the assignment before class
e. highlighting the key ideas in the text

ANSWER

b and **d**

PRACTICE PROBLEMS

Try Practice Problems 1.11 to 1.14

PRACTICE PROBLEMS

1.3 Studying and Learning Chemistry

1.11 What are four things you can do to help yourself to succeed in chemistry?

1.12 What are four things that would make it difficult for you to learn chemistry?

1.13 A student in your class asks you for advice on learning chemistry. Which of the following might you suggest?
a. forming a study group
b. skipping class
c. asking yourself questions while reading the text
d. waiting until the night before an exam to study
e. answering the Engage questions

1.14 A student in your class asks you for advice on learning chemistry. Which of the following might you suggest?
a. studying different topics at the same time
b. not reading the text; it's never on the test
c. attending review sessions
d. working the problems again after a few days
e. keeping a problem notebook

1.4 Key Math Skills for Chemistry

LEARNING GOAL Review math concepts used in chemistry: place values, positive and negative numbers, percentages, solving equations, and interpreting graphs.

During your study of chemistry, you will work many problems that involve numbers. You will need various math skills and operations. We will review some of the key math skills that are particularly important for chemistry. As we move through the chapters, we will also reference the key math skills as they apply.