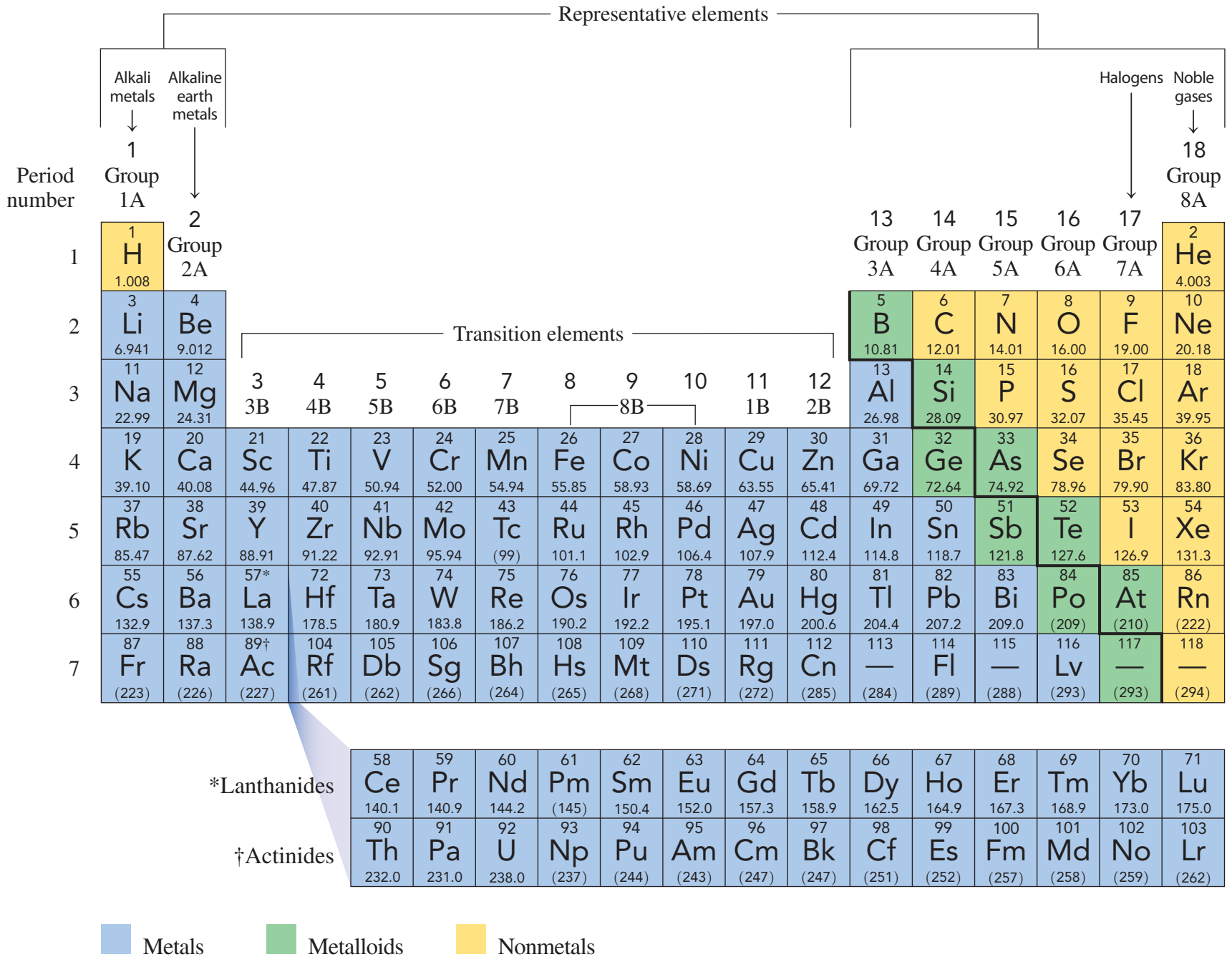
FIFTH EDITION

BASIC CHEMISTRY

Timberlake & Timberlake

Periodic Table of Elements



Atomic Masses of the Elements

Name	Symbol	Atomic Number	Atomic Mass[a]	Name	Symbol	Atomic Number	Atomic Mass[a]
Actinium	Ac	89	(227)[b]	Mendelevium	Md	101	(258)
Aluminum	Al	13	26.98	Mercury	Hg	80	200.6
Americium	Am	95	(243)	Molybdenum	Mo	42	95.94
Antimony	Sb	51	121.8	Neodymium	Nd	60	144.2
Argon	Ar	18	39.95	Neon	Ne	10	20.18
Arsenic	As	33	74.92	Neptunium	Np	93	(237)
Astatine	At	85	(210)	Nickel	Ni	28	58.69
Barium	Ba	56	137.3	Niobium	Nb	41	92.91
Berkelium	Bk	97	(247)	Nitrogen	N	7	14.01
Beryllium	Be	4	9.012	Nobelium	No	102	(259)
Bismuth	Bi	83	209.0	Osmium	Os	76	190.2
Bohrium	Bh	107	(264)	Oxygen	O	8	16.00
Boron	B	5	10.81	Palladium	Pd	46	106.4
Bromine	Br	35	79.90	Phosphorus	P	15	30.97
Cadmium	Cd	48	112.4	Platinum	Pt	78	195.1
Calcium	Ca	20	40.08	Plutonium	Pu	94	(244)
Californium	Cf	98	(251)	Polonium	Po	84	(209)
Carbon	C	6	12.01	Potassium	K	19	39.10
Cerium	Ce	58	140.1	Praseodymium	Pr	59	140.9
Cesium	Cs	55	132.9	Promethium	Pm	61	(145)
Chlorine	Cl	17	35.45	Protactinium	Pa	91	231.0
Chromium	Cr	24	52.00	Radium	Ra	88	(226)
Cobalt	Co	27	58.93	Radon	Rn	86	(222)
Copernicium	Cn	112	(285)	Rhenium	Re	75	186.2
Copper	Cu	29	63.55	Rhodium	Rh	45	102.9
Curium	Cm	96	(247)	Roentgenium	Rg	111	(272)
Darmstadtium	Ds	110	(271)	Rubidium	Rb	37	85.47
Dubnium	Db	105	(262)	Ruthenium	Ru	44	101.1
Dysprosium	Dy	66	162.5	Rutherfordium	Rf	104	(261)
Einsteinium	Es	99	(252)	Samarium	Sm	62	150.4
Erbium	Er	68	167.3	Scandium	Sc	21	44.96
Europium	Eu	63	152.0	Seaborgium	Sg	106	(266)
Fermium	Fm	100	(257)	Selenium	Se	34	78.96
Flerovium	Fl	114	(289)	Silicon	Si	14	28.09
Fluorine	F	9	19.00	Silver	Ag	47	107.9
Francium	Fr	87	(223)	Sodium	Na	11	22.99
Gadolinium	Gd	64	157.3	Strontium	Sr	38	87.62
Gallium	Ga	31	69.72	Sulfur	S	16	32.07
Germanium	Ge	32	72.64	Tantalum	Ta	73	180.9
Gold	Au	79	197.0	Technetium	Tc	43	(99)
Hafnium	Hf	72	178.5	Tellurium	Te	52	127.6
Hassium	Hs	108	(265)	Terbium	Tb	65	158.9
Helium	He	2	4.003	Thallium	Tl	81	204.4
Holmium	Ho	67	164.9	Thorium	Th	90	232.0
Hydrogen	H	1	1.008	Thulium	Tm	69	168.9
Indium	In	49	114.8	Tin	Sn	50	118.7
Iodine	I	53	126.9	Titanium	Ti	22	47.87
Iridium	Ir	77	192.2	Tungsten	W	74	183.8
Iron	Fe	26	55.85	Uranium	U	92	238.0
Krypton	Kr	36	83.80	Vanadium	V	23	50.94
Lanthanum	La	57	138.9	Xenon	Xe	54	131.3
Lawrencium	Lr	103	(262)	Ytterbium	Yb	70	173.0
Lead	Pb	82	207.2	Yttrium	Y	39	88.91
Lithium	Li	3	6.941	Zinc	Zn	30	65.41
Livermorium	Lv	116	(293)	Zirconium	Zr	40	91.22
Lutetium	Lu	71	175.0	—	—	113	(284)
Magnesium	Mg	12	24.31	—	—	115	(288)
Manganese	Mn	25	54.94	—	—	117	(293)
Meitnerium	Mt	109	(268)	—	—	118	(294)

[a]Values for atomic masses are given to four significant figures.
[b]Values in parentheses are the mass number of an important radioactive isotope.

BASIC CHEMISTRY

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BASIC CHEMISTRY

Fifth Edition

KAREN TIMBERLAKE
WILLIAM TIMBERLAKE

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Brief Contents

Table of Contents

4 Atoms and Elements 102

5 Electronic Structure of Atoms and Periodic Trends 131

6 Ionic and Molecular Compounds 165

7 Chemical Quantities 194

14 Acids and Bases 443

15 Oxidation and Reduction 491

16 Nuclear Chemistry 523

Applications and Activities

Key Math Skills

Core Chemistry Skills

Guide to Problem Solving

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 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*, fifth edition, she is also the author of *General, Organic,* and *Biological Chemistry: Structures of Life*, fifth edition, with the accompanying *Study Guide*, *and Chemistry: An Introduction to General, Organic, and Biological Chemistry*, twelfth 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 taking 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***

Preface

Welcome to the fifth 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 a positive experience for you by relating the structure and behavior of matter to real life. This new edition introduces more problem-solving strategies, more problem-solving guides, new Analyze the Problem with Connect features, new Try It First and Engage features, conceptual and challenge problems, and new sets of combined 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 that lead to your success in chemistry
- promote learning and success in chemistry

New for the Fifth Edition

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

- **NEW AND UPDATED! Chapter Openers** provide timely examples and engaging, topical issues of the chemistry that is part of contemporary professions.
- **NEW!** A **Follow Up** story continues with material and questions related to the chapter opener.
- **NEW! Engage** feature asks students to think about the paragraph they are reading and to test their understanding by answering the Engage question in the margin, which is related to the topic.
- **NEW! Try It First** now precedes the Solution section of each Sample Problem to encourage the student to work on the problem before reading the given Solution.
- **NEW! Connect** feature added to **Analyze** the **Problem** boxes indicates the relationships between *Given* and *Need*.
- **NEW! Applications** are added to Questions and Problems sets that show the relevance between the chemistry content and the chapter opener story.
- **NEW!** A new topic with questions and problems on Hess's Law, was added to Chapter 9.
- **NEW! Interactive Videos** give students the experience of step-by-step problem solving for problems from the text.
- **UPDATED! Chapter Readiness** sections at the beginning of each chapter list the Key Math Skills and Core Chemistry Skills from the previous chapters, which provide the foundation for learning new chemistry principles in the current chapter.
- **UPDATED! Key Math Skills** review basic math relevant to the chemistry the students are learning throughout the text. A **Key Math Skill Review** at the end of each chapter summarizes and gives additional examples.
- **UPDATED! Core Chemistry Skills** identify the key chemical principles in each chapter that are required for successfully learning chemistry. A **Core Chemistry Skill Review** at the end of each chapter helps reinforce the material and gives additional examples.
- **UPDATED! Analyze the Problem** features included in the Solutions of the Sample Problems strengthen critical-thinking skills and illustrate the breakdown of a word problem into the components required to solve it.
- **UPDATED! Questions and Problems, Sample Problems, and art** demonstrate the connection between the chemistry being discussed and how these skills will be needed in professional experience.
- **UPDATED! Combining Ideas** features offer sets of integrated problems that test students' understanding by integrating topics from two or more previous chapters.

Chapter Organization of the Fifth 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, 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 and Follow Up feature the work and career of a forensic scientist.
- "Scientific Method: Thinking Like a Scientist" discusses the scientific method in everyday terms.

- A new Sample Problem requires the interpretation of a graph to determine the decrease in a child's temperature when given Tylenol.
- Key Math Skills are: Identifying Place Values, Using Positive and Negative Numbers in Calculations including a new feature Calculator Operations, Calculating Percentages, Solving Equations, Interpreting Graphs, and Converting between Standard Numbers and 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 and Follow Up feature the work and career of a registered nurse.
- New photos, including an endoscope, a urine dipstick, a pint of blood, Keflex capsules, and salmon for omega-3 fatty acids, are added to improve visual introduction to clinical applications of chemistry.
- Updated Sample Problems relate questions and problem solving to health-related topics such as the measurements of blood volume, omega-3 fatty acids, radiological imaging, and medication orders.
- New Applications feature questions about measurements of daily values for minerals and vitamins, equalities and conversion factors for medications.
- A new Key Math Skill, Rounding Off, has been added.
- 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 changes and physical and chemical properties are discussed.

- The Chapter Opener and Follow Up feature the work and career of a dietitian.
- New Questions and 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, and ice bag therapy for muscle injury.
- Core Chemistry Skills are: Classifying Matter, 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 element. The names and symbols of element 114, Flerovium, Fl, and element 116, Livermorium, Lv, are part of the periodic table. Atomic numbers and mass number are determined for isotopes. Atomic mass is calculated using the masses of the naturally occurring isotopes and their abundances.

- The Chapter Opener and Follow Up 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.
- A weighted average analogy uses 8-lb and 14-lb bowling balls and the percent abundance of each to calculate weighted average of a bowling ball.
- Core Chemistry Skills are: Counting Protons and Neutrons, and Writing Atomic Symbols for Isotopes.

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 radius and ionization energy, are related to their valence electrons. Small periodic tables illustrate the trends of periodic properties.

- The Chapter Opener and Follow Up feature the work and career of a materials engineer.
- The diagram for the electromagnetic spectrum has been updated.
- 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.
- Core Chemistry Skills are: Writing Electron Configurations, Using the Periodic Table to Write Electron Configurations, Identifying Trends in Periodic Properties, and Drawing Lewis Symbols.

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 and Follow Up feature the work and career of a pharmacist.
- 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 Follow Up feature the work and career of a veterinarian.
- New and updated Guides to Problem Solving are: Converting the Moles (or Particles) of a Substance to Particles (or Moles), Calculating Moles of a Compound or Element, Calculating the Grams of an Element (or Compound) from the Grams of a Compound (or Element), and Calculating Mass Percent Composition from Molar Mass.
- 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 introduces the method of balancing chemical equations, and discusses how to classify chemical reactions into types: combination, decomposition, single replacement, double replacement, and combustion reactions. A new section, Oxidation–Reduction Reactions, has been added.

- The Chapter Opener and Follow Up feature 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. A first section was divided into two new sections with an emphasis on the Law of Conservation of Mass.

- The Chapter Opener and Follow Up feature the work and career of an environmental scientist.
- Mole and mass relationships among the reactants and products are examined along with calculations of percent yield and limiting reactants.
- A new subsection, with questions and problems on Hess's Law, was added.
- 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, 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 Follow Up feature the work and career of a histologist.
- 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 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 Follow Up feature the work and career of a respiratory therapist.
- Applications includes 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 ionic compounds, concentrations, and osmosis. New problem-solving strategies clarify

the use of concentrations to determine volume or mass of solute. The volumes and concentrations of solutions are used in calculations of dilutions, reactions, and titrations. Properties of solutions, osmosis in the body, dialysis and changes in the freezing and boiling points of a solvent are discussed.

- The Chapter Opener and Follow Up feature the work and career of a dialysis nurse.
- 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 Follow Up feature the work and career of a chemical oceanographer.
- New problems that visually represent equilibrium situations are added.
- 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 and Follow Up feature work and career of a clinical laboratory technician.
- A new Guide to Writing the Acid Dissociation Expression has been added.
- 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 spontaneous direction of an oxidation–reduction reaction.

- The Chapter Opener and Follow Up feature the work and career of a dentist.
- A new Guide to Identifying Oxidizing and Reducing Agents has been 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 Follow Up feature the work and career of a radiologist.
- 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 and line-angle structural formulas of alkanes, alkenes, alcohols, ethers, aldehydes, ketones, carboxylic acids, esters, amines, and amides.

- The Chapter Opener and Follow Up feature the work and career of a firefighter/emergency medical technician.
- The properties of organic and inorganic compounds are now compared in Table 17.1.

- Line-angle structural formulas were added to Table 17.2 IUPAC Names, Molecular Formulas, Condensed and Line-Angle Structural Formulas of the First Ten 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.
- The topic of structural isomers was added using condensed and line-angle structural formulas.
- Common substituents butyl, isobutyl, *sec*-butyl and *tert*-butyl were added to Table 17.3.
- Properties of solubility and density of alkanes were added.
- The chemical reaction of hydrogenation of alkenes and unsaturated fats was added.
- Updated recycling symbols for polymers were added.
- 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 Follow Up feature the work and career of a clinical lipid specialist.
- Fischer projections with and D and L notations are described.
- Monosaccharides are classified as aldo or keto pentoses or hexoses.
- Haworth structures are drawn for monosaccharides, disaccharides, and polysaccharides.
- The Guide to Drawing Haworth Structures has been rewritten.
- Lipids distinguishes between the structures of fatty acids, waxes, triacylglycerols, and steroids.
- 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 Products for the Hydrogenation and Saponification of a Triacylglycerol, Drawing the Ionized Form for an Amino Acid, Identifying the Primary, Secondary, Tertiary, and Quaternary Structures of Proteins, Writing the Complementary DNA Strand, and Writing the mRNA Segment for a DNA Template.
- The interchapter problem set, Combining Ideas from Chapters 17 and 18, completes the chapter.

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We are especially proud of the art program in this text, which lends beauty and understanding to chemistry. We would like to thank Marilyn Perry and Gary Hespenheide, interior and cover design managers and book designer, whose creative ideas provided the outstanding design for the cover and pages of the book. Erica Gordon, photo researcher, was invaluable 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 Production Solutions and Precision Graphics 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 put in by the marketing team in the field and Executive Marketing Manager, Chris Barker.

We are 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.

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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FAVORITE QUOTES

The whole art of teaching is only the art of awakening the natural curiosity of young minds.

—Anatole France

One must learn by doing the thing; though you think you know it, you have no certainty until you try.

—Sophocles

Discovery consists of seeing what everybody has seen and thinking what nobody has thought.

—Albert Szent-Györgyi

I never teach my pupils; I only attempt to provide the conditions in which they can learn.

—Albert Einstein

Reviewers

Fifth Edition Reviewers

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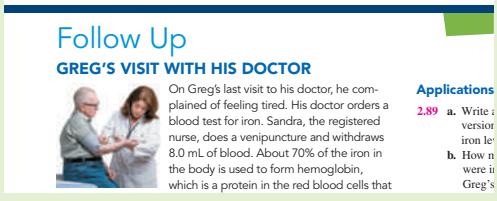
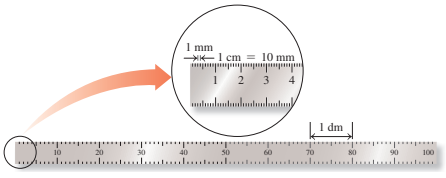
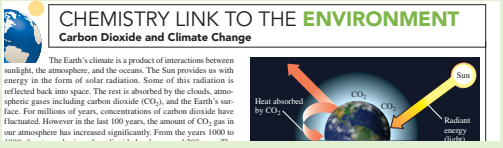
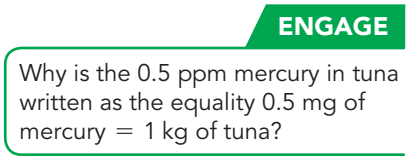
Truman College

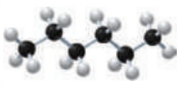
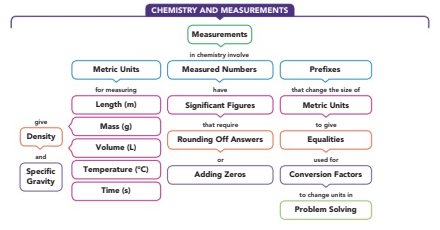
Marie Wolff
Joliet Junior College

Regina Zibuck
Wayne State University

Students learn chemistry using real-world examples

Feature	Description	Benefit	Page
	**Chapter Openers** discuss careers that involve chemistry.	Connects the chemistry in the chapter with the professionals who use chemistry every day.	27
	**Chemistry Links to Health** apply chemical concepts to health and medicine such as weight loss and weight gain, alcohol abuse, blood buffers, and kidney dialysis.	Provide you with connections that illustrate the importance of understanding chemistry in real-life situations.	52
	**Follow Ups** give a follow up to the discussion in the chapter opener and include Application questions.	Continue a theme through the entire chapter utilizing the new chemistry content.	60
	**Macro-to-Micro Art** utilizes photographs and drawings to illustrate the atomic structure of chemical phenomenas.	Helps you connect the world of atoms and molecules to the macroscopic world.	41
	**Chemistry Links to the Environment** relate chemistry to environmental topics such as climate change, radon in our homes, and fuel cells.	Help you extend your understanding of the impact of chemistry on the environment.	84
	**Engage** feature is a question in the margin next to a paragraph of new material.	Reminds you to think about the paragraph you are reading and to test your understanding by answering the Engage question.	47

Engage students in the world of chemistry

Feature	Description	Benefit	Page
LEARNING GOAL Describe the intermolecular forces between ions, polar covalent molecules, and nonpolar covalent molecules.	**Learning Goals** at the beginning and end of each section identify the key concepts for that section and provide a roadmap for your study.	Help you focus your studying by emphasizing what is most important in each section.	311
Volume (V) The volume of gas equals the size of the container in which the gas is placed. When you inflate a tire or a basketball, you are adding more gas particles. The increase in the number of particles hitting the walls of the tire or basketball increases the volume. Sometimes, on a cold morning, a tire looks flat. The volume of the tire has decreased because a lower temperature decreases the speed of the molecules, which in turn reduces the force of their impacts on the walls of the tire. The most common units for volume measurement are liters (L) and milliliters (mL).	Timberlake's accessible **Writing Style** is based on careful development of chemical concepts suited to the skills and backgrounds of students in chemistry.	Helps you understand new terms and chemical concepts.	326
KEY MATH SKILL Calculating pH from $[H_3O^+]$	**Key Math Skills** review the basic math needed for chemistry. Instructors can also assign these through MasteringChemistry.	Help you master the basic quantitative skills to succeed in chemistry.	462
CORE CHEMISTRY SKILL Using Significant Figures in Calculations	**Core Chemistry Skills** identify content crucial to problem-solving strategies. Instructors can also assign these through MasteringChemistry.	Help you master the basic problem-solving skills needed to succeed in chemistry.	36
TRY IT FIRST	The **TRY IT FIRST** feature encourages you to try to solve the problem before you compare your work with the Solution.	Helps you identify what you know about the solution and what you need to learn.	30
CHAPTER REVIEW 17.1 Alkanes **LEARNING GOAL** Write the IUPAC names and draw the condensed or line-angle structural formulas for alkanes. 	The **Chapter Reviews** include Learning Goals and visual thumbnails to summarize the key points in each section.	Help you determine your mastery of the chapter concepts and study for your tests.	600
KEY TERMS **Avogadro's number** The number of items in a mole, equal to 6.022×10^{23}. **empirical formula** The simplest or smallest whole-number ratio of the atoms in a formula. **formula unit** The group of ions represented by the formula of an ionic compound.	**Key Terms** with definitions are listed at the end of each chapter as well as in the **Glossary/Index** at the end of the text.	Help you recall the important new terms in each chapter.	217
CONCEPT MAP 	**Concept Maps** at the end of each chapter show how all the key concepts fit together.	Encourage learning by giving you a visual guide to the interrelationship among all the concepts new to each chapter.	61

Tools to engage students in chemistry and show them how to solve problems

Feature	Description	Benefit	Page
Applications **2.23** Identify the number of significant figures in each of the following: **a.** The mass of a neonate is 1.607 kg. **b.** The Daily Value (DV) for iodine for an infant is 130 mcg. **c.** There are 4.02×10^6 red blood cells in a blood sample.	**Applications** in Questions and Problems show the relevance to the chemistry concepts in the chapter.	Show you how the chemistry you are learning is related to real life.	35
Guide to Determining the Polarity of a Molecule STEP 1 Determine if the bonds are polar covalent or nonpolar covalent.	**Guides to Problem Solving** (GPS) illustrate the steps needed to solve problems.	Visually guide you step-by-step through each problem-solving strategy.	298
ANALYZE THE PROBLEM Given: 260. g of ice at 0 °C Need: joules to melt ice at 0 °C Connect: heat of fusion	**Analyze the Problems** convert a word problem into components for problem solving. New **Connect** features specify information that relates the *Given* and *Need* sections.	Help you identify and connect the components within a word problem to set up a solution strategy.	303
QUESTIONS AND PROBLEMS **10.4 Electronegativity and Bond Polarity** **LEARNING GOAL** Use electronegativity to determine the polarity of a bond. **10.23** Describe the trend in electronegativity as *increases* or *decreases* for each of the following: **a.** from B to F **b.** from Mg to Ba **c.** from F to I	**Questions and Problems** placed at the end of each section are paired. The **Answers** to the odd-numbered problems are given at the end of each chapter.	Encourage you to become involved immediately in the process of problem solving.	296
SAMPLE PROBLEM 2.4 Rounding Off Round off each of the following numbers to three significant figures: **a.** 35.7823 m **b.** 0.002 621 7 L **c.** 3.8268×10^3 g TRY IT FIRST SOLUTION **a.** To round off 35.7823 m to three significant figures, drop 823 and increase the last retained digit by 1 to give 35.8 m. **b.** To round off 0.002 621 7 L to three significant figures, drop 17 to give 0.002 62 L. **c.** To round off 3.8268×10^3 g to three significant figures, drop 68 and increase the last retained digit by 1 to give 3.83×10^3 g. STUDY CHECK 2.4 Round off each of the numbers in Sample Problem 2.4 to two significant figures. ANSWER **a.** 36 m **b.** 0.0026 L **c.** 3.8×10^3 g	**Sample Problems** illustrate worked-out solutions with explanations and required calculations. **Study Checks** associated with each Sample Problem allow you to check your problem-solving strategies with the **Answer**.	Provide the intermediate steps to guide you successfully through each type of problem.	36
UNDERSTANDING THE CONCEPTS *The chapter sections to review are shown in parentheses at the end of each question.* **8.35** Balance each of the following by adding coefficients, and identify the type of reaction for each: (8.1, 8.2, 8.3) **a.** _ + _ ⟶ _	**Understanding the Concepts** are questions with visual representations placed at the end of each chapter.	Build an understanding of newly learned chemical concepts.	244
ADDITIONAL QUESTIONS AND PROBLEMS **8.43** Identify the type of reaction for each of the following as combination, decomposition, single replacement, double replacement, or combustion: (8.3) **a.** A metal and a nonmetal form an ionic compound. **b.** A compound of hydrogen and carbon reacts with oxygen to produce carbon dioxide and water.	**Additional Questions and Problems** at the end of each chapter provide further study and application of the topics from the entire chapter. Problems are paired and the **Answers** to the odd-numbered problems are given at the end of each chapter.	Promote critical thinking.	245
CHALLENGE QUESTIONS *The following groups of questions are related to the topics i ter. However, they do not all follow the chapter order, and t you to combine concepts and skills from several sections. T tions will help you increase your critical thinking skills and your next exam.* **8.53** Balance each of the following chemical equations, a the type of reaction: (8.1, 8.2, 8.3) **a.** $K_2O(s) + H_2O(g) \longrightarrow KOH(aq)$ **b.** $C_8H_{18}(l) + O_2(g) \xrightarrow{\Delta} CO_2(g) + H_2O(g)$	**Challenge Questions** at the end of each chapter provide complex questions. **Answers** to the odd-numbered questions are given at the end of each chapter.	Promote critical thinking, group work, and cooperative learning environments.	246
COMBINING IDEAS from CHAPTERS 4 to 7 **CL7** For parts **a** to **f**, consider the loss of electrons by atoms of the element X, and a gain of electrons by atoms of the element Y. Element X is in Group 2A (2), Period 3, and Y is in Group 7A (17), Period 3. (4.2, 5.4, 5.5, 6.2, 6.3) X Y Y **a.** Which element is a metal, X or Y? **b.** Which element is a nonmetal, X or Y? **c.** What are the ionic charges of X and Y? **a.** What is the empirical form **b.** If oxalic acid has an exper is its molecular formula? **c.** Using the LD_{50}, how man toxic for a 160-lb person? **d.** How many kilograms of r part **c** need to eat to reach **CL10** The active ingredient in Tums Tums tablet contains 500. mg o 7. 2, 7.3 7.4)	**Combining Ideas** are sets of integrated problems placed after every two to four chapters that are useful as practice exams. Answers to the odd-numbered problems are given at the end of each Combining Ideas.	Test your understanding of the concepts from previous chapters by integrating topics.	222

Resources

Basic Chemistry, fifth edition, provides an integrated teaching and learning package of support material for both students and professors.

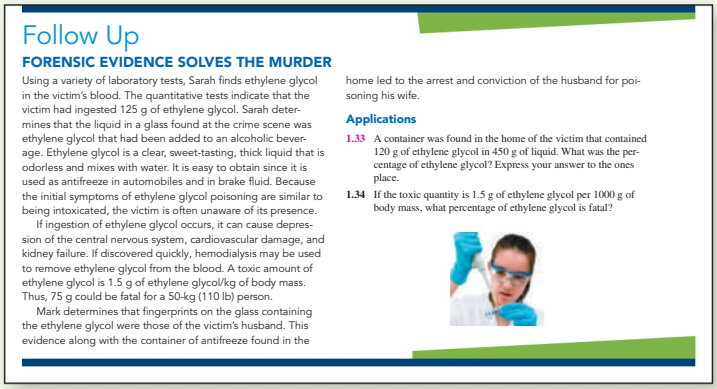
Name of Supplement	Available in Print	Available Online	Instructor or Student Supplement	Description
Study Guide and Selected Solutions Manual (ISBN 0134167260)	✓		Resource for Students	The Study Guide and Selected Solutions Manual, by Karen Timberlake and Mark Quirie, promotes active learning through a variety of exercises with answers as well as practice tests that are connected directly to the learning goals of the textbook. Complete solutions to odd-numbered problems are included.
MasteringChemistry® (www.masteringchemistry.com) (ISBN 0134177150)		✓	Resource for Students and Instructors	MasteringChemistry® from Pearson is the leading online teaching and learning system designed to improve results by engaging students before, during, and after class with powerful content. Ensure that students arrive ready to learn by assigning educationally effective content before class, and encourage critical thinking and retention with in-class resources such as Learning Catalytics. Students can further master concepts after class through traditional homework assignments that provide hints and answer-specific feedback. The Mastering gradebook records scores for all automatically graded assignments while diagnostic tools give instructors access to rich data to assess student understanding and misconceptions.
MasteringChemistry with Pearson eText (ISBN 0133899306)		✓	Resource for Students	The fifth edition of *Basic Chemistry* features a Pearson eText enhanced with media within Mastering. In conjunction with Mastering assessment capabilities, Interactive Videos, and 3D animations will improve student engagement and knowledge retention. Each chapter will contain a balance of interactive animations, videos, sample calculations, and self-assessments/quizzes embedded directly in the eText. Additionally, the Pearson eText offers students the power to create notes, highlight text in different colors, create bookmarks, zoom, and view single or multiple pages.
Instructor's Solutions Manual–Download Only (ISBN 0134167279)		✓	Resource for Instructors	Prepared by Mark Quirie, the solutions manual highlights chapter topics, and includes answers and solutions for all questions and problems in the text.
Instructor Resource Materials–Download Only (ISBN 0134167252)		✓	Resource for Instructors	Includes all the art, photos, and tables from the book in JPEG format for use in classroom projection or when creating study materials and tests. In addition, the instructors can access modifiable PowerPoint™ lecture outlines. Also available are downloadable files of the Instructor's Solutions Manual and a set of "clicker questions" designed for use with classroom-response systems. Also visit the Pearson Education catalog page for Timberlake's *Basic Chemistry*, fifth edition, at www.pearsonhighered.com to download available instructor supplements.
TestGen Test Bank–Download Only (ISBN 0133891895)		✓	Resource for Instructors	Prepared by William Timberlake, this resource includes more than 2000 questions in multiple-choice, matching, true/false, and short-answer format.
Laboratory Manual by Karen Timberlake (ISBN 0321811852)	✓		Resource for Students	This best-selling lab manual coordinates 35 experiments with the topics in *Basic Chemistry*, fifth edition, uses laboratory investigations to explore chemical concepts, develop skills of manipulating equipment, reporting data, solving problems, making calculations, and drawing conclusions.
Online Instructor Manual for Laboratory Manual (ISBN 0321812859)		✓	Resource for Students	This manual contains answers to report sheet pages for the Laboratory Manual and a list of the materials needed for each experiment with amounts given for 20 students working in pairs, available for download at www.pearsonhighered.com.

Highlighting Relevancy and Applications

Designed to prepare students for science-related careers, ***Basic Chemistry*** organizes chemical concepts and problem solving into clear, manageable pieces, ensuring students follow along and stay motivated throughout their first chemistry course. Timberlake's friendly writing style, student focus, challenging problems, and engaging applications continue to help students make connections between chemistry and their future careers as they develop problem-solving skills they'll need beyond the classroom.

Follow Ups and Applications

Chapter Openers throughout the text connect chemistry to real life. Each chapter begins with an image and details of a profession such as engineering, medicine, environmental science or agriculture science, or exercise physiology. **Follow Ups** at the end of chapter discuss the chemistry in the Chapter Opener and include Applications. These questions show students how the chemistry they are learning applies specifically to their professional careers.



Follow Up

FORENSIC EVIDENCE SOLVES THE MURDER

Using a variety of laboratory tests, Sarah finds ethylene glycol in the victim's blood. The quantitative tests indicate that the victim had ingested 125 g of ethylene glycol. Sarah determines that the liquid in a glass found at the crime scene was ethylene glycol that had been added to an alcoholic beverage. Ethylene glycol is a clear, sweet-tasting, thick liquid that is odorless and mixes with water. It is easy to obtain since it is used as antifreeze in automobiles and in brake fluid. Because the initial symptoms of ethylene glycol poisoning are similar to being intoxicated, the victim is often unaware of its presence.

If ingestion of ethylene glycol occurs, it can cause depression of the central nervous system, cardiovascular damage, and kidney failure. If discovered quickly, hemodialysis may be used to remove ethylene glycol from the blood. A toxic amount of ethylene glycol is 1.5 g of ethylene glycol/kg of body mass. Thus, 75 g could be fatal for a 50-kg (110 lb) person.

Mark determines that fingerprints on the glass containing the ethylene glycol were those of the victim's husband. This evidence along with the container of antifreeze found in the home led to the arrest and conviction of the husband for poisoning his wife.

Applications

1.33 A container was found in the home of the victim that contained 120 g of ethylene glycol in 450 g of liquid. What was the percentage of ethylene glycol? Express your answer to the ones place.

1.34 If the toxic quantity is 1.5 g of ethylene glycol per 1000 g of body mass, what percentage of ethylene glycol is fatal?

1

Chemistry in Our Lives

A CALL CAME IN TO 911

from a man who found his wife lying on the floor of their home. When the police arrived, they determined that the woman was dead. The husband said he had worked late, and just arrived home. The victim's body was lying on the floor of the living room. There was no blood at the scene, but the police did find a glass on the side table that contained a small amount of liquid. In an adjacent laundry room/garage, the police found a half-empty bottle of antifreeze. The bottle, glass, and liquid were bagged and sent to the forensic laboratory.

In another 911 call, a man was found lying on the grass outside his home. Blood was present on his body, and some bullet casings were found on the grass. Inside the victim's home, a weapon was recovered. The bullet casings and the weapon were bagged and sent to the forensic laboratory.

Sarah and Mark, forensic scientists, use scientific procedures and chemical tests to examine the evidence from law enforcement agencies. Sarah proceeds to analyze blood, stomach contents, and the unknown liquid from the first victim's home. She will look for the presence of drugs, poisons, and alcohol. Her lab partner Mark will analyze the fingerprints on the glass. He will also match the characteristics of the bullet casings to the weapon that was found at the second crime scene.

Evidence from a crime scene is sent to the forensic laboratory.

CAREER

Forensic Scientist

Most forensic scientists work in crime laboratories that are part of city or county legal systems where 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 the criminal case. Some of the chemicals they look for include alcohol, illegal or prescription drugs, poisons, arson debris, metals, and various gases such as carbon monoxide. In order to identify these substances, a variety of chemical instruments and highly specific methodologies are used. Forensic scientists also 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.

Focusing on New Problem-Solving Strategies

This new edition introduces more problem-solving strategies, more problem-solving guides, new Analyze the Problem with Connect features, new Try It First and Engage features, conceptual and challenge problems, and new sets of combined problems.

- **NEW! Connect** feature has been added to the **Analyze the Problem** boxes, which specifies the information that relates the *Given* and *Need* sections.
- **NEW! Try It First** now precedes the Solution section of each Sample Problem to encourage the student to work on the problem before reading the given Solution.
- **NEW! Engage** feature asks students to think about the paragraph they are reading and to test their understanding by answering the Engage question in the margin, which is related to the topic.

ANALYZE THE PROBLEM	Given	Need	Connect
	standard number	scientific notation	coefficient is at least 1 but less than 10

SAMPLE PROBLEM 1.7 **Scientific Notation**

Write each of the following in scientific notation:

a. 3500 **b.** 0.000 016

TRY IT FIRST

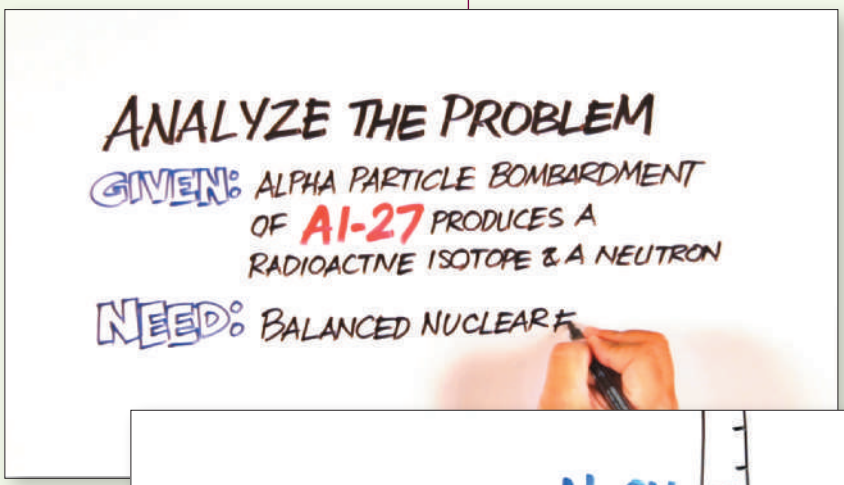
ENGAGE

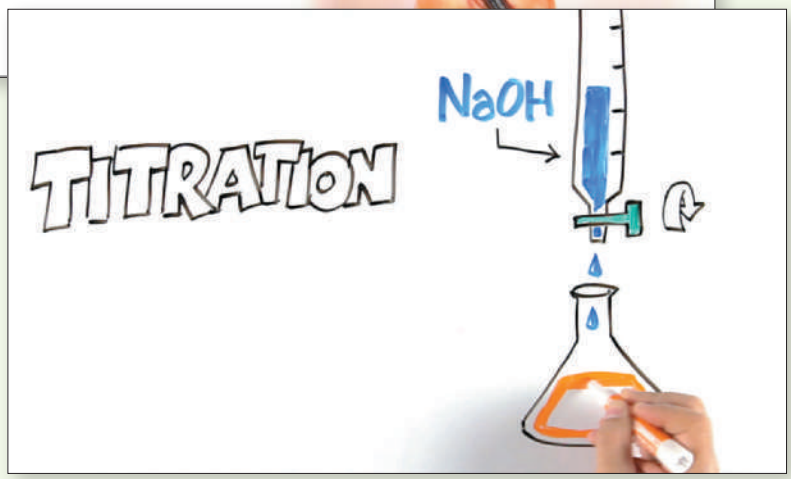
What is different and what is the same for an atom of Sn-105 and an atom of Sn-132?

Interactive Videos

Interactive videos and demonstrations help students through some of the more challenging topics 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, Balancing Nuclear Equations, and Chemical v. Physical Change.

Sample Calculations walk students through the most challenging chemistry problems and provide a fresh perspective on how to approach individual problems and plan solutions. Topics include Using Conversion Factors, Mass Calculations for Reactions, and Concentration of Solutions.





Green play button icons appear in the margins throughout the text. In the eText, the icons link to new interactive videos that the student can use to clarify and reinforce important concepts. All Interactive Videos are available in web and mobile-friendly formats through the eText, and are assignable activities in MasteringChemistry.

Interactive Video

Solving Equations

SAMPLE PROBLEM 1.5 Solving Equations

Solve the following equation for V_2:

$$P_1V_1 = P_2V_2$$

TRY IT FIRST

SOLUTION

$$P_1V_1 = P_2V_2$$

To solve for V_2, divide both sides by the symbol P_2.

$$\frac{P_1V_1}{P_2} = \frac{P_2V_2}{P_2}$$

$$V_2 = \frac{P_1V_1}{P_2}$$

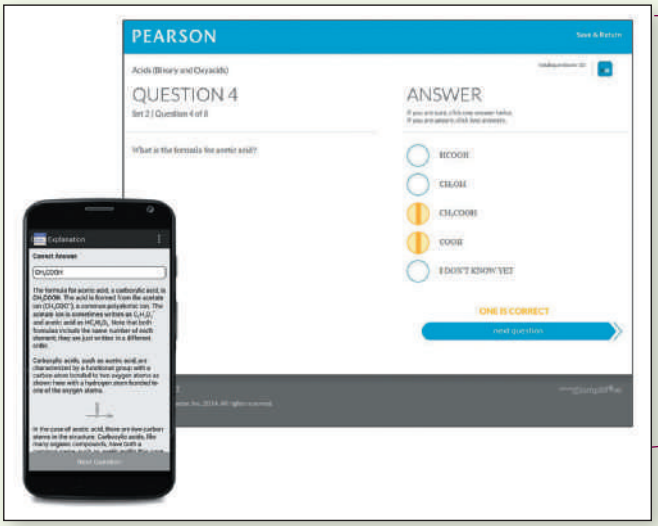
STUDY CHECK 1.5

MasteringChemistry®

MasteringChemistry® from Pearson is the leading online teaching and learning system designed to improve results by engaging students before, during, and after class with powerful content. Instructors may ensure that students arrive ready to learn by assigning educationally effective content before class, and encourage critical thinking and retention with in-class resources such as Learning Catalytics. Students can further master concepts after class through traditional homework assignments that provide hints and answer-specific feedback. The Mastering gradebook records scores for all automatically graded assignments while diagnostic tools give instructors access to rich data to assess student understanding and misconceptions.

Mastering brings learning full circle by continuously adapting to each student and making learning more personal than ever—before, during, and after class.

Before Class



Dynamic Study Modules

Help students quickly learn chemistry!

Now assignable, Dynamic Study Modules (DSMs) enable your students to study on their own and be better prepared with the basic math and chemistry skills needed to succeed in the course. The mobile app is available for iOS and Android devices for study on the go and results can be tracked in the MasteringChemistry gradebook.

Reading Quizzes

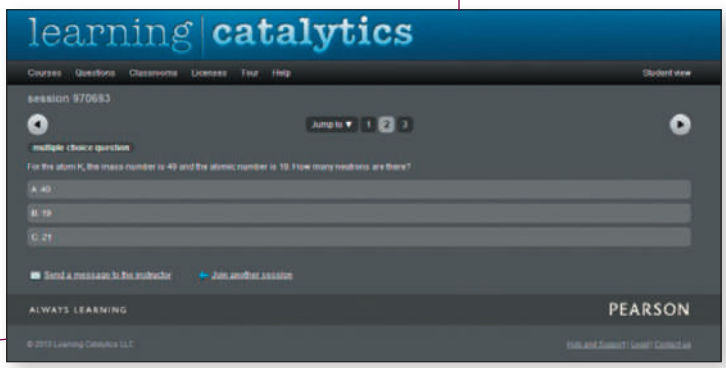
Reading Quizzes give instructors the opportunity to assign reading and test students on their comprehension of chapter content.

During Class

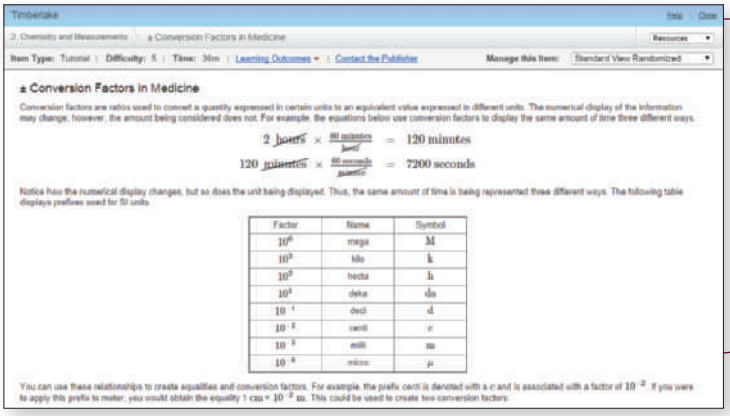
Learning Catalytics

Learning Catalytics is a "bring your own device" student engagement, assessment, and classroom intelligence system. With Learning Catalytics you can:

- Assess students in real time, using open-ended tasks to probe student understanding.
- Understand immediately where students are and adjust your lecture accordingly.
- Manage student interactions with intelligent grouping and timing.



After Class



Tutorials and Coaching

Students learn chemistry by practicing chemistry.

Tutorials, featuring specific wrong-answer feedback, hints, and a wide variety of educationally effective content, guide your students through the toughest topics in Basic Chemistry.

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1

Chemistry in Our Lives

A CALL CAME IN TO 911

from a man who found his wife lying on the floor of their home. When the police arrived, they determined that the woman was dead. The husband said he had worked late, and just arrived home. The victim's body was lying on the floor of the living room. There was no blood at the scene, but the police did find a glass on the side table that contained a small amount of liquid. In an adjacent laundry room/garage, the police found a half-empty bottle of antifreeze. The bottle, glass, and liquid were bagged and sent to the forensic laboratory.

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LOOKING AHEAD

1.1 Chemistry and Chemicals

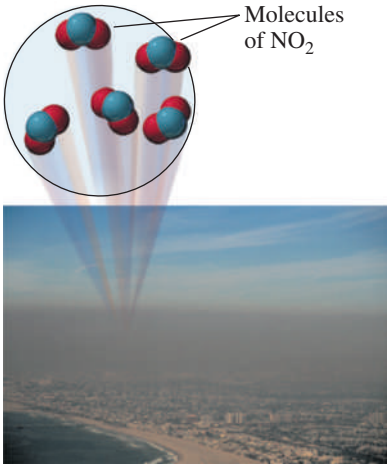
LEARNING GOAL Define the term chemistry and identify substances as chemicals.

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 how smog is formed 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



The chemical reaction of NO with oxygen in the air forms NO_2, which produces the reddish brown color of 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, thereby reducing inflammation, pain, and fever. Chemists in the medical field develop new treatments for diabetes, genetic defects, cancer, AIDS, and other diseases. Chemists in the environmental field study the ways in which human development impacts the environment and develop processes that help reduce environmental degradation. For the chemist in the forensic laboratory, the nurse in the dialysis unit, the dietitian, the chemical engineer, or the agricultural scientist, chemistry plays a central role in understanding problems, assessing possible solutions, and making important decisions.

Chemistry

Chemists working in research laboratories test new products and develop new pharmaceuticals.

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.

Antacid tablets undergo a chemical reaction when dropped into water.

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. Chemical processes take place in chemistry laboratories, manufacturing plants, and pharmaceutical labs as well as every day in nature and in our bodies. 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. 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**.

In cosmetics and lotions, chemicals are used to moisturize, prevent deterioration of the product, fight bacteria, and thicken the product. Your clothes may be made of natural materials, such as cotton, or synthetic substances, such as nylon or polyester. 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. Antioxidants are chemicals added to food to prevent it from spoiling. Some of the chemicals you may encounter when you cook in the kitchen are shown in **FIGURE 1.1**.

Toothpaste is a combination of many chemicals.

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
Triclosan	Inhibits bacteria that cause plaque and gum disease
Sodium fluorophosphate	Prevents formation of cavities by strengthening tooth enamel with fluoride
Methyl salicylate	Gives toothpaste a pleasant wintergreen flavor

FIGURE 1.1 ▶ Many of the items found in a kitchen are chemicals or products of chemical reactions.
What are some other chemicals found in a kitchen?

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.

QUESTIONS AND PROBLEMS

1.1 Chemistry and Chemicals

LEARNING GOAL Define the term chemistry and identify substances as chemicals.

In every chapter, odd-numbered exercises in the *Questions and Problems* are paired with even-numbered exercises. The answers for the magenta, odd-numbered *Questions and Problems* are given at the end of each chapter. The complete solutions to the odd-numbered *Questions and Problems* are in the *Study Guide*.

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?

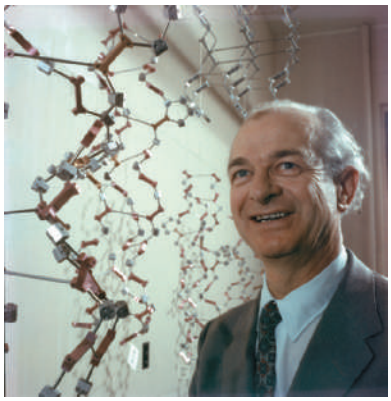
1.4 Obtain a box of breakfast cereal and read the list of ingredients. What are four chemicals from the list?

1.5 Read the labels on some items found in your medicine cabinet. 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 activities that are part of the scientific method.



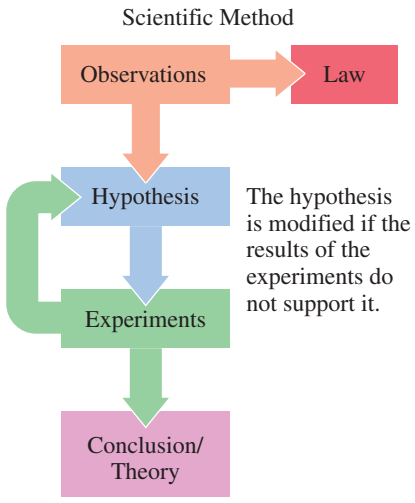
Linus Pauling won the Nobel Prize in Chemistry in 1954.

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 water 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 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.

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.



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

1. **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 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 table or the floor but this law does not explain why our book falls.
2. **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. **Experiments** To determine if a hypothesis is true or false, experiments are done to find a relationship between the hypothesis and the observations. The results of the experiments may confirm the hypothesis. However, if the experiments do not confirm the hypothesis, it is modified or discarded. Then new experiments will be designed to test the hypothesis.
4. **Conclusion/Theory** When the results of the experiments are analyzed, a conclusion is made as to whether the hypothesis is *true* or *false*. When experiments give consistent results, the hypothesis may be stated to be true. Even then, the hypothesis

continues to be tested and, based on new experimental results, may need to be modified or replaced. If many additional experiments by a group of scientists continue to support the hypothesis, it may become a *scientific theory*, which gives an explanation for the initial observations.

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 about the sixteenth century, alchemists described matter in terms of four components of nature: earth, air, fire, and water, with the qualities of hot, cold, damp, or dry. By the eighth century, alchemists believed that they could rearrange these qualities in such a way as to 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 equipment 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, not underground spirits, 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.

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 ask yourself why you are sneezing and 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.

Students make observations in the chemistry laboratory.

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

ENGAGE

Why would the statement "If I stop drinking coffee in the evening, I will be able to sleep at night." be considered a hypothesis?

SAMPLE PROBLEM 1.1 Scientific Method

Identify each of the following statements as an observation (O), a hypothesis (H), or an experiment (E):

a. A silver tray turns a dull gray color when left uncovered.
b. When a silver tray is covered with plastic wrap, it does not tarnish.
c. Oxygen reacts with silver when the tray is exposed to air.

Tomato plants grow faster when placed in the sun.

TRY IT FIRST

SOLUTION

a. observation (O) **b.** experiment (E) **c.** hypothesis (H)

STUDY CHECK 1.1

The following statements are found in a student's notebook. Identify each of the following as an observation (O), a hypothesis (H), or an experiment (E):

a. "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."
b. "After 50 days, the tomato plants in the garden are 3 ft high with green leaves. The plants in the closet are 8 in. tall and yellow."
c. "Tomato plants need sunlight to grow."

ANSWER

a. experiment (E) **b.** observation (O) **c.** hypothesis (H)

QUESTIONS AND PROBLEMS

1.2 Scientific Method: Thinking Like a Scientist

LEARNING GOAL Describe the activities that are part of the scientific method.

1.7 Define each of the following terms of the scientific method:
a. hypothesis **b.** experiment
c. theory **d.** observation

1.8 Identify each of the following activities in the scientific method as an observation (O), a hypothesis (H), an experiment (E), or a conclusion (C):
a. Formulate a possible explanation for your experimental results.
b. Make notes about nature.
c. Design an experimental plan that will give new information about a problem.
d. State a generalized summary of your experimental results.

Applications

1.9 Identify each activity, **a** to **f**, as an observation (O), a hypothesis (H), an experiment (E), or a conclusion (C).
At a popular restaurant, where Chang is the head chef, the following occurred:

Customers rated the sesame seed dressing as the best.

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 lettuce, each with a new dressing: sesame seed, olive oil and balsamic vinegar, creamy Italian, and blue cheese.
d. The 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.

1.10 Identify each activity, **a** to **f**, as an observation (O), a hypothesis (H), an experiment (E), or a conclusion (C).
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.

1.11 Identify each of the following as an observation (O), a hypothesis (H), an experiment (E), or a conclusion (C):
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.

1.12 Identify each of the following as an observation (O), a hypothesis (H), an experiment (E), or a conclusion (C):
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 Learning Chemistry: A Study Plan

LEARNING GOAL 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.

Features in This Text Help You Study Chemistry

This text has been designed with study features to complement your individual learning style. 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. *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. In the *Chapter Readiness* list at the beginning of every chapter, the *Key Math Skills* and *Core Chemistry Skills* from previous chapters related to the current chapter concepts are highlighted for your review.

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. For example, for section 1.1, "Chemistry and Chemicals," you could ask, "What is chemistry?" or "What are chemicals?" When you come to a *Sample Problem*, take the time to work it through and compare your solution to the one provided. As you read the text, you will see *Engage* features in the margin, which remind you to pause your reading and interact with a question related to the material.

The *Try It First* feature above the Solution of each Sample Problem is a reminder for you to work out the problem before you look at the Solution. Many *Sample Problems* are accompanied by a *Guide to Problem Solving*, which gives the steps needed to work the problem. The *Analyze the Problem* feature in some Sample Problems includes *Given*, the information we have; *Need*, what we are going to accomplish; and *Connect*, how we proceed from Given to Need. When you compare your answer with the Solution provided, you know what you need to correct or change. This process of trying the problem first will help you develop successful problem solving techniques. Then work the associated *Study Check*. The answers to all the Study Checks are included and you can compare your answer to the one provided.

At the end of each chapter section, you will find a set of *Questions and Problems* that allows you to apply problem solving immediately to the new concepts. 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 connect 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.

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. The *Key Terms*, which are in boldface type within the chapter, are listed with their definitions. *Understanding the Concepts*, a set of questions that use art and models, helps you visualize concepts. *Additional Questions and Problems* and *Challenge Problems* provide additional exercises to test your understanding of the topics in the chapter. *Applications* are groups of problems that apply section content to current topics. *Answers* to all of the odd-numbered problems complete the chapter and you can compare your answers to the ones provided.

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

KEY MATH SKILL

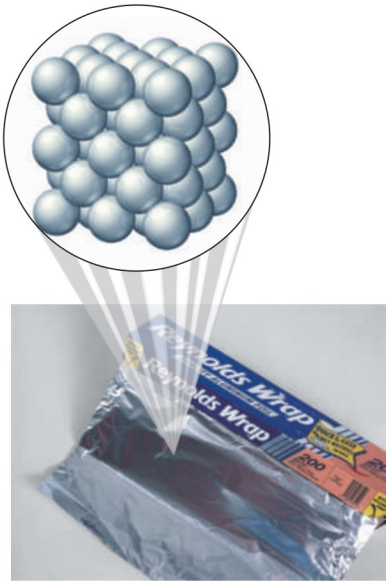
CORE CHEMISTRY SKILL

ENGAGE

What is different and what is the same for an atom of Sn-105 and an atom of Sn-132?

TRY IT FIRST

	Given	Need	Connect
ANALYZE THE PROBLEM	165 lb	kilograms	conversion factor



Using Active Learning

A student who is an active learner continually interacts with the chemical ideas while reading the text, working problems, and attending lectures. Let's see how this is done.

As you read and practice problem solving, you remain actively involved in studying, which enhances the learning process. In this way, you learn a small amount of information and establish the necessary foundation for understanding the next section. You may also note questions you have about the reading, which you can discuss with your professor or laboratory instructor. **TABLE 1.2** summarizes these steps for active learning. The time you spend in a lecture is a useful learning time. By keeping track of the class schedule and reading the assigned material before a lecture, you become aware of the new terms and concepts you need to learn. Some questions that occur during your reading may be answered during the lecture. If not, you can ask your professor for further clarification.

TABLE 1.2 Steps in Active Learning

1.	Read each *Learning Goal* for an overview of the material.
2.	Form a question from the title of the section you are going to read.
3.	Read the section, looking for answers to your question.
4.	Self-test by working *Sample Problems* and *Study Checks*.
5.	Complete the *Questions and Problems* that follow that section, and check the answers for the magenta odd-numbered problems at the end of the chapter.
6.	Proceed to the next section and repeat the steps.

Studying in a group can be beneficial to learning.

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. You may find that it is easier to retain new material and new ideas if you study in short sessions throughout the week rather than all at once. Waiting to study until the night before an exam does not give you time to understand concepts and practice problem solving.

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 lecture
_____ going to lecture
_____ reviewing the *Learning Goals*
_____ keeping a problem notebook
_____ reading the text as an active learner
_____ answering the *Engage* questions
_____ trying to work the *Sample Problem* before looking at the *Solution*
_____ working the *Questions and Problems* at the end of each section and checking answers

Students discuss a chemistry problem with their professor during office hours.

_____ being an active learner in lecture
_____ organizing a study group
_____ seeing the professor during office hours
_____ reviewing *Key Math Skills* and *Core Chemistry Skills*
_____ attending review sessions
_____ organizing my own review sessions
_____ studying as often as I can

SAMPLE PROBLEM 1.2 A Study Plan for Learning Chemistry

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

a. skipping lecture
b. going to the professor's office hours
c. keeping a problem notebook
d. waiting to study until the night before the exam
e. trying to work the Sample Problem before looking at the Solution

TRY IT FIRST

SOLUTION

Your success in chemistry can be improved by:

b. going to the professor's office hours
c. keeping a problem notebook
e. trying to work the Sample Problem before looking at the Solution

STUDY CHECK 1.2

Which of the following will help you learn chemistry?

a. skipping review sessions
b. working assigned problems
c. staying up all night before an exam
d. reading the assignment before a lecture

ANSWER

b and **d**

QUESTIONS AND PROBLEMS

1.3 Learning Chemistry: A Study Plan

LEARNING GOAL Develop a study plan for learning chemistry.

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

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

1.15 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 a lecture
c. visiting the professor during office hours
d. waiting until the night before an exam to study
e. answering the Engage question

1.16 A student in your class asks you for advice on learning chemistry. Which of the following might you suggest?
a. doing the assigned problems
b. not reading the text; it's never on the test
c. attending review sessions
d. reading the assignment before a lecture
e. keeping a problem notebook